Exploring the role of affect on conditions and processes in the integrated model of socially shared regulation of learning

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Abstract

Effective socially shared regulation of learning (SSRL) requires socially shared metacognitive processes, group-level monitoring, and control and regulation of shared cognitive processes, affect, and motivation (Iiskala et al., 2004; Vauras et al., 2003). Studies to-date on metacognition have mainly focused on the individual and how experiences in a social context influence individual metacognition (Azevedo et al., 2004; Efklides, 2011). To study processes involved in SSRL, a comprehensive model of SSRL considering existing theories on learning regulation and metacognition, is required. Following suggestions for theory development related to social metacognitive processes outlined by Efklides (2008), I describe the role of metacognition, affect and motivation in SSRL through the proposed Integrated Model, an extension of Efklides' (2008) Metacognitive and Affective Model of Self-Regulated Learning model. Specifically, I describe how facets of Person-, Person x Group, and Group-level metacognition, affect and motivation related to conditions and Task x Person x Group-level processes facilitate or constrain regulatory phases. To explore facets of the model, 29 fifth grade students were asked to solve a complex math problem in collaborative groups. The current study used a mixed methods approach to explore conditions at the Person-, and Person x Group-level and how they related to emotions, metacognitive experiences, and emotion regulation at the Task x Person x Group-level. In turn, the study explored how experiences at the Task x Person x Group-level informed Person x Group- and Group-level conditions. Result revealed that pride was positively related to value for the learning task at the Person- and Person x Group-level, and concurrent metacognitive experiences at the Task x Person x Group-level co-occurred or closely occurred to instances of emotion. As well, pride was associated with feelings of relatedness at the Person x Group-level and appeared to improve negative self-concept and ability at the Person-level. Educational implications, limitations and future directions are subsequently provided.

Résumé

Une régulation par partage social efficace nécessite des processus métacognitifs partagés, ainsi que la surveillance, le contrôle et la régulation des processus cognitifs partagés, y compris l'affect et la motivation (Iiskala et al., 2004 ; Vauras et al., 2003). Les études sur la métacognition se sont principalement concentrées sur l'individu et sur la façon dont les expériences dans un contexte social influencent la métacognition individuelle (Azevedo et al., 2004 ; Efklides, 2011). Un modèle complet de régulation par partage social tenant compte des théories existantes sur la régulation de l'apprentissage et la métacognition est nécessaire. Par suite des suggestions de développement théorique liées aux processus métacognitifs sociaux décrites par Efklides (2008), je décris le rôle de la métacognition, de l'affect et de la motivation dans la régulation par partage social à travers le modèle intégré proposé, une extension du modèle métacognitif et affectif de soi d'Efklides (2008), modèle d'apprentissage réglementé. Plus précisément, je décris comment les facettes de la métacognition au niveau Personne, Personne x Groupe et Groupe, l'affect et la motivation liés aux conditions et les processus au niveau Tâche x Personne x Groupe facilitent ou contraignent les phases de régulation. Pour explorer les facettes du modèle, 29 élèves de cinquième année ont été invités à résoudre un problème mathématique complexe en groupes collaboratifs. La présente étude a utilisé une approche de méthodes mixtes pour explorer les conditions au niveau de la personne et de la Personne x Groupe et leur lien avec les émotions, les expériences métacognitives et la régulation des émotions au niveau Tâche x Personne x Groupe. À son tour, l'étude a exploré comment les expériences au niveau de la Tâche x Personne x Groupe informaient les conditions aux niveaux Personne x Groupe et Groupe. Le résultat a révélé que la fierté était positivement liée à la valeur de la tâche d'apprentissage aux niveaux de la Personne et de la Personne x Groupe, et que des expériences métacognitives simultanées au niveau Tâche x Personne x Groupe se produisaient ou se produisaient étroitement avec des instances d'émotion. De plus, la fierté était associée à des sentiments

d'appartenance au niveau Personne x Groupe et semblait améliorer le concept de soi négatif et la capacité au niveau Personne. Les implications pédagogiques, les limites et les orientations futures sont ensuite fournies.

Dedication

I dedicate this dissertation to my children, Dylan Branston and Ethan Branston – *thank you for your love, patience, faith in me, and for always reminding me that cuddles come first.*

Acknowledgments

There are numerous people for whom I would like to express my gratitude for helping me to achieve this academic milestone.

Firstly, Dr. Krista R. Muis, my supervisor and mentor – Krista, you have been a source of encouragement and mentorship throughout my MA and PhD. Your guidance, insight and dedication have been an inspirational model throughout my eight years in the Muis lab. You have afforded me professional opportunities, and financial and resource support, included me in collaborative projects and supported me in my professional aspirations. Thank you for always being there; being a voice of reason, believing me in times that I doubted myself, and always asking me to bring my best to the table.

Thank you to my dissertation committee members – Dr. Susanne Lajoie, Dr. Jeffrey Greene, and Dr. Nikki Lobczowski for your feedback, time, and dedication to the field of teaching and learning.

I would also like to express gratitude for the contributions of past and present members of the Muis lab, my peers within the larger Department of Educational and Counselling Psychology (ECP), and professionals in the field who have supported me throughout my degree. To those who helped with data collection, transcriptions of audio files and interrater reliability, Dr. Ivana Di Leo, Dr. Marianne Chevrier, Dr. Kelsey Losenno, and James Vivian – thank you for your time and efforts – your assistance was invaluable. To my colleagues and friends at Concordia university, Dr. Nathalie Rothschild, and Cathy Mott – *I got it done!* Dr. Helena Osana – thank you for introducing me to the field of Educational Psychology back in 2001. And the late Sara Weinberg whose expression of pride in me gave me the fuel to always keep going.

I wish to acknowledge the financial support I received during my doctoral studies from the institution of McGill University and federal agencies, the Social Sciences and Humanities Research Council of Canada. I also wish to express gratitude to the faculty and staff of the Department of Educational and Counselling Psychology.

Last, but not least, I would like to acknowledge the support of my friends and family members; without them, I would not be where I am today. To my parents, Sharon Coles, and Paul Singh – thank you for your love and for providing me with the opportunity to always follow my dreams and supporting me in all my endeavors. To my cherished and dearest friends, the most heartfelt *thank you*. Ellen and Guy Gelinas thank you for checking-in, holding me accountable and seeing me through the final stretch of my degree. Dr. Nathalie Rothschild, thank you taking the time to listen, offer advice, and encourage me. Amanda Cardillo, thank you for the much-appreciated comic relief when I needed it most. Jerry Dzindzio, I will never be able to express how much I value your support and friendship; you believed in me and encouraged me every moment of the way and you spent hours truly listening to me when I would ramble on about my research. Dr. Ivana Di Leo, thank you for being supportive and steadfast, and an exceptional defence Maid of Honour. And finally, a huge thank you to my family. Ryan, thank you for embarking on this journey with me and continually demonstrating your unwavering love, support, and encouragement for me, through thick and thin. Thank you to Dylan, Ethan, and fur babies, Ludo and the late, Ernie – thank you for your cuddles, and patience. My cherished friends and family, thank you for always being my biggest fans (as I am yours) and my soft place to land.

Contribution of Original Knowledge

I certify that I am the primary author of this dissertation and am therefore responsible for its content. The conclusions drawn from the dissertation chapters are considered original and distinct contributions to knowledge.

The theoretical framework of this dissertation presents and illustrates the integrated model, an extension to Efklides' (2008) Metacognition and Affect in Self-regulated Learning, entitled the Integrated Model. The integrated model is a theoretical framework developed in consideration of existing theories of metacognition, learning regulation, and affect and motivation at the individual level and aims to situate metacognition, learning regulation, affect and motivation as it occurs at the social level within collaborative learning contexts. Within this model, proposed condition levels (i.e., Person x Group- and Group-level) were introduced and operationalized. As well, regulatory processes are operationalized at the proposed Task x Person x Group-level. Within the Task x Person x Group-level, *concurrent metacognitive experiences* are presented, which are metacognitive judgements and feelings that occur in relation to group dynamics and a consequence of collaborative groups working together on a task. It is put forth that metacognition about group dynamics is proposed as occurring concurrently to prospective, during, and retrospective metacognitive experiences.

The dissertation study is the first exploration of the dynamics that exist between the various conditions and processes involved in the integrated model. The dissertation study also reveals evidence of conditions related to Person x Group- and Group-level conditions and concurrent metacognitive experiences that take place at the Task x Person x Group-level in relation to group dynamics.

Contribution of Authors

Contributions to each chapter of the dissertation are summarized below. Portions of the chapters presented in this dissertation were co-authored with Dr. Krista R. Muis. My supervisor, Dr. Krista R. Muis and committee member, Dr. Susanne P. Lajoie provided feedback throughout the dissertation preparation process. Current and former Muis lab members, namely Dr. Ivana Di Leo, Kelsey Losenno, Dr. Courtney Denton-Hurlbut, and James Vivian, contributed to the preparation of this dissertation by providing support with exploring analysis software, conducting data collection, creating transcriptions of audio files and the establishing inter-rater reliability.

Chapter 1 and 2

Citation

Singh, C.A. & Muis, K. R. (accepted). An integrated model of socially shared regulation of learning: The role of metacognition, affect, and motivation. Educational Psychologist.

Contributions

The theoretical framework for this dissertation (i.e., Chapters 1 and 2) were independently written by me. Portions of the original version of Chapters 1 and 2 were prepared in fulfillment of my comprehensive exam on which Dr. Krista R. Muis and Dr. Susanne P. Lajoie provided feedback as members of the comprehensive exam evaluation committee. Portions of Chapter 1 and Chapter 2 are currently contained in a manuscript co-authored with Dr. Muis and under review with *Educational Psychologist*. Dr. Jeffrey Greene, editor of Educational Psychologist, provided detailed and integral feedback on the Integrated Model that contributed to the preparation of the manuscript for the resubmission process and Chapters 1 and 2 of this dissertation.

Chapter 3

Citation

Singh, C. A., & Muis, K. R. (2021). The role of social emotions and co-regulation of learning during complex mathematics problem solving. In P. Metallidou and D. Moraitou (Eds.), *Trends and Prospects in Metacognition Research across the Life Span - A Tribute to Anastasia Efklides*. Netherlands: Springer.

Contributions

The original research design for this study was devised by me and approved by Dr. Muis and committee member, Dr. Lajoie. Considering the Covid-19 situation, the study as presented to my committee members was unable to take place and was therefore amended. Both Dr. Muis and Dr. Lajoie approved the use of a previous study design as described in my dissertation in replacement of the proposed one. The research study described in this dissertation was designed by me with guidance provided by Dr. Muis. Specifically, Dr. Reinhard Pekrun suggested the Basic Psychological Needs in Relationships Scale (BPNS – R) as a measure of social motivation. Dr. Muis supported me in adapting the language of a self-report measures (i.e., BPNS-R) so that it was appropriate for students at the fifth-grade level. As well, Dr. Muis helped me to adapt the Epistemically-Related Emotions Scale to include an individual and social focus of emotions (i.e., self or socially focused) and social emotions.

Coding schemes related to emotion regulation strategies and negative socio-emotional interactions were borrowed from Lobczowski (2022) and Bakhtiar et al. (2018) respectively. I was responsible for applying for and obtaining ethics for the study, the conceptualization of interview questions, research questions, carrying out the research study, data analysis, as well as writing the manuscript in its entirety. The fifth-grade teacher at St. George's Elementary

school, where the study took place, collaborated with me on the data collection process (i.e., assisted in the data collection procedure) and in developing the collaborative complex mathematics problem. Portions of the methodology, specifically the materials and data collection procedure are described in Chapter 3 are included in a co-authored book chapter (Singh & Muis, 2021).

Fellow Muis lab members James Vivian and Kelsey Losenno assisted in transcribing audio files of students solving the complex problem and interviews. Dr. Ivana Di Leo assisted with data collection, interviewing students, and provided inter-rater reliability for coded transcriptions and interviews. Dr. Courtney Denton-Hurlbut and I discussed the use of Atlas.ti as a coding and analysis software. Based on her experiences in using the software for her own dissertation, she assisted me in evaluating Atlas.ti as an appropriate software for a qualitative exploration of the data collected.

Chapter 4

Contributions

Dr. Krista R. Muis supported me in the quantitative analysis approach by providing feedback on my quantitative results and provided me with readings and resources to support me in reporting qualitative results.

Chapter 5

Citation

Singh, C.A. & Muis, K. R. (submitted). An integrated model of socially shared regulation of learning: The role of metacognition, affect, and motivation. *Educational Psychologist.*

Contributions

Educational implications, study limitations and future directions for research were independently written by me. Feedback was provided by Dr. Krista R. Muis, Dr. Susanne Lajoie. Dr. Jeffrey Greene and reviewers provided feedback on portions of the future directions and educational implications as they are included in the manuscript currently under review with Educational Psychologist.

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Chapter 1

Introduction[1]

[1] Portions of Chapter 1 are under submission with Educational Psychology: Singh & Muis (accepted). An integrated model of socially shared regulation of learning: The role of metacognition, affect, and motivation. *Educational Psychologist*

Future-proof learning requires learners to develop the understanding, skills, and attitudes that are essential for them to learn in a reliable and meaningful way in an ever-changing world (Kirschner & Stoyanov, 2020). Rapid technological advances require that teachers prepare learners for a future that holds the possibility of occupations and jobs that have yet to be created. Future-proof learning supports the notion that there is a need for learners to develop the efficacy to work collaboratively with others who possess diverse knowledge and/or skillsets (Kirschner & Stoyanov, 2020). Individuals must be able to work together effectively and efficiently to solve critical issues. In responding to calls that indicate that graduates are ill-equipped to meet the collaborative requirements of today's workplace (Griffen & Care, 2014), educational institutions at all levels need to increase their focus on the higher-level thinking and working skills involved in future-proof learning. In today's classroom context, emphasis on developing a sense of community, engaging in group dialogue and consensus building, and the co-construction of knowledge has developed in relation to the shift from teacher-centered, to more holistic, student-centered pedagogy (Panadero & Järvelä, 2015). Therefore, it is vital that we develop a concise understanding of the processes that contribute to effective collaboration. Therefore, the purpose of this dissertation is to explore the role of affect on the conditions and processes involved in socially shared regulation of learning (SSRL).

Effective collaborative learning and problem solving require members to employ a specific set of skills throughout regulation processes to be successful. Specifically, effective collaboration requires group members to engage in specific social skills that involve participation, perspective taking and social regulation (Hesse et al., 2015). Additionally, group members need to calibrate cognitive skills including task representation and learning and knowledge building processes (Hesse et al., 2015), which include integrating, refining, and synthesising information offered by other group members (Scardmalia & Bereiter, 2002).

While collaborative skills have been identified and metacognitive and regulatory processes delineated, one important question remains: *How do these factors at the individual and collaborative group level interact and influence the quality of regulatory processes?*

During collaboration, students may experience enthusiasm when working with peers whom they like, and who in turn express a like for them, which may spur interest and motivation to learn (Furrer & Skinner, 2003). Positive affect experienced in a collaborative context has been shown to relate to *high-level collaborative processes,* a deep-level processing where members share inferences, justifications, elaborations, inquiry, and relationships, which contribute to the co-construction of knowledge (Volet et al., 2009a). However, given that emotional reactions may relate to personality differences or interpersonal interactions, negative affective experiences can also hinder progress on a collaborative task (Lobczowski, 2020; Rogat & Adam-Wiggins, 2014). Indeed, coordination between group members can be particularly challenging given that each person holds different goals, regulatory skills, and task understandings (Järvelä & Hadwin, 2013). When problems arise, it is critical that students engage in regulatory processes to improve their group's collaborative efforts (Lobczowksi, 2020; Lobczowski et al., 2021a; Rogat & Linnenbrink-Garcia, 2011). This requires effective monitoring, control, and regulation of shared cognitive processes, affect, and motivation. In other words, students must engage in effective SSRL or the "… group level deliberate, strategic, and transactive planning, task enactment, reflection, and adaptation" (Hadwin et al., 2018, p. 91).

Additionally, the occurrence of SSRL has an impact on achievement outcomes (Zhou & Tsai, 2022). As previous research has shown, during collaborative learning the exchange of ideas and information is not sufficient to foster effective learning (Webb et al., 2022). Collaboration requires group members engage in and regulate task-related and social activities (Janssen et al., 2012; McGrath, 1991). Behaviours, such as displaying negative

emotions or antisocial behaviour, as well as inappropriate responses to other group members, have been shown to constrain collaboration (Barron, 2003; Wilson et al., 2006). However, when groups engage in communal regulation, students display positive emotions towards other group members, engage in appropriate responses, collaboratively monitor task progress, and reflect on how collaboration can be improved, all of which improves learning outcomes and increases performance (Barron, 2003; Johnson et al., 1990; Saab et al., 2012).

In the collaborative learning context, it is also important for students to engage in self-regulated learning (SRL) and co-regulated learning (CoRL). It is important to note I use Hadwin et al.'s (2018) definitions of SRL, CoRL and SSRL. SRL refers to an individual's deliberate and strategic metacognitive planning, enactment, reflection, and adaptation during a learning task. CoRL involves regulation via social interactions, which has the capacity to transition or shift groups towards a more communal form of regulation (see Hadwin et al., 2018). Specifically, CoRL involves an individual, or other group members, temporarily regulating the planning, enactment, reflection, and adaptation of an individual or the group during a learning task. Like SSRL, SRL and CoRL involves the regulation of cognition, behaviour, motivation, and emotions as needed during learning. In the collaborative learning context, SRL shapes and is shaped by personal and group-based beliefs and experiences, the environment, and collaborative task engagement (Hadwin et al., 2018). Importantly, as Hadwin et al. (2018) argued, individual SRL is *absolutely necessary* for effective collaboration to occur and is complementary to the emergence of SSRL. CoRL involves the awareness of group members' beliefs, goals, and progress and temporarily offloads monitoring and regulation to an "other" and has been found to be entrenched in instances of shared regulation (Grau & Whitebread, 2012). Accordingly, I posit that during collaborative learning, there may be important interactions between individual SRL, CoRL, and group-level SSRL, which could facilitate or constrain group learning and learning outcomes. To

date, no theoretical model has been proposed to account for the metacognitive and regulatory processes involved in individual and group-level regulation.

As such, a theoretical model of SSRL is needed to account for the individual and communal points of view in relation to the learning task. Specifically, for my doctoral research, I advance an elaboration of Efklides' (2011) MASRL model, that I have called *the integrated model*, which incorporates metacognition and SSRL, and affect and motivation while taking into consideration the individual and communal point of view. The proposed model adds substantively to the literature as it provides the field of SSRL with a coherent and inclusive model that considers the work of both Efklides (2011) and Hadwin et al., (2018) regarding metacognitive and regulatory processes involved in individual and group-level regulation. Subsequently, I empirically tested facets of the conditions and processes outlined in the integrated model by studying the emotions that arose amongst fifth grade students, grouped into collaborative teams, as they worked their way through solving a complex mathematics problem.

Overview of the Chapters

Chapter 2 provides a comprehensive review of the relevant literature in relation to the proposed integrated model. The proposed integrated theoretical model of SSRL situates metacognition, affect, and motivation at the socially shared level and also considers regulation at the individual and group level. Further, this review and model is the basis that informs the subsequent research study. An overview of the current study, the research aim and research questions are also provided. Chapter 3 encompasses the body of the thesis which includes a detailed description of the research study methodology including information on the context and participants, the study design, materials, study procedure and coding schemes and processes. Chapter 4 contains a thorough explanation of the research findings gleaned from the data and in relation to the research questions. Chapter 5 is a thorough discussion in

relation to the research study findings and includes a summary of research themes as well as limitations of the current study, avenues for future research, and educational implications in relation to the integrated model and subsequent research findings.

Chapter 2

Literature Review[2]

[2] Portions of Chapter 2 are under review with Educational Psychology: Singh & Muis (submitted). An integrated model of socially shared regulation of learning: The role of metacognition, affect, and motivation. *Educational Psychologist*

An Integrated Model of Socially Shared Regulation of Learning: The Role of Metacognition, Affect and Motivation

Why is SSRL important to consider in the collaborative learning context? Collaborative learning requires cooperation, or the coordinated efforts of group members, directed at achieving a common goal. Effective collaboration involves mutual respect for others' abilities and contributions, and a willingness to communicate intentions, knowledge, authority, skills, and responsibility (Levine & Moreland, 2004). Additionally, collaboration requires the members to interdependently coordinate interactive negotiations and respond to the requirements of the task through insightful participation with the group (Bandura, 2001; Hesse et al., 2015). That is, collaboration involves the alignment of goals, the development of a mutual understanding of the task, and the socially shared regulation of learning, emotion, motivation, and behaviour (Levine & Moreland, 2004). To do this, collaborative groups need to be able to engage in SSRL, or the intentional collective task-related planning, enactment, reflection, and adaptation (Hadwin et al., 2018). Effective SSRL involves socially shared metacognitive processes, and the communal monitoring, control, and regulation of shared cognitive processes, affect, and motivation (Iiskala et al., 2004; Vauras et al., 2003). Essentially, socially shared regulation includes the regulatory phases the group engages in (i.e., task definition, planning and goal setting, enactment and reflection and adaptation) while socially shared metacognition entails the underlying processes (i.e., orientating, planning, monitoring, and evaluating) that guide these phases.

As previously mentioned, a theoretical model of SSRL is needed to account for the individual and communal points of view in relation to the learning task. *The integrated model*, incorporates metacognition, SSRL, affect and motivation from the individual and collective perspective. I chose these three facets of SSRL (i.e., metacognition, affect, and motivation) as they are generally considered core component processes in the effective

regulation of learning (Bandura, 1994). I first present a broad overview of the motivation and affect in self-regulated learning MASRL model (Efklides, 2011). Subsequently, an overview of SSRL is presented followed by the integrated model of metacognition and SSRL where metacognition, affect, and motivation are situated at the metacognitive and socially shared level. Empirical evidence that supports the integrated model is then discussed and critically evaluated. The proposed model adds substantively to the literature by responding to calls to provide the field of SSRL with a coherent and inclusive model that considers both metacognitive and regulatory processes involved in individual and group-level regulation.

An Integrated Model

The integrated model, presented in Figure 1, is an elaboration of Efklides' (2011) MASRL model which situates metacognition, affect, and motivation at the socially shared level and thus depicts the facets, processes, and interactions involved in SSRL. As well, the integrated model considers the reciprocal relationship between individual and group level conditions and products as put forth by Hadwin et al. (2018).

Figure 1

An integrated model of socially shared regulation of learning

Note: MK = metacognitive knowledge; MS = metacognitive skills; ME – metacognitive experiences.

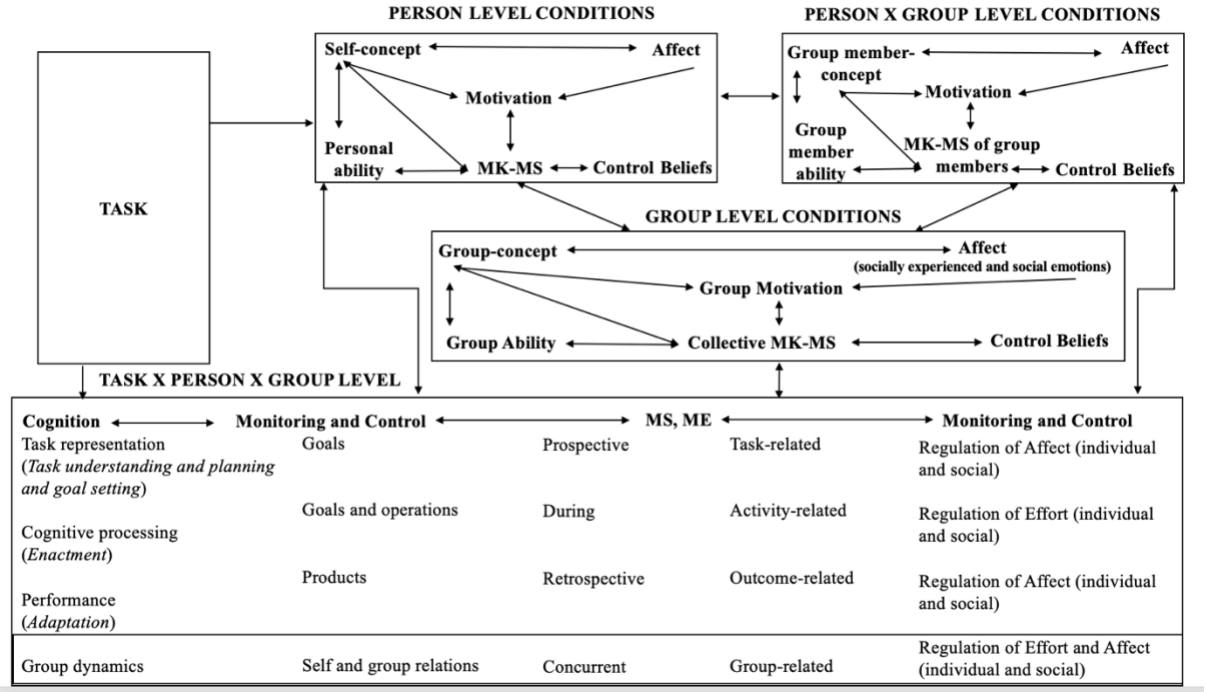


Figure adapted from Efklides, A. (2011). Interactions of metacognition with motivation and affect in self-regulated learning: The MASRL model. Educational Psychologist, 46, 6-25.

Conditions are considered and processes commence when students are presented with a collaborative learning task. At this point, Person-level conditions are considered and assessed by each group member. That is, each individual assesses their capabilities, goals and expectations, affect in relation to learning/the subject area, ability, perceptions of control, metacognitive knowledge of the self and learning strategies, to create a profile of the self. Person-level considerations in turn frame Person x Group-level conditions. At this level, each individual considers their group members' capabilities, potential goals, and expectations, affect in relation to learning, abilities, perceptions of control and metacognitive knowledge of the group members and their learning strategies, which develop into each group member

developing a profile of their fellow group members. Metacognition is often considered to be an individual process that assists an individual in their regulation of cognition (Efklides, 2008). However, recent research is challenging earlier conceptualizations of metacognition as being an individual phenomenon. Efklides (2008) ascertains that metacognitive awareness underpins the social level of metacognition. Social level metacognition is considered to be a meta level of personal awareness that uses metacognitive experiences and metacognitive knowledge to communicate our thought processes to other individuals and assess the thinking of others Efklides (2008).

Person- and Person x Group-level condition profiles then inform a Group-level, or communal, understanding of the group's conditions. That is, the group as an entity collectively considers its capability, goals, and expectations, affect in relation to learning, ability, perceptions of control and metacognitive knowledge of the group and learning strategies. Person-, Person x Group-, and Group-level condition profiles inform Task x Person x Group-level processes across the four cognitive phases of the task (i.e., task representation, cognitive processing, performance, and group dynamics). That is, conditions inform top-down learning regulation and regulation of affect and motivation in relation to task representation, cognitive processing, performance, and group dynamics. At the same time, individual and collective experiences gleaned from the Task x Person x Group-level result in bottom-up regulation, where conditions at the Person-, Person x Group-, and Group-level are then renegotiated. To situate the processes in the integrated model at the social level, I first present a brief overview the MASRL model. Subsequently, I further detail processes involved in the integrated model through a description of how socially shared metacognition and regulation of learning function within the integrated model.

The MASRL model

Metacognition involves the cognitive monitoring and control of information that is received or produced (Flavell, 1979; Winne, 2018). The MASRL model connects metacognitive facets of the Person-level, the learning task, and monitoring aspects of the online task processing that in turn prompt the subsequent control of decisions that occur during phases of self-regulated learning. The interplay between metacognition and SRL is situated in the MASRL model by referring to top-down (i.e., goals gleaned from macrolevel personal characteristics that inform self-regulation on the task, effort and/or affect) and bottom-up self-regulation (i.e., microlevel self-regulation gleaned from monitoring of the task processing and subsequently control of decisions) (Efklides, 2011). Efklides (2008; 2009; 2011) identified three facets of metacognition involved at the Person-level that influence regulation at the Task x Person level, which in turn informs Person-level characteristics: metacognitive knowledge, experiences, and skills.

Metacognitive knowledge refers to declarative knowledge, or information of facts, tasks, goals, and strategies, including information an individual has about themself and other individuals. Metacognitive knowledge is continually updated because of the monitoring of observations, awareness, interactions, and language use. *Metacognitive experiences* include awareness of, and the feelings experienced in relation to a task and/or the processing of incoming information. Metacognitive experiences encompass three sub-facets: metacognitive feelings, metacognitive judgements, and online task-specific knowledge. Metacognitive feelings involve feelings of difficulty (i.e., difficulty and ease), and confidence (see Efklides et al., 1999; Efklides, 2002). Metacognitive judgements include the estimates that individuals make about effort, time, and appropriateness of responses. Online task-specific information refers to an awareness of task information, and ideas and thoughts in relation to the task. To note, metacognitive feelings are nonanalytic, or implicit and intuitive, whereas metacognitive judgements may be both analytic, or deliberate and intentional, and nonanalytic. However,

online task-specific information is purely analytical in nature. These facets are subject to an individual's conscious and unconscious control and monitoring and instrumental to regulation (Efklides, 2008). Lastly, *metacognitive skills* include the intentional use of strategies to control cognition, and focus on orientation, planning, regulation of cognition (e.g., rehearsal and elaboration), monitoring, and evaluation. Together these facets support the monitoring and control functions involved in self-regulation with metacognitive knowledge and experiences involved in the function of monitoring of cognition, and metacognitive skills involved in the control of cognition (Efklides, 2008). However, within a collaborative learning context I additionally need to consider socially shared forms of metacognition and learning regulation. Therefore, I provide an overview of socially shared metacognition and regulation of learning in relation to the conditions and processes involved in the integrated model.

Socially Shared Metacognition and Regulation of Learning

Socially shared metacognition involves the group, as a social entity, monitoring and controlling group processes needed to work towards a single objective (Lobczowski et al., 2021a). It involves collectively sharing, evaluating, negotiating, co-constructing, and reflecting on facets of the learning task, group functioning, collective understanding, and learning outcomes (Lobczowski et al., 2021a). Most studies to date on metacognition have focused on the individual and how experiences in a social context influence individual metacognition (Azevedo et al., 2004; Efklides, 2011). Research has found that socially shared metacognition is positively related to higher-level problem-solving, success on a learning task, and understanding (see Borge & White, 2016; Hurme et al., 2015; Iiskala et al. 2011; Khosa & Volet, 2014); however, a comprehensive framework is required to better understand how underlying processes interact and are influenced by internal, social, and contextual factors. Extending the MASRL model's initial aims (see Efklides, 2011), the integrated

model proposed here seeks to account for the interactions between metacognition, motivation, and affect at the Person-, Person x Group-, and Group level, and operationalize the person and group characteristics that operate across learning situations. As well, the integrated model seeks to account for how cognition, metacognition, affect, and motivation interact to predict SSRL at the Task x Person x Group level and considers how SSRL at the Task x Person x Group level informs Person-, Person x Group- and Group-level characteristics. Lastly, such an extension would aid in addressing the cognitive-situative divide (i.e., the inability for the cognitive or situative perspective alone to independently account for the transfer of learning (see Vosniadou, 2007)), in relation to shared metacognitive processes, and its situatedness among SSRL processes.

As previously mentioned, SSRL involves shared and communal conscious and intentional planning, task enactment, reflection, and adaptation during a learning task (Hadwin et al., 2018). Hadwin et al. (2018) proposed that SSRL, like SRL and CoRL, progresses over four roughly ordered recursive phases. During Phase 1, *task understanding*, the collaborative group negotiates communal opinions and understandings of the learning task. In Phase 2, *goal setting and planning,* the group develops a communal awareness of the conditions, contexts, and objectives to develop shared goals, standards, and plans in relation to the learning task. In Phase 3, *task enactment*, group members coordinate engagement by jointly harnessing various cognitive, socio-emotional, motivational, and behavioural strategies. Finally, during Phase 4, *adaptation*, group members collectively monitor and evaluate each of these regulatory sequences to direct decision-making and adjustments of collaborative processes.

To demonstrate the processes involved in the integrated model, the following example is used. A collaborative group containing four members, Ola, Devon, Sasha, and Adrian, are tasked with collectively solving a complex mathematics problem. The task itself contains

several objective features and instructional goal(s) and is embedded within a learning context that provides various affordances and constraints. Esmonde (2009) describes various contextual factors that can influence how individuals interact with one another in a group learning context including how the learning activity is assessed, evaluation practices (i.e., peer assessments), reward systems used in the classroom, whether roles are assigned to group members, group composition (e.g., number of group members, the hetero- or homogenous grouping of students based on ability) (see Webb 1984), and clarity of the learning task. In relation to the example group, the complex mathematics problem objectively is ill-structured with multiple pathways that can lead to the correct solution. It entails a high degree of complexity and requires requisite knowledge of various math operations that need to be used systematically to solve the problem. The task also requires that the group must show all their math operations. The individuals in the group have received a moderate amount of training on how to work effectively in a collaborative learning context. Instructionally, the goal of solving the mathematics problem is for students to demonstrate that they can effectively and collaboratively harness and apply the appropriate mathematical concepts so that they can solve the complex problem successfully. They have been informed that they will all receive the same achievement grade based on their collective performance. Lastly, the classroom is brightly lit, allows for ease of movement, and contains ample materials, space, and equipment designed for effective collaboration.

At the Person-level, each group member has a varying degree of understanding about their capabilities (i.e., ability, knowledge, and skills), motivation, confidence, affect (i.e., attitudes and emotions), perceptions of control, metacognitive knowledge (i.e., knowledge of self and others based on a history of experiences), and metacognitive strategies (i.e., planning, self-monitoring, self-evaluation). This level is comprised of what Hadwin et al. (2018) referred to as the individual *conditions.* For example, group members Ola and Devon

consider their mathematical capabilities required to solve the complex problem as high, and their motivation is high for engaging in and completing the activity. They feel confident and are curious about mathematics. They feel a high degree of control over their ability to understand complex mathematics problems. They hold the belief that they are able to successfully and appropriately use mathematical operations and have an awareness of the repertoire of math and math-related strategies that they can use. By contrast, group members Sasha and Adrian have a fragile understanding of their mathematical capabilities. They have a low degree of confidence in their ability (i.e., competence) to effectively apply the mathematical concepts required by the situation, and thus, their motivation for engaging in and completing mathematical operations is low. Members Sasha and Adrian are anxious and fearful to engage in mathematics learning. They hold the belief that they are unable to use mathematical understandings successfully and are unsure of the strategies that they can use to help them navigate solving mathematical operations. However, members Sasha and Adrian are receptive to receiving support from Ola and Devon to assist them in their mathematics understanding.

At the Person X Group-level, each group member may have a varying degree of understanding about their fellow group member's capabilities depending on the amount of prior experiences working with those group members and pre-existing relationships. Each individual may understand their group members' motivation, level of confidence, affect (i.e., attitudes and emotions), perceptions of control, and metacognitive knowledge (i.e., knowledge of the others based on a history of experiences), and qualities relating to group members' metacognitive strategies (i.e., planning, self-monitoring, self-evaluation). For example, group member Ola, based on previous experiences and observations, knows that Devon similarly considers their mathematical capabilities required to solve the complex problem as high, and has observed that they are most often motivated to complete

mathematical tasks. Ola senses a confidence about Devon in relation to their mathematics ability and has often witnessed Devon asking meaningful questions about mathematical concepts in class. Members Ola and Devon both feel like they are effective collaborators who can meaningfully and effectively support others in their understanding of mathematics. By contrast, group members Sasha and Adrian have worked together in remedial mathematics learning situations and independently know that the other considers their mathematical capabilities to be weak. Adrian has witnessed Sasha frequently ask the teacher and their peers to verify their answers to mathematical operations, which leads Adrian to think that Sasha may lack confidence in her math abilities (i.e., competence). Sasha has noticed that Adrian is often nervous before math classes and struggles to remain calm before math tests and thus deduces that Adrian is often anxious and fearful to engage in mathematics learning. However, members Sasha and Adrian are receptive to receiving support from Ola and Devon to assist them in their mathematics understanding.

Metacognitive knowledge of other group members can be conceived in similar ways to distributed or shared memory. Tindale and Kameda (2000) proposed that groups collaborating on a task can be considered an information processing system that entails multiple working memories that create a collective working space. Within this collective space, each member of the group can share their task-relevant information and knowledge. Each individual within the group may also understand different facets of the task or may know how to complete one aspect of the task, whereas others may not. Under this condition, shared memory systems require clear communication and knowledge of who knows what and who has which skills. There is a rich history of research that has been done on shared memory systems during collaborative learning contexts, often situated in Wegner's (1978) transactive memory theory (i.e., an awareness of who knows what in the group). Research has shown that shared or transactive memory can facilitate group performance in groups whose

members are aware of other group members' knowledge compared to groups who are not aware (Michinov & Michinov, 2009; for a review, see Moreland & Argote, 2003). With more complex tasks, shared memory that is regulated effectively can be beneficial because it reduces the cognitive load required given the distribution of cognitive capacity (Kirschner et al., 2009). Group members can benefit from each other's knowledge and skills if they develop a solid, shared understanding and awareness of who knows what in the group (Kirschner et al., 2011). This requires effective collaboration for successful outcomes; regulation of group memory is essential and metacognitive knowledge of each group member's knowledge and skills is necessary for conflict resolution or when problems occur during task processing. Communally pooling this understanding of the others' abilities enables the group to holistically set goals for the learning task, share the labour for the learning task, allow members to specialize in different skills and responsibilities related to the learning task, and rely upon each other's domain-specific knowledge (Lewis, 2003, Wegner, 1987).

At the Group-level the group develops a collective entity, or a collective group concept, that is based on an amalgamation of Person- and Person x Group-level characteristics (or conditions), which establishes perceptions about the group's capabilities. These perceptions of collective capabilities influence Group-level motivation, competence, and affect (i.e., attitudes, socially experienced emotions, and social emotions). Perceptions of collective control over the task and learning are informed by metacognitive knowledge of the group based on knowledge of self and others informed through a history of experiences. Control beliefs are informed by motivation using metacognitive strategies, which are group-level processes including orienting, planning, group monitoring and evaluation. For example, despite the range in ability and knowledge perceptions, together group members Ola, Devon, Sasha, and Adrian collectively consider that their communal mathematical capabilities are

fair. Together they feel fairly confident in mathematics and believe that they are capable of being successful in mathematics when working together. As a consequence, they are willing to put a collective effort into their mathematics learning. Collectively, the group believes that they have a high degree of control over the mathematics learning task and believe that they are able to successfully and appropriately use mathematical operations based on the repertoire of math and math-related strategies that some of their members possess. However, despite the collaborative group's perceptions of knowledge, considering the task's time limit, and the self-concept and control beliefs held by members Sasha and Adrian, the group decides that they will need a moderate (rather than minimal) amount of time to complete the task successfully.

These perceptions of Person-, Person x Group-, and Group-level conditions contribute to the quantity and quality of SSRL that takes place at the Task x Person x Group level, where the group begins to cognitively process the task as well as the group's dynamics. Therefore, I propose that *group dynamics* is a facet of cognition that influences regulation while processing the task. Cognition of group dynamics develops in relation to cognition of the phases of task processing and occurs when self- and group-relations are metacognitively considered concurrent to the task unfolding. It is important to note that the use of the term *concurrent* is not synonymous to metacognitive experiences that occur *during* the task (see Papadopolous et al., 2021), rather the term, *concurrent* is used to describe metacognitive experiences related to group dynamics that occur parallel with the task. In this fourth phase, *group dynamics,* I propose that group members must effectively monitor and control self- and group-relations to successfully facilitate the previous three phases.

It is within these four cognitively guided facets that the four recursive phases of SSRL (i.e., task understanding (Phase 1), goal setting and planning (Phase 2), enactment (Phase 3), and adaptation (Phase 4)) are found, which are informed by metacognitive functioning of

control and monitoring and communal regulation of cognition, affect, and effort. The experiences at the Task x Person x Group-level recursively re-inform perceptions of Person-, Person x Group-, and Group-level conditions. The following discussion further illustrates the interplay between metacognition, affect, and motivation, and SSRL at the Task x Person x Group level.

Metacognition at the Task x Person x Group Level

At the Task x Person x Group level, during *task representation* where SSRL Phases 1 and 2 *(task understanding, planning and goal setting)* mostly take place, the collaborative group negotiates communal opinions and understandings about the learning task. During this initial phase, the group considers the macro-level conditions of the learning task, self, and group. To develop the group's representation of the task, prospective Person-, Person x Group-, and Group-level metacognitive experiences contribute to the development of communal online task-specific knowledge (Efklides, 2002), or a joint judgement of effort depending on whether the group's knowledge is coherent or fragile, deep, or shallow (Efklides, 2011). Simultaneously, the group employs the use of metacognitive strategies of orienting, planning, monitoring, and controlling group cognition to determine the task at hand, develop goals, identify gaps in their understanding of the task and/or content (Lobczowski et al., 2021a) and establish a plan for solving the complex problem.

Once again, I refer to the collaborative group working through the complex math problem. Each group member develops a representation of the task based on their Person-level conditions. Additionally, each group member monitors their task-specific knowledge and ascertains a personal belief that the task will be easy or effortful based on their metacognitive knowledge about the facets of the task. At the Person x Group-level, each group member also assesses their perception of the other group member's task-specific knowledge. These Person-, and Person x Group-level conditions contribute to the group, as

an entity, developing a communal understanding of their combined task-specific knowledge, which contributes to a collective judgement of effort/ease based on their pooled quality and depth of knowledge. During learning regulation phases 1 and 2 (i.e., task definition, and planning and goal setting), group members may be heard discussing how they interpret the task and/or sharing ideas about their content knowledge (or a lack thereof) in relation to the task with their group mates. In socially regulating their learning they may be overheard developing a communal understanding of the task, summarizing their group understanding and possibly collaboratively deciding on timelines for task completion.

Empirically, researchers have considered how individual instances of metacognition function as a catalyst for shared instances of metacognition. Some researchers have looked at shared metacognition via a learner's outward demonstration of metacognitive skills (i.e., orienting, planning, and/or monitoring of their cognition) in a group context (De Backer et al., 2015; De Grave et al., 1996; Jin & Kim, 2018; Khosa & Volet, 2014). For example, DeBacker and colleagues (2015) examined the adoption of socially shared metacognitive regulation amongst higher education students in a reciprocal peer-tutoring intervention. They found that metacognitive regulation slowly moved from individually oriented to socially shared instances as the familiarity with group members increased. The authors also found that acts of shared regulation of metacognition were more apparent when students were engaged in the metacognitive strategies of orienting and monitoring, in contrast to planning and evaluating strategies.

For example, recall that group members Ola and Devon have a high degree of math confidence and believe that they can successfully and appropriately use mathematical operations and have an awareness of the repertoire of math and math-related strategies. When Ola and Devon review the complex problem, they are motivated to solve the problem based on these Person-level perceptions. By contrast, group members Sasha and Adrian have a low

degree of math confidence and believe that they are likely to be unsuccessful in using mathematical operations. However, through sharing and negotiation, Ola, Devon, Sasha, and Adrian develop a communal perception of their abilities, knowledge, and group concept in relation to the task parameters, which influence the group's motivation to engage in the learning activity. Feelings of difficulty may be mediated by an understanding of Person x Group-level conditions which include the degree to which members believe that their fellow group members are knowledgeable and able to carry out the task. This, in turn, contributes to creating a collective feeling of knowing and effort/ease of the task. Based on this collective understanding, the group communally develops goals for solving the problem and identifies a plan of action.

At this point, the group shifts to *cognitively processing* the task where SSRL Phase 3 (*enactment*) is undertaken. There are enactment strategies involving the rehearsal, elaboration and monitoring and control of cognitive processes used to solve the problem. It is during this phase where, depending on how the problem-solving session progresses, collective judgements of ease or effort influence subsequent control strategies. For example, if a misalignment occurs between the products created during cognitive processing via monitoring of the standards and goals set in task representation, the group may have to coordinate further control over the operations or the standards they set. Once cognitive processing concludes, the group engages in evaluating their *performance* (Phase 4 adaptation/evaluation) on the task. It is during this phase that the group experiences feelings of confidence or insecurities about the outcome of their performance as well as their perceptions of other members' performance. If the group deems, through feelings of insecurity about their performance, that their cognitive processing of the task does not meet the standards or goals set out in the plan established during task representation, then the group may collaboratively decide to revisit their representation of the task, re-evaluate the

standards, goals, or conditions and/or exert further monitoring and control over the operations. For example, if the group evaluates their calculations and determines that errors are being made, then the group may decide to revisit their understanding of the task, adapt the plan and goals they set, or engage in re-calculations. These experiences in turn influence and inform macro-level perceptions of Person-level, Person x Group-, and Group-level conditions, which influence subsequent micro-level SSRL phases embedded in task representation, cognitive processing, and performance.

In the fourth phase, *group dynamics,* group members effectively monitor and control self- and group-relations while recursively moving through the three aforementioned phases. Successfully monitoring and controlling of group dynamics involves aptitudes that, like subject matter, need to be taught explicitly and practiced often. Additionally, I theorize that successful monitoring and control of group dynamics, practiced over time, would bring about increased instances of SSRL. Lastly, it is important to note that metacognitive skills and experiences involved in the prospective, during, retrospective and concurrent monitoring and controlling during the four phases in turn informs Person-, Person x Group-, and Group-level conditions.

However, despite the group recursively engaging within the four phases of task processing as they work their way through the complex learning task, each individual's amount of effort, engagement, and commitment to the group's effort may differ. For instance, *social loafing*, or the conscious or unconscious inclination of individuals working in a group context to expend less effort and engagement than they would when working in an individual learning context (Latané et. al., 1979), has been found to be influenced by apathy, levels of competency, and group conflict. Recall that group members Sasha and Adrian have a low degree of math confidence and their competence in using mathematical operations is thus low. Perhaps these two members, based on their perceptions of ability, develop an

independent goal to simply complete the collaborative task by expending as little effort as possible. Therefore, despite feelings of difficulty in relation to the task being mediated by other group members' knowledge and ability, individual group members may develop individual goals in solving the problem that may compromise the quality of engagement and SSRL.

Conversely, it has been found that students who exhibit dominant behaviour in a collaborative learning context can negatively impact how a collaborative group functions (Theobald et al., 2017). However, with proper training in managing group dynamics, and thoughtful task structuring that promotes interdependence as suggested by Theobald et al., (2017), group members could be better able to independently and collectively monitor and control group member's efforts and in turn mediate the effects of negative Person-level conditions associated with perceptions of ability and self-concept. Recall that group members Ola and Devon have a high degree of math confidence and their competence in using mathematical operations is thus high. Paired with two students with lower math confidence and competence, these members may dominate task processes. Alternatively, Sasha and Adrian, who experience lower math confidence, may overly rely on their highly confident peers, and expend less effort during the task. Khosa and Volet (2014) studied the quality and impact of productive engagement and metacognitive regulation among two groups of university students on a science-learning task. Along with cognitive activity, the authors studied the frequency of metacognitive regulation (planning, monitoring, and evaluating) and the quality of the regulatory episodes (high versus low quality). They found that group goals that focused on maximizing learning (over simply completing the task) paired with high-level cognitive activity were associated with high-level metacognitive regulatory episodes. Therefore, at the Task x Person x Group Level, low cohesion, misaligned goals, or a lack of effort could compromise regulation.

In summary, studies have found that individual metacognition and metacognitive experiences play an important role in the initiation of instances of shared metacognition and metacognitive regulation. Additionally, the learning task influences the quality and use of metacognitive skills in a collaborative learning context. Affect is another ingredient that plays an important role in the operationalization of the integrated model. Examples of how socially shared affect connects to metacognition and SSRL are presented next.

Socially Shared Affect in Metacognition and Regulation of Learning

Affect, an umbrella term that includes feelings, moods, attitudes, emotions, and self-esteem, is considered to be the subjective experiential state that has a pleasant or unpleasant valence (Efklides, 2017; Forgas, 1994). *Feelings*, a component of metacognitive experiences, are both affective and cognitive in nature (Efklides, 2008). They arise from the recognition of states (i.e., feelings of confidence and difficulty) that come about from the monitoring of cognitive processes and are denoted by associations with pleasure or unpleasantness. *Moods* are the residue left by emotion and, as such, last longer in duration compared to emotions (Forgas, 1994; Frijda, 1986). *Emotions* are synchronized psychological processes that involve affective, cognitive, physiological, motivational, and expressive components (Pekrun & Stephens, 2012). Emotions are relatively short-lived in their duration and are activated in response to events that relate to an individual's goals or concerns. They make individuals act in a situation and involve making subsequent evaluations based on their triggering stimuli (Pekrun, 2006). Emotions can predict students' or a collaborative group's attentional resources, their motivation to learn, the quality and effectiveness of their learning strategies, and ultimately, the regulation of learning (Pekrun & Stephens, 2012).

Efklides et al. (2018) considered the interactions between metacognition and affect. Metacognitive experiences, affective in their nature, are metacognitively oriented feelings, judgments, and levels of confidence that are connected to a learning task, cognition, or

cognitive outcomes. As such, metacognitive experiences are prospectively, currently, or retrospectively oriented, and contribute to the kinds of appraisals that an individual makes in relation to a learning task (Efklides, 2002; 2009). Efklides proposed that metacognitive experiences establish the ground for appraisals that give way to emotions (Efklides, 2009; Efklides et al., 2018). At this point, it is worthwhile to differentiate between metacognitive experiences and metaemotional experiences (see Norman & Furnes, 2016). Metacognitive experiences are the experience-based judgements and feelings that occur in relation to a cognitive activity (Koriat, 2007; Norman et al., 2010), whereas metaemotional experiences are emotions experienced in relation to emotions (e.g., feeling angry that we are feeling sad, or feeling happy that we are feeling pride). In relation to the integrated model shown in Figure 1, metacognitive experiences and metacognitive processes to control and monitor affect may be additionally informed by, and occur in response to, one's metaemotional experiences.

Additionally, emotions indirectly provide feedback to metacognitive knowledge (i.e., knowledge of facts and information, and beliefs about cognition, the learning task, goals, and strategies) via motivation and perceptions of control (Efklides, 2011). For example, metacognitive experiences that entail feelings of difficulty serve to inform appraisals of control over learning, whereas metacognitive experiences that involve feelings of effort assist in informing an individual's value for a given learning task (Efklides, 2017). Lastly, one's feeling of confidence, which serves to inform one's self-efficacy, and self-concept (which includes self-perceptions, self-efficacy, and self-esteem) are associated with attributions of competence, and in turn serve to predict and inform one's metacognitive experiences (Efklides et al., 2018; Metallidou & Efklides, 2001).

Affect, which includes attitudes and emotions, are components of the Person-level in the MASRL model. The attitudes and emotions at the Person-level are dispositions that an

individual holds in relation to their past learning experiences (Efklides, 2011). The affective residue of previous learning experiences forms the foundation of metacognitive knowledge related to the self and the task, which in conjunction with metacognitive experiences, informs expectancy-value beliefs, or expectations of success (Wigfield & Eccles, 2000). According to Muis et al. (2018), these beliefs about control, value, and the self, interact and predict the kinds of emotions students experience when engaged in the learning task. Similarly, at the Task x Person level, metacognitive experiences, which include metacognitive judgements, play a significant role in the regulation of learning and the kinds of emotions that are experienced. These emotions serve to inform the learner about progress on a given learning task (Efklides, 2011; Singh & Muis, 2021).

For example, when the perceived difficulty of the task and the effort required to complete the task are manageable (i.e., high control) and the learner values the task (i.e., high value), the learner will experience enjoyment, which indicates that all is well with the progression of learning. Conversely, when the perceived difficulty of the task and the effort required to complete the task is too great (i.e., low control and high value), anxiety may ensue and inhibit regulatory processes (Muis et al., 2018). Moreover, emotions experienced at the Task x Person level predict motivation for learning and task completion (Efklides, 2011). However, collaboration on a task may bring about emotions that are a consequence of personal and/or social relations experienced in the group. Additionally, metacognitive experiences have been found to play a critical role in activating instances of shared metacognition (Iiskala et al., 2011), as emotions may have the capacity to affect mood states and the accuracy of metacognitive experiences, which in turn may impact the effectiveness of SSRL (Efklides, 2011).

To illustrate the interplay of metacognitive experiences in SSRL, I refer back to collaborative group members, Ola, Devon, Sasha, and Adrian who are working through a

complex mathematics problem. At the Person-, and Person x Group-level, all group members hold metacognitive knowledge in relation to themselves and their fellow group members. In entering the learning situation, Ola, and Devon each enjoy mathematics (affect at the Person-level condition) and believe that solving the mathematics problem will be fairly undemanding (metacognitive judgement of the task condition). Informing Group x Person-level related affect, individuals Ola and Devon may also be friends with Sasha and Adrian and via previous collaborative learning experiences, know that they are easy to work with (metacognitive knowledge of the group condition gleaned from metacognitive feelings from prior learning tasks with the same group members). However, Sasha and Adrian enter the learning situation with a general dislike for mathematics (affect at the Person-level condition) and believe that solving the mathematics problem will be arduous (metacognitive feelings of the task condition). However, Sasha and Adrian are friends with Ola and Devon and have found working together to be generally trouble-free (metacognitive knowledge of the Group-level condition based on metacognitive judgments from prior learning tasks with the same group members).

Empirical investigations corroborate the link between affect and metacognition and regulation of learning at the social level (Ainley, 2007; Jin & Kim, 2018; Lobczowski et al., 2020; 2021b; Malmberg et al., 2022; Singh & Muis, 2021). For example, it has been found that perceptions of task difficulty may be influenced by engaging in complex problem-solving in a collaborative learning context. Malmberg et al. (2022) examined the change in individual perceptions of task difficulty within a collaborative learning context amongst 64 students ages 13 and 14 years old, enrolled in a five-week physics course. They found that students found the learning task to be less difficult after collaboratively engaging and completing the task. They concluded that the perception of task difficulty may be a result of the collaborative learning process. Therefore, prior experiences in collaboration may inform

individual feelings of task difficulty/ease and confidence. In relation to the collaborative group metacognitive knowledge of Person-level conditions (i.e., mathematics is easy and mathematics is effortful),), and Person x Group-level conditions (i.e., friendly group members who have been enjoyable to work with) paired with metacognitive experiences related to the task (i.e., undemanding versus arduous task) shapes motivation for learning at the Group-level, and informs Task x Person x Group-level metacognitive engagement, experiences and strategy use.

Affect at the Task x Person x Group Level

The group context can conjure metacognitive feelings that may present themselves not only in relation to the task but in relation to group interactions during task engagement. Affectively speaking, the Task x Person x Group level functions in a similar way as the Task x Person level. However, the Task x Person x Group level is additionally focused on group interactions that are task, activity, outcome, or group related. At the Task x Person level, metacognitive feelings experienced prospectively, during, and retrospectively in relation to the task influence the Person-level perceptions of motivation for learning, providing the individual with information about how to navigate the task, and predicting subsequent affect. At the Task x Person x Group level, metacognitive feelings and judgements experienced concurrently while engaged in the learning task additionally contribute to influencing and informing the motivation for group functioning, providing the group and its members with information about how to navigate group processes and predict socially oriented emotions.

Referring to the collaborative group as an example, consider that at the Task x Person level, Sasha experienced a misalignment between the products created during the enactment phase via monitoring of the standards set in Phase two. Sasha then experienced outcome-related confusion and, in response, feelings of difficulty arose (metacognitive feelings). At the Task x Person x Group level, this experience of confusion and feeling of difficulty is

experienced differently (or perhaps not experienced at all) by different members of the group depending on their Person-level interpretation of the facets of the self, task, and the group level characteristics. In this way, Sasha may be confused, and then perhaps hopeless and indifferent to the task; precursors involved in instances of social loafing (Luo et. al., 2021), and experience a decline in metacognitive strategy use and SRL (Muis et al., 2015). Whereas Devon may be surprised or curious about the misalignment and in turn engage in increased instances of metacognitive strategies like monitoring and evaluating (Muis et al., 2015). Additionally, one group member may feel shame because they were the ones who initiated actions that contributed to the misalignment, and at the same time, another group member may be frustrated with the initiator.

Task x Person x Group level metacognitive feelings and judgments may influence the kinds of emotions experienced during the collaborative learning process including social emotions, which encompass social achievement emotions or emotions that are related to the attainments of others (i.e., empathy, pride, jealousy, shame, schadenfreude, guilt, envy) (Hofmann & Doan, 2018; Pekrun & Stephens, 2012) and/or socially-experienced emotions (i.e., emotions directed towards others such as teachers or classmates which include frustration, anxiety, enjoyment, confusion, curiosity, boredom, hopelessness) (Pekrun & Stephens, 2012). Emotions experienced at the Task x Person x Group-level sets the emotional climate of the group, which is a composition of other group members' emotions, informed by feelings of difficulty or ease in relation to group functioning on the task. When these emotions arise at the Task x Person x Group level, each group member will have to self-regulate their individual activity-related effort and control operations, but the group will have to socially regulate to persevere or redirect their collaborative efforts and control group-related regulatory processes (via metacognitive strategies/skills).

Singh and Muis (2021) investigated the role of emotions on the co-regulation of learning with 29 fifth grade students as they collaboratively solved a complex mathematics problem. The researchers considered how instances of social emotions impacted the function and focus (see Iiskala et el., 2011) of co-regulatory processes. Functions of co-regulation either facilitated socially shared metacognition by activating or confirming understanding or inhibited socially shared metacognition by slowing processes or changing the direction of activity. They additionally considered at what phase in learning regulation these functions took place. They found that empathetic feelings for fellow group members were associated with group members facilitating the confirmation of understanding during task representation or task definition, and performance, or Phase 4, adaptation, and evaluation, of SSRL. Conversely, frustration and anxiety were negatively associated with facilitating the activation of performance or Phase 4 adaptation and evaluation. Social emotions including shame, jealousy, embarrassment, guilt, and envy experienced in the group context led to students changing the agreed-upon goals and strategies needed to solve the problem (Singh & Muis, 2021). Therefore, negative individual and social emotions experienced in the example group may result in challenges in the group being able to evaluate their performance and/or deciding on the kinds of goals they need to set and strategies they need to use to solve the complex problem.

Collaborative learning contexts tend to have higher instances of socio-emotional challenges as compared to individual learning situations (Ainley, 2007). Specifically, collaborative learning contexts can bring about negative emotions and in turn create motivational barriers when group members' goals, personalities and demands conflict (Järvelä et al., 2000; Kreijns et al., 2003). Therefore, emotions, like cognition, are subject to regulation (Winne, 2018). Emotion regulation refers to an individual's monitoring, evaluation, and modification of the occurrence, length, or intensity of an emotional

experience (Wolters, 2003). In their study on socially shared emotion regulation with teacher-education students, Järvenoja and Järvelä (2009) found that emotional control in a collaborative learning situation required not only controlling one's own emotions but also control of group-level emotional experiences. They found that over 80% of social challenges experienced during the collaborative situation were related to issues with teamwork, collaboration, or work and communication. Those challenges were emotional in nature and groups used a combination of self- and shared regulation of emotion to navigate social challenges.

Additionally, Järvenoja et al. (2019) explored the emotion regulation strategies of 62 higher education students during challenging learning situations in a collaborative context. They found that different kinds of learning challenges evoked group-level emotion regulation. Specifically, the authors found that group-level emotion regulation in the form of encouragement, increasing awareness, social reinforcement, and task restructuring were activated in response to cognitive, social interaction, and emotional and motivational challenges. Emotion and motivational challenges were most often regulated through co-regulatory emotion regulation and specifically involved increasing the awareness of group members' emotional discord to allow for opportunities for regulation. Task structuring, a cognitive strategy, was also found to be a group-level emotion regulatory strategy when its purpose focused on restoring the on-task behaviour of group members experiencing negative emotions.

In summary, emotions can influence the regulatory processes at the individual and social levels of learning regulation. Emotions are a part of the internal conditions of the individual, play a role in the standards one uses to evaluate products, and importantly, emotions can be regulated (Winne, 2018). Efklides' MASRL model once again provides a complementary perspective on metacognitively experienced affect that can be extended to the

integrated model. However, motivation influences metacognitive processes and SSRL and plays an integral role in the degree to which groups commence, sustain, and complete the collaborative learning process. Examples of how socially shared motivation connect to metacognition and SSRL are presented next.

Socially Shared Motivation in Metacognition and Regulation of Learning

Motivation, the "…psychological drive that leads to cognitive engagement and ultimately achievement" (Järvelä et al., 2010, p. 16), plays an integral role in the initiation and sustaining of collaborative learning processes (Hadwin et al., 2018). Motivational influences are shaped by the kinds of emotions experienced in relation to the learning task and context (Efklides et al., 2018). Motivation in relation to learning regulation and metacognition is positioned as a consequence triggered by the task and an antecedent of what occurs next, and the contextual factors in which the task is embedded (Efklides, 2011). For example, Miele and Scholer (2018) describe the role of metamotivational knowledge in monitoring and control processes. According to the authors, metamotivational knowledge includes knowledge about the task, strategies, and self. For example, in working on a complex problem in a collaborative setting, effective metacognitive regulation of motivation requires an individual having an understanding of *task knowledge*, or the required level of motivation to complete the task, *strategy knowledge*, which includes an understanding of the strategies they can use to enhance or shift motivation, and *self-knowledge* or their ability to implement these strategies.

From an SSRL standpoint, motivation has been conceptualized as playing a role in shared regulatory processes, although it is not explicitly situated in the original COPES architecture (i.e., that is, the conditions, operations, products, evaluations, and standards, or processes involved in learning regulation) (see Winne & Hadwin, 2008). From an SRL standpoint, motivation is demonstrated by enacted changes to the products, operations, or

standards in the regulatory phases to align standards and products moving forward (Winne & Hadwin, 2008). From a metacognitive standpoint, motivation is the result of, and arises in response to, metacognitive experiences that occur in relation to a learning task (Efklides, 2011). To position motivation within the integrated framework, this section will be organized as follows. First, motivation is discussed as it pertains to metacognitive processes at the Person-level. Metacognition and motivation in collaboration at the Group-level and its connection to SSRL are then considered.

Nolen and Ward (2008) discuss a dualistic approach in the representation of motivation as it occurs in the larger social context; motivation as being *influenced* by the learning environment, and motivation as being *constructed* by the learning environment. This intra-, inter-conceptualization lends itself well to bridging the cognitive-situative gap in studying socially shared facets of learning processes and the influences on these processes (Järvelä et al, 2010). As a consequence, what I call *intra-motivation in collaboration*, or individual motivation influenced by the collaborative context, can be viewed as an individual member's beliefs, achievement goals, and appraisals, and how collaborative processes affect those intra-motivational constructs that are grounded in a sociocultural perspective (Nolen & Ward, 2008).

By contrast, *inter-motivation in collaboration,* or socially constructed motivation, is a situated approach to the study of motivation that occurs in a collaborative learning context and involves the group's communal ability to maintain group member engagement through collaboration (Järvelä et al., 2010, Nolen & Ward, 2008). Accordingly, for effective group monitoring and control to take place the individuals in the group must develop an understanding of the level of motivation the group requires to complete the task (*collaborative task knowledge*), the strategies the group can use to enhance or shift the

group's motivation (*collaborative strategy knowledge*), and the group's ability to implement these motivational strategies (*collaborative group knowledge*).

Specific to the MASRL model, motivation manifests as a response to metacognitive and affective experiences triggered by the demands, familiarity, and context of the learning task, as well as the expectations, values, and beliefs one holds in relation to the task (Efklides, 2011). Intra-motivation at the Person-level manifests itself in the form of goal orientations and expectancy-value beliefs, which directly influence one's metacognitive knowledge and metacognitive skills (Efklides, 2011). The motivational drive that occurs, which is the result of affectively focused metacognitive experiences, could take the form of intrinsic academic motivation, for example, in relation to task enjoyment, pride and/or hope (Pekrun et al., 2002). Metacognitive feelings shape motivation in that they inform an individual about the degree of effort required for a task, the employment of control processes such as memory search and strategy use, and attributions in relation to the task outcome (Efklides, 2011). Motivation experienced during the task, or Efklides' Task x Person level, is seen as the result of metacognitive and affective experiences brought about by the demands of the task, the task topic, and an individual's familiarity with the task, as well as contextual or situational factors surrounding the task, and considerations of expectancy-value associated with a specific learning task (Ainley et al., 2002; Nurmi & Aunola, 2005).

By contrast, under a situative lens, or the perspective that knowledge, behaviours, and beliefs are a consequence of an individual participating in their social environment (Turner & Nolen, 2015), inter-motivation uses the social system, and the shared activity of individuals as the unit of analysis (Nolen & Ward, 2008). Therefore, from a situative perspective of motivation, it is what groups *do*, the actual communal shifts in the group's behaviour as a result of motivation. For example, Winne and Hadwin (2008) explained the quintessential feature of SRL is adaptation or change. Adaptation can manifest itself in three different

possibilities: changes in conditions, operations, and/or standards. Changes in task conditions seek modifications to the external facets of the task context, for example, accumulating more resources, or asking a teacher for more time. Changes in operations are the modifications one makes to the searching, monitoring, assembling, rehearsing, and translating of task-related information. Lastly, changes in standards are modifications to the evaluation criteria set for a task. Changes are based on task-related judgements that are the result of metacognitive monitoring and control and are thought to be the result of motivation.

As previously mentioned, Hadwin et al.'s (2018) operationalization of SSRL describes conditions, or the resources available, as being based on the task, self, as well as the group. Motivation-related Person, Person x Group, and Group-level conditions consider personality traits of group members and social relationships, and the facility of group member communication ability. Motivation in SRL manifests when an individual finds themselves in a state that allows change and subsequently, they engage in that specific change (Winne & Hadwin, 2008). Therefore, proposed changes in SSRL, as in SRL, would be a consequence of judgements based on metacognitive monitoring and control of these conditions. Therefore, adaptations or changes in external conditions that pertain to SSRL would include adaptations that would facilitate effective collaboration. For example, group-related changes in the condition would involve changes to the communal engagement in the task where environmental adaptations, such as re-organizing seating arrangements for better communication or members deciding to meet outside of the core learning environment to continue working on the learning task, are carried out. These actions are motivationally driven, and evident by the display of group behaviour rather than one individual member's conduct.

Järvelä and Järvenoja (2011) explored motivation in a collaborative learning context and investigated the kinds of motivation regulation strategies 16 higher education students

used when they worked in groups of four on three collaborative learning tasks. Through self-reports, the authors found 14 challenging scenarios that they grouped into five thematic categories (i.e., personal priorities, work and communication, teamwork, collaboration, and external constraints). The authors also identified six socially shared regulation of motivation strategies: task structuring, social reinforcing, efficacy management, interest enhancement, socially shared goal-oriented talk and handicapping of group functioning. Through video analysis of the collaborative learning situation, the authors found, similar to socially shared regulation of emotion, groups most often used task structuring, which targeted changing the task or environmental conditions in response to challenges with teamwork and collaboration. Groups also employed social reinforcing strategies, or strategies that reinforce a sense of togetherness and collaborative engagement to overcome challenges associated with personal priorities and teamwork.

To illustrate the interplay of motivation in SSRL, I again refer to the example group working their way through a complex mathematics problem. At the Person-level, Ola and Devon are motivated to engage in mathematics based on their perceptions that they hold a high degree of mathematical understanding and their general enjoyment of mathematics. By contrast, Sasha, and Adrian hold perceptions that they have a low degree of mathematical understanding. They enter the learning situation with a dislike for mathematics and believe solving the mathematics problem will be arduous, which in turn lowers their motivation to engage in math learning. However, Sasha and Adrian's understanding of Person x Group-level conditions related to Ola and Devon's abilities in mathematics contribute to the group, along with Ola and Devon's Person-level feelings of competence in, and like for, mathematics leads the group to collectively consider their communal mathematical capabilities are fair. They feel mostly competent in mathematics and believe they are capable of being successful in mathematics when working together and are willing to put a collective

effort into their mathematics learning. Additionally, the group members generally enjoy working together. Therefore, Group-level group concepts, informed by Person-, and Person x Group-level understandings, influence and are influenced by socially experienced and socially focused affect, which in turn impact group-level motivation for learning.

Motivation at the Task x Person x Group Level

The Task x Person x Group level would involve motivation that is in relation to microlevel group interactions experienced during the task. It is at this level where motivation is directed by the degree to which the group supports individual members in their feelings of efficaciousness. For example, self-determination theory (SDT) suggests motivation is based on the fulfillment of three basic innate psychological needs (BPN) (i.e., competency, autonomy, and relatedness). These needs must be met to function at a psychologically optimal level and to experience personal and social well-being (Ryan & Deci, 2000). Specifically, the level of quality of an individual's motivation is contingent upon the degree to which they feel they are efficacious within their environment (i.e., competence), in charge of their behaviour (i.e., autonomy), and connected to other group members and are being cared for (i.e., relatedness). The motivational impact resulting from the satisfaction of the triad of needs directly predicts learning goals, outcomes, regulatory processes, and ultimately, performance (Deci & Ryan, 1985, 2010; Ryan & Deci, 2000).

The origin of intra-motivation experienced at the Task x Person x Group level aligns well with a sociocultural perspective of motivation where the result of feelings of competency, autonomy, and relatedness are socially influenced but individually experienced (Volet, 2001; Walker, 2010). Once again, I will revisit the collaborative group for an illustration of these processes. Consider if Adrian's metacognitive feelings experienced at the Task x Person x Group level were associated with feelings of constraint, ineffectiveness and/or disconnect. This may result in affective responses such as frustration or anger towards

their group and disengagement in group processes, which subsequently impede regulatory processes and negatively affect group-level motivation. Contrariwise, consider if Adrian experienced feelings of value, efficacy, and connectedness in the group context, this may result in the experience of enjoyment and pride, which in turn can facilitate regulatory processes and support group-level motivation. These feelings arise in part from the regulation of group dynamics and self-, co-, or socially shared monitoring and control of self- and group-relations. Empirically, in a collaborative mathematics problem-solving situation with fifth grade students, Singh and Muis (2021) found that the more group members felt competent and autonomous in the group context, the less they experienced hopelessness and confusion, and the more they experienced pride. Additionally, greater feelings of relatedness to the group positively predicted pride and negatively predicted social emotions of jealousy and boredom.

Empirical evidence in this area has reiterated the notion that motivation regulation is a socially constructed activity and is related to culminating factors involving the person, context, and social milieu (Boekaerts, 2006; Järvelä & Järvenoja, 2011; Volet et al., 2009b). For example, Järvenoja et al. (2020) explored the activation of co- and socially shared motivation and emotion regulation among 44 higher education students as they worked in a collaborative learning context. The authors investigated the frequency of student-reported motivational and emotional reasons for group challenges and found moderate challenges were mostly associated with the group's inability to work with the task, with more severe motivational challenges being associated with a group's lack of interest in the task. Although instances of co- and socially shared regulation of motivation were rare, they were activated throughout the collaborative task. Co-regulation of motivation occurred almost twice as often compared to socially shared episodes, however socially shared episodes of motivation regulation lasted the longest in duration. The authors posited socially shared regulation of

motivation occurs in relation to an arising need rather than coinciding with a specific phase in the collaborative process.

In summary, motivation is the result of metacognitive and affective experiences initiated by task demands, task topic, task familiarity and contextual factors surrounding the task, along with expectancy-value beliefs (Ainley et al., 2002; Nurmi & Aunola, 2005). The integrated model considers how motivation is additionally influenced as well as constructed by working in a collaborative group context.

The Current Study

Overall, the integrated model provides a theoretical organization of the metacognitive, affective, and motivational mechanisms that underpin person- and group-level macrolevel processes, as well as microlevel processes that may occur during SSRL. To date, researchers have considered the function, frequency, and quality of metacognitive processes at the social level and have studied how individual instances of metacognitive processes constrain or bring about metacognitive processes at the group level (Iiskala et al., 2011; Iiskala et al., 2015; Khosa & Volet, 2014). However, the relationship between group regulation and individual metacognitive processes has yet to be thoroughly examined (De Backer et al., 2021; Schnaubert et al., 2021; Volet et al., 2009a). Haataja et al. (2022) found that higher frequency in group-level metacognitive interactions and regulation were associated with learning achievement and that individuals who experienced low accuracy in metacognitive monitoring (i.e., an over- or under-estimation in their understanding, strategies, and performance on the task) improved through instances of CoRL. The researchers found that successful collaboration involves an interchange between individual and group level regulatory processes that are supported by metacognition. A comprehensive understanding of how these phenomena relate to one another using a unified and integrated framework would contribute to organizing and extending these outcomes to other facets of metacognition and SSRL and

provide clearer avenues for future research. Therefore, empirical work is needed to evaluate various aspects of my proposed integrated model. As a starting point in exploring facets of the integrated model, this study's purpose is to explore the conditions of affect and motivation at the Person-, Person x Group- and Group-level and subsequent metacognitive experiences, emotions, emotion regulation and interactions experienced at the Task x Person x Group level related to the regulation of cognition of the task and group dynamics.

Specifically, this study's first aim is to explore the microlevel processes of the integrated model related to Person-, Person x Group-, and Group-level conditions of affect and motivation. Second, the aim of this research is to explore the occurrences of concurrent metacognitive experiences, judgments. and feelings that occur in relation to group dynamics during a collaborative complex mathematics problem solving session with fifth grade students. Subsequently, this study explores emotions and associated emotion regulation strategies and interactions that took place in relation to concurrent metacognitive experiences related to group dynamics. Lastly, this study aims to explore how Task x Person x Group-level group dynamics inform Person-, Person x Group- and Group-level conditions. This study targets important suggestions made by previous research in the field of SSRL, particularly calls for consideration of the social context (Dowson & McInery, 2003; Hickey & McCaslin, 2001; Volet & Järvelä, 2001). Additionally, Hadwin et al. (2018) describe research techniques that lend well to the study of SSRL. Specifically, the authors describe the use of microanalytic discourse analysis to study processes at the group level examined within macro level regulatory episodes. Therefore, this research study was carried out in an authentic learning environment, specifically, in a fifth-grade mathematics classroom. This study used a convergent mixed methods approach to explore the following research questions:

1. *What kinds of relations exist between Person- and Person x Group-level affect and other conditions?*

2. *What kinds of metacognitive experiences related to group dynamics arise at the Task x Person x Group-level?*
3. *What emotions and subsequent emotion regulation strategies or negative socio-emotional interactions took place in response to concurrent metacognitive experiences related to group dynamics at the Task X Person X Group-level?*
4. *How do Task x Person x Group-level experiences inform Person-, Person x Group-, and Group-level conditions?*

Chapter 3[3]

Methodology

[3] Portions of Chapter 3 are contained in a book chapter in Trends and Prospects in Metacognition Research across the Life Span - A Tribute to Anastasia Efklides: Singh, C. A., & Muis, K. R. (2021). The role of social emotions and co-regulation of learning during complex mathematics problem solving. In P. Metallidou and D. Moraitou (Eds.), *Trends and Prospects in Metacognition Research across the Life Span - A Tribute to Anastasia Efklides*. Netherlands: Springer.

Context and Participants

Thirty-one grade five students (*n* = 17 girls) from a private elementary school in a single classroom were invited to take part in this study. Of the 31 students, one student was unable to participate as they followed a separate math program as per their individualized education program. Another student was absent on the day of data collection. Therefore, a total of twenty-nine fifth grade students (n = 17 girls), with a mean age of 11.38 years (*SD* = .45), participated in the study. Parental consent and student assent were obtained prior to data collection. The study took place in the last semester of the students' fifth grade year; therefore, the students knew each other well with friendships firmly established within the classroom group. The students in this study had previous experience working independently with problems similar to the one presented in this study and working in collaborative groups, although the collaborative learning tasks to-date had not been complex in nature. Additionally, the students had no formal training in managing group dynamics during collaborative learning tasks and interpersonal issues were not mediated by teachers or researchers as groups engaged in the collaborative complex mathematics problem solving session.

The homeroom classroom was brightly lit with a wall of west-facing floor to ceiling windows. The back, or northside of the classroom, contained the shelves that housed the classroom library. A Smart Board was located at the southern side of the classroom and storage in the form of overhead and undercounter cabinetry lined the east facing wall of the class. The teacher's desk and a classroom sink were in the south-east corner of the classroom. Depending on the daily schedule, the students spent 30 to 50% of their school day in their homeroom class where they were taught subjects including mathematics, English language arts, and social studies. Students' desks were organized in groups of four and spaced about the classroom. Grouped desks were placed a comfortable distance from other groups so that

at least two people at a time could easily pass between grouped desks. For the research study, students were asked to switch from their assigned seats so that they could work in their assigned collaborative groups. Collaborative groups were created by the homeroom teacher and based on ability (i.e., high, medium, low). Ability level was established by the students' achievement grade on their most recent report card.

Students were asked to collaboratively solve a complex problem entitled, *The Dragon's Desserts* (see Appendix A). The classroom teacher and primary investigator created the complex problem collaboratively to ensure that the mathematical concepts required to solve the problem had been reviewed in class. Additionally, the complex problem's level of difficulty was assessed to ensure that the problem would be challenging but achievable given the students' current math ability. To assess group's performance on the complex problem, a rubric was developed to evaluate students' achievement score (see Appendix B). The problem required collaborative groups to calculate the bill totals of four families' orders at an ice cream store. Each family member's order was listed and, using an attached price list, students were required to tally each family member's order, and subsequently each of the four family's total bill. Collaborative groups were also asked to calculate a 15% tax rate on each bill. To do this, groups were required to convert percentages to decimals and calculate the tax rate accordingly for each bill total. In the final step of the problem, groups had to calculate the end of the day total sales, before and after taxes. The complexity of the problem stems from the fact that there was no clear pathway to a solution. Students had to rely on their prior knowledge of mathematics concepts to develop a plan and apply various strategies to solve the problem.

Study Design

I employed a convergent mixed-methods approach to data collection, whereby both quantitative and qualitative measures were collected within a close timeframe, analyzed

independently and then integrated during the interpretive process to corroborate results (Creswell & Clark, 2011; McCrudden et al., 2019). As a mixed-method design lends itself well to gaining a wider range of understanding about a specific phenomenon (Hurmerinta-Peltomäki & Nummela, 2006), I believe that the mixed-methods design of this research study will help the reader to gain a more in-depth understanding of the macro- and micro-level processes involved in the integrated model and help to further clarify the complexity of the model (see McKim, 2017; Onwuegbuzie & Leech, 2004).

In the current study, I gathered quantitative pre-measures where students were asked to indicate their global emotions regarding mathematics (Academic Emotions Questionnaire), the degree to which they felt control for learning mathematics, and the perceived value for learning and problem solving in mathematics (Academic Control and Value scales). Qualitative data about the antecedents and consequences related to students' perceptions of group affect, group motivation, and emotion regulation strategies used during collaborative mathematics problem solving process were collected. A Type I think aloud protocol and semi-structured retrospective interviews were analyzed using both inductive and deductive discourse analyses. Post measures, where students were asked to retrospectively indicate the degree to which they experienced individual and social emotions (Epistemically-Related Emotions Scale) and the degree to which they felt that the group contributed to feelings of autonomy, competency, and relatedness (Basic Psychological Needs Scale in Relationships) were also administered to triangulate the quantitative pre-measures and qualitative data.

Materials

Prior Knowledge

The students' mathematics grade on their most recent report card functioned as a measure of their prior knowledge and ability. Mathematics grades were based on achievement scores on complex situational problems, formal examinations, project-based mathematics

activities, as well as reviews of mathematics homework, in-class work, and mathematics warm-up activities. The breadth and array of assessments that contributed to students' math grades is considered a reliable estimate of students' prior mathematics knowledge.

Global Emotions Regarding Mathematics

The Achievement Emotions Questionnaire – Elementary Version (AEQ) (Pekrun et al., 2007) was used as a baseline measure to assess students' global emotions regarding mathematics. Specifically, the AEQ was used to measure Person-level affect for RQ1. This questionnaire measures the degree of boredom, enjoyment, and anxiety that students experience during math homework (eight items, e.g., "*When I do math homework, I worry that I will ever understand it*"), completing a math exam (eight items, e.g., "*I get very nervous during math tests*"), and during math class (twelve items, e.g., "*I look forward to math class*"). Previous research has established the validity and reliability of the AEQ (Pekrun et al., 2011). Reliability ratings for the scale ranged between fair and excellent given the small sample size for this study. Cronbach's alpha reliability estimates ranged from .65 to .93. (See Appendix C).

Academic Control

Perry et al.'s (2001) Academic Control Scale, modified for elementary school students by Muis et al. (2015), was used to measure students' perceptions of control for learning mathematics content and engaging in the problem-solving activity. Specifically, the Academic Control Scale was used to measure Person-level control beliefs. The Academic Control Scale is an 8-item questionnaire that measures two dimensions of control (i.e., action and outcome) on a 5-point Likert scale ranging from "completely disagree" (rating of 1) to "completely agree" (rating of 5). Examples include "*I have a lot of control over my grades in math*" and "*My grades are decided by thing out of my control, and there is little I can do to change that*". The higher the score, the greater the amount of perceived control for learning

mathematics content and engaging in the problem-solving activity. In line with previous research (see Muis et al., 2015) all items were summed and averaged to obtain an overall control score. Cronbach's alpha reliability estimate was .66. Seeing that this study was a replication of the study design by Muis et al. (2015), measures were kept the same despite a low reliability rating on this scale due to the small sample size (See Appendix D).

Task Value

Students' task value for learning and problem solving in mathematics was measured using Pekrun and Meier's (2011) Task Value Measure, which was adapted from Wigfield (1994). Specifically, the Task Value Scale was used to measure Person-level motivation for RQ1. The task value measure is a 7-item questionnaire that measures three dimensions of perceptions regarding mathematics learning (i.e., interest, utility, and importance) along a 5-point Likert scale ranging from "not at all true of me" (rating of 1) to "very true of me" (rating of 5). Question examples include "*In general, learning about math is useful*" (utility), "*In general, I find learning about math very interesting*" (interest), and "*I feel that, to me, learning more about math is very important*" (importance). Previous research using the task value scale has summed and averaged all scale items (see Muis et al., 2015) since it has been established that younger students do not necessarily differentiate between the three types of value (i.e., interest, utility, and importance) (see Wigfield, 1994). All seven questionnaire items were summed and averaged to obtain a global value score for each student, with higher scores representing greater the perceived task value. Cronbach's alpha reliability estimate was .87. (See Appendix E).

Activity Emotions

The Epistemically-Related Emotions Scale (EES) (Pekrun et al., 2016), adapted for elementary-age students (see Muis et al., 2015) measured the activity-related emotions that students experienced during the problem-solving session (i.e., confusion, curiosity, surprise,

joy, anxiety, frustration, boredom). Social emotions were also added to the EES (i.e., embarrassment, guilt, shame, envy, jealousy, empathy, and pride). Specifically, the EES was used to measure emotion for RQ3 and RQ4. The EES is a single-item adjective questionnaire (e.g., "curious"), which includes a 5-point Likert scale. Participants were asked to indicate the degree to which they experienced each emotion. Response options ranged from "Not at all" (a rating of 1) to "Very strong" (a rating of 5). Students were also asked to indicate the object focus of the emotion (i.e., whether the emotion was directed at themselves, members of their group, or both) since both activity emotions and more traditional social emotions could be experienced during problem solving, (see Appendix F).

Basic Needs Satisfaction

The Basic Psychological Needs Scale – Relationship Domain (BPNS-R) was administered subsequent to the problem-solving activity. The BPNS-R assessed the degree to which participants' needs were met in the group context, an adaptation of La Guardia et al.'s (2000) measure. The BPNS-R assesses the degree to which an individual's needs are satisfied in relation to the group experience along three dimensions: the degree to which an individual felt a sense belonging, relatedness, and competent within the group. The BPNS-R was modified to reflect language and vocabulary that aligned with the age of the participants, and specific to the learning task. Specifically, the BPNS-R was used to measure Group-level motivation for RQ4.The BPNS-R is measured along a 7-point Likert scale ranging from "not at all true" (rating of 1) to "very true" (rating of 7). Examples include, "*When I was solving the math problems with my group, I had a say in what happens, and I could voice my opinion*." (autonomy), "*When I was solving the math problems with my group, I felt like I can do this problem*" (competence), and *"When I was solving the math problems with my group, I felt a lot of closeness and kindness."* (relatedness). Previous research has established the validity and reliability of the BPNS (Vlachopoulos & Michailidou, 2006). Cronbach's alpha

reliability estimate was .62 for autonomy, .58 for competence and .72 for relatedness, with an overall scale reliability of .79. (See Appendix G).

Procedure

Parental consent and participant assent were collected, along with basic student demographic information (i.e., age, sex, first language spoken) prior to the study. The study took place over a period of two sessions. During the first session, which took approximately 40 minutes, students completed questionnaires that measured their academic control for learning mathematics (*Academic Control Scale*), value for learning mathematics (*Task Value*), and activity emotions (*Epistemically-Related Emotions Scale)*. Students also received a thinking-aloud training session where the primary investigator modelled examples of how to think out loud while solving the complex mathematics problem and working collaboratively. Students were asked to verbalize everything that they would normally say to group members while solving the problem. Students were also advised that that if they were silent for an extended period, they would be prompted to keep talking out loud. Next, in groups of three, students were asked to collaboratively solve a simple mathematics problem (i.e., *Kim can walk 3 kilometers in one hour, how many kilometers can Kim walk in 2.5 hours?*) while being audio recorded using the Simple Recorder application to practice verbalizing and externalizing their thought-processes. Feedback to support students in verbally expressing thoughts, emotions and group communication was provided as students solved the simple mathematics problem.

During the second session, which occurred on a separate day from session one, the students in the class were organized into groups of two[1], three, or four students. Groups were comprised of students of mixed ability, but the same gender for control purposes. Student ability based on students' achievement to-date and the classroom teacher was responsible for devising the groups so that ability was varied. Groups were provided with one iPad per group

(for audio-recording purposes) as well as the complex mathematics problem, *The Dragon's Desserts*, that they would solve collaboratively. Students were advised that the activity was similar to other mathematics activities that they had done during their mathematics class, and therefore should be considered with the same importance. Students were asked to place the iPad they had been provided with face-up in the middle of their table and to press the "record" button on the Simple Recorder application once they were ready to begin. During this time metacognitive skills and positive and negative socio-emotional interactions were recorded during task engagement for later coding.

Students worked on the problem for the entirety of the 75-minute mathematics class. All groups were able to complete the problem within the timeframe. The primary investigator along with one research assistant and the classroom teacher prompted groups if they were silent for more than 10 seconds to ensure that students were continuously thinking aloud. Students were asked to individually complete the Epistemically-Related Emotions Scale (EES), and the Basic Psychological Needs Satisfaction in Relationships Scale (BPNS–R) after the problem had been completed and submitted. Remaining time in the mathematics class allowed for 6 students, one randomly selected from 6 out of the 10 groups, were asked one at a time to complete a retrospective cognitive interview that took place in an open area outside of the classroom. Interviews were recorded using the Simple Recorder application. Selected students were informed that, if they assented, they would complete an interview where they would be asked questions about the emotions experienced during the collaborative problem-solving session. They were told that there were no "right" or "wrong" answers, and that they could answer openly and honestly as their responses would be confidential. Subsequently, each student was asked three questions (see Appendix H) that required them to reflect and articulate the individual emotions they experienced during the collaborative problem-solving session, the emotions they experienced in relation to the whole

group or a specific group member, and to provide examples of when they felt specific emotions (e.g., happy, curious, bored, proud, confused). During this time, further evidence of affect and motivation and positive and negative socio-emotional interactions were recorded for later coding. The length of the interviews ranged between 1 minute 30 seconds to 5 minutes in length. A $100 cash gift was given to the classroom teachers upon completion of the study.

Coding and Scoring

Person-, Person x Group-, and Group-level Affect and Antecedents

Semi-structured retrospective interviews were conducted with six, randomly selected students upon the class's completion of the problem-solving activity. Each of the six students were members of a team containing three or four members. The semi-structured interviews were used to determine individual group member's perspective and understanding of the emotions that were experienced towards their group and group members during the collaborative problem-solving task. Interviews were first transcribed verbatim by the primary investigator. The transcribed interviews ranged in time from 1 minute and 30 seconds to 5 minutes and generated 22 double-spaced pages of transcriptions (4 306 words).

An inductive discourse analysis (Thomas, 2006) was used to parse out categories and themes related to facets of the Person-, Person x Group-, and Group-level conditions described in the integrated model. Specifically, all transcripts were read, and coded in vivo where 153 codes were generated. After subsequent analysis, a coding framework was developed from the in vivo coding which resulted in a total of 37 codes. In the occurrence that new codes emerged, or existing codes overlapped, the coding framework was amended accordingly, and the transcripts were reread and re-coded as per the new coding scheme. For example, codes that expressed, *independent work* and *rushing ahead* were assessed to have overlapping boundaries and were subsequently merged and renamed *low cohesion.* This

process resulted in the development of codes which were subsequently organized and filtered into seven broad categories. Categories that emerged from the interview transcripts included individual and social emotions (see Table 5), Person-, Person x Group- and Group-level conditions (i.e., perceptions of self- and group-ability, and self- and group-concept), and antecedent events (i.e., answers/responses, approach/strategy, complexity, task context, low cohesion and working collaboratively). See Table 1and 2 below for the main categories and associated examples that were gleaned from the interviews. Inter-rater reliability was achieved by comparing agreement ratings of one randomly selected, re-coded (blind) transcript which was completed by a research assistant. The research assistant was trained on the coding scheme prior to re-coding. Inter-rater agreement was 92% for the 3-page (651 words) transcript.

Table 1

Person-, Person x Group- and Group-level conditions related to ability and concept.

Person-, Person x Group- and Group-level Conditions	Description	Example
Self-ability	An individual's belief that they can complete a task or accomplish a goal.	"…I felt like I was capable of doing it."
Group-ability	An individual's belief that their group members, or a group's collective belief they can complete a task or accomplish a goal.	"…I knew we were going to solve it."
Self-concept	A central idea or image that an individual has about themselves.	"…I know I'm not really good at doing math equations and I was like, proud, because I was able to do them…'

Group-concept	A central idea about who our group members are, and the image we have about them. A collective idea about our group and the image we have about our group as a collective entity.	"…but then, when we started doing it, and we started getting into it, I think we were much more confident about each other.'

Table 2

Antecedent events related to Person-, Person x Group- and Group-level affect.

Antecedent Events	Description	Example
Answers/Responses	Involves the group coming up with an answer, finding a correct answer, or obtaining a reasonable answer, which brings about an emotion.	"I felt happy when we got answers. I was happy when they sounded reasonable… the answers." (expressing enjoyment)
Approach/Strategy	The development of a strategy or approach to solving the problem. Alternatively, not having strategy or approach to solve the problem, which brings about an emotion.	"Well at the beginning we were a bit stressed 'cause we didn't really know what to do, but then as we got probably to the second or third family, we… we felt a bit more relaxed and we were getting through things faster because we had made a new system." (expressing anxiety)
Complexity	The complexity of the problem brings about an emotion.	[When asked when the student experienced confusion] "…but then the problem got, like, more complicated to do, like, for example the taxes." (expressing confusion)
Task Context	Facets of the task context/environment outside of collaboration or working with friends brings about an emotion.	"I guess that we were definitely a bit more stressed because we were being recorded." (expressing anxiety)
Low Cohesion	Group members working independently or being at odds with one another brings about an emotion.	"I felt just a little confused sometimes because some people were going ahead of me, or I was going ahead of them." (expressing confusion)
Working with friends	Working with friends or in a collaborative learning context brings about an emotion.	[When asked when the student experienced enjoyment/happiness] "'Cause it was like, a huge relief. Umm… maybe the beginning 'cause I was doing it with a lot of friends that I like… so one of the friends I really like." (expressing enjoyment)

Metacognitive Experiences, and Phases of Group Development

A Type I, concurrent, think aloud protocol was used (i.e., thinking aloud while completing a task; see Ericsson & Simon, 1998; Kuusela, & Pallab, 2000; Wolcott & Lobczowski, 2021) to capture students' emotion expression, stimulus events, metacognitive judgements and feelings, emotion regulation strategies and emotion interactions as they collaboratively solved the complex mathematics problem. A concurrent protocol was used to acquire the group's real-time regulatory processes as they were engaged in the collaborative complex mathematics problem-solving session. Each group was provided with an Apple iPad to record their problem-solving session using the Simple Recorder application. Students were told to verbally express all thoughts and feelings as they collaboratively worked on the problem, which included thinking aloud, conversing aloud, describing their thought processes, calculating, and verbalizing suppositions and emotions that may arise. A concurrent Type I think-aloud protocol allows for individuals to fluidly express their thoughts or achievement without restrain or disruptions. When compared to reflective self-report questionnaires, a Type I think aloud protocol offers a more accurate evaluation of students' emotion regulation processes as they transpired in real-time (see Winne et al., 2002). Think alouds were then transcribed verbatim by two research assistants and the primary investigator. The transcribed think alouds ranged in time from 25 minutes and 2 seconds to 55 minutes and 47 seconds and generated 316 double-spaced pages of transcriptions (38 885 words). The ninth and tenth transcript, which were generated by the think alouds of two, two-person groups, were omitted so the study stayed consistent with recent research studies that have examined SSRL (see Nguyen et al., 2022; Nguyen et al., 2023; Li et al., 2022; Ito & Umemoto, 2022; Sobocinski et al., 2022). Additionally, Muir (2019) suggests that optimal collaborative group sizes at the elementary and secondary level are recommended to be between three to five members, with five being the upper limit. Groups of three members or

more tend to have more conversations, have an increase in varying perspectives and breadth of skills and are found to be optimal in bringing about group learning (see Corrigé & Michinov., 2021; Muir, 2019). The remaining eight transcripts contained the think alouds of eight separate groups totaling 25 students. Transcriptions of the audio recordings were merged with their respective audio recordings so that conversations could be coded using the qualitative research software, Atlas.ti version 23.1.1.

A critical deductive discourse analysis was conducted to identify instances of metacognitive experiences, namely feelings and judgements that took place during the collaborative mathematics problem-solving session (see Table 3). Firstly, transcriptions were analysed and coded to identify instances of metacognitive experiences (i.e., feelings and judgements) that took place in relation to cognition involving the three phases of task processing; task representation (prospective), cognitive processing (during), and performance (retrospective). Efklides (2009) ascertains that metacognitive experiences are situated in-context and temporal. A study design that considers metacognitive experiences prospectively or retrospectively in relation to collaborative problem-solving provides a limited illustration of the processes involved in collaborative problem-solving (Reiter-Palmon et al., 2017). Metacognitive experiences have mostly been measured before or after a task. Save for few studies (Ainley et al., 2002; Dindar et al., 2020; Efklides, 2002; Tapola et al., 2013), the measurement of metacognitive experiences has not occurred during tasks. Considering this, I measured metacognitive experiences by coding their occurrences in the transcripts of the groups collaboratively solving the complex mathematics problem.

Table 3

Examples of metacognitive experiences: Judgements and feelings

Metacognitive experiences	Description	Example
Judgements	Estimates made in relation to the degree of effort expenditure, time needed or spent, solution correctness, and learning. A recall of where, why, and how we acquired information.	“I don’t think my answer is right.”
Feelings	Positive or negative valanced feelings associated with difficulty, confidence, satisfaction, familiarity, and a sense of knowing.	"This is going to be hard”

In coding metacognitive feelings and judgements in relation to task processing, a category began to emerge that could not be attributed to any of the three existing phases. A fourth category was subsequently developed, *group dynamics*, which was categorized as concurrent metacognitive feelings and judgments made in relation to group dynamics and self- and social relations (see Table 4 for a comparison of concurrent metacognitive experiences related to cognition of task versus group dynamics).

Table 4

Prospective, during, retrospective and concurrent metacognitive experiences

Metacognitive experiences	Description	Example
Judgements	Estimates made in relation to the representation of the task, cognitive processing, or performance about the degree of effort expenditure, time needed or spent, solution correctness, and learning. A recall of where, why, and how information is acquired and when it was used.	Retrospective judgment: "I don't think my answer is right."
Concurrent judgments	Social comparisons that are made about the knowledge of one's own and other's cognition and/or ability.	Concurrent judgment: "You are better at multiplication."
Feelings	Positive or negative valanced feelings expressed in relation to the representation of the task, cognitive processing, or performance associated with difficulty, confidence, satisfaction, familiarity, and a sense of knowing.	Prospective feeling: "This is going to be hard"
Concurrent feelings	Feelings associated with group dynamics that involve confidence in, and satisfaction with the group, familiarity with characteristics of past work experiences with group members.	Concurrent feeling: "We can solve this problem"

Tuckman and Jensen's (1977) phases of group functioning was used to ascertain which phase of group development each group was primarily engaged in. Episodes containing metacognitive experiences and frequency of specific emotions could be attributed to one of the five phases typically involved in effective group functioning: forming, storming, norming, performing and adjourning. Therefore, instances of concurrent metacognitive

feelings and judgments were coded as occurring concurrently in relation to one of the five phases of group functioning to ascertain how the expressed feelings and judgements depicted the development of the group dynamics. See Table 5 for definitions and examples of concurrent metacognitive feelings and judgements related to the phases of group development. Researchers have put forth that metacognitive feelings and judgements may influence the kinds of emotions experienced during the collaborative learning process (Hofmann & Doan, 2018; Pekrun & Stephens, 2012). Therefore, instances of metacognitive feelings and judgments related to group dynamics were coded prior to coding for individual and social emotions.

Table 5

Phases of group development with associated examples of concurrent metacognitive feelings and judgements in relation to group dynamics

Phases	Definition	Example
Forming	First stage characterized by group members orienting themselves to the task, establishing rules, and setting behavioral boundaries. Group members get to know one another.	A: It's like you enjoy math. (*J*) B: I like… I like math class. (*J*) A: Do you like this math class? B: Yeah. It's kinda like she makes it more like fun
Storming	Second stage characterized by intergroup conflict and an absence of unity. Group members experience emotional responses to task and may resist the formation of the group.	A: I'm always right. (*F*) B: No, no you're not! (*J*) C: Oh god…This is a nightmare!
Norming	Third stage is characterized by group cohesion and an acceptance of individual differences of group members. Group members avoid conflict to maintain harmony.	A: I'm not even there yet. Haha! B: What? (*inaudible*) C: Okay, so. Oh, sorry, I forgot to… (*inaudible*) A; It's okay. Okay, so… C: Sorry guys that I'm going so fast. (*J*) A and B: It's okay. That's alright.
Performing	Fourth stage characterized by a sense of relatedness and a collective energy is dedicated to the task. Group members adapt their roles to enhance group functioning.	Well, I think we're doing great! (*J*)
Adjourning	Fifth stage characterized by the conclusion of the activity and an end to the group's need to work on the task. Group members may experience feelings of pride, celebration and engage in reflection about task-related processes.	Teacher: Are you guys done? A: Almost. (*inaudible*) B: You okay, (name)? A: Even though we had our answers wrong, it's okay! (*J*)

Emotion, Emotion Regulation, Negative Socio-Emotional Interactions, and Motivation Regulation

A critical deductive discourse analysis was then conducted to identify instances of emotions, emotion regulation and negative-socio-emotional interactions. (See Table 6 for a list of coded emotions and associated examples). Subsequently, transcriptions were coded for occurrences of individual and social emotions (see Table 6) and then linked to co-occurring or close-occurring existing metacognitive feelings or judgments. Co-occurring metacognitive judgements or feelings preceded, occurred during, or directly after instances of emotion in the same episode. Close-occurring metacognitive judgments and feelings were episodes containing metacognitive experiences and emotion that followed each other in close succession and were not interrupted by sustained instances of task definition, planning, enactment or evaluation and adaptation that were unrelated to or failed to address the emotion or metacognitive experience. Instances of emotion and metacognitive experiences were coded for emotion regulation strategies, and/or negative socio-emotional interactions. A code “no regulation” was used for instances of emotion that were not met with any emotion regulation strategy.

Table 6

Emotions and associated examples: positive, negative, and epistemic

Emotions	Example quote
Positive emotions	
Happiness/joy	"39.10! Did it! Whoo-hoo!"
Hopefulness/optimism	"But you'll find out. I think I got it right. I'm hopeful!
Pride (S)	"I'm so proud of myself!"
Empathy (S)	"That would be mean because she is already here."
Negative emotions	
Frustration/annoyance/anger	"You guys are so annoying."
Anxiety/worry/dread	"This is a nightmare."
Embarrassment/shame (S)	"Oh, yeah, yeah… sorry, you're right."
Disappointment/sadness	"This is so sad."
Hopelessness	"Just whatever, it doesn't really matter."
Epistemic emotions	
Confusion	"But that's kinda confusing when you combine them altogether."
Curiosity	"Why did you put two decimals?"
Surprise	"I was like, 'Woah! That's an expensive ice cream!'"

Note: (S) = social emotion

Miller and Hadwin (2015) describe two varieties of co-regulation that may occur during collaborative work sessions. In the first variety, regulation may be initiated by one group or more group members to help regulate a peer (CoRL – peer). In the second variety, regulation may be stimulated in multiple group members by one or more group members (CoRL – group). Lobczowski (2022) includes this differentiation in their formation and regulation of emotions in collaborative learning FRECL coding scheme where modes of regulation include SRL, CoRL-peer, CoRL-group and SSRL. Therefore, emotion regulation strategies were coded as regulated by the self, peer, group members or group as a collective via the co-construction of a strategy to mediate an emotion (see Lobczowski, 2022) that occurs during one of the four phases of learning regulation (i.e., task definition, planning and goal setting, enactment and adaptation and evaluation) and in relation to a stimulus event. The emotion regulation coding scheme was also borrowed and adapted from Lobczowski's (2022) FRECL coding scheme for identifying emotional expressions (e.g., individual, and

social emotions), stimulus events (e.g., communication, content and task, external factors, interpersonal dynamics, priorities, and work habits – see Table 7) and regulation strategies (e.g., addressing understanding, adopting a new tactic, disengagement, looking ahead, reframing, restructuring the task, seeking help, showing empathy, using humour, and venting/complaining – see Table 8).

Table 7

Stimulus events for emotion regulation strategies

Stimulus event	Example quote
Communication: Interactions between students (may be verbal or non-verbal).	Miscommunication of information, "How did you get 78? You just said your answer was wrong."
Content and task: Understanding of the task, planning, and/or strategies used.	Understanding facets of the task, "It's pretty much the same thing as the subtotal. So, what is the cost?"
External factors: Peripheral or personal events/circumstances.	Personal expression, "Why do you write so big?"
Interpersonal dynamics: Interactions relating to personality issues, power dynamics or previous experiences.	Unequal distribution of materials between members, "Wait, why do you have this [paper], and I don't?"
Priorities: Goals and expectations for the activity, task, or collaboration	Completing a portion of the activity, "We did it!"
Working Habits: Involvement, attention, responsibilities, or standards	Pace, "You're rushing ahead of the group! We are a group here, you're not by yourself. You're not by yourself!"

Not all instances of emotion on their initial occurrence were met with a regulation strategy as some instances arose more than once before the emotion was addressed. For example, a group member in the following excerpt experienced confusion in relation to the content and task and was not met with any kind of emotion regulation strategy or negative socio-emotional interaction at its first instance. It was only after another group member experienced confusion that the group engaged in a help seeking strategy.

Episode 1

A: …I'm confused, <Student B>.
B: So, I'll just (inaudible) 32, 34….58.25.
A: 58.25? So that's the total?
B: 58…wait…
C: I'm gonna sharpen my pencil, I'll be back. (inaudible)
B: (calculating)…Alright! A hundred and eighty-four dollars and seventy-five cents!
C: That's a lot of money. (inaudible)
A: I don't know.
C: Uhm, this number doesn't look right. A hundred and eighty-four dollars and seventy-five cents?
Teacher: Okay, so you know it doesn't look right….

In episode 1, student A's initial confusion is overlooked while the other member of the group (student B) continues their calculations. It is not until student A experiences confusion for a second instance ("I don't know"), and student C experiences expresses a retrospective metacognitive judgement relating to the estimate of solution correctness ("Uhm, this number doesn't look right."), that the group looks to support from a teacher. The first occurrence of confusion would have been followed with the code "no regulation", and the second occurrence of confusion would have been coded as confusion and emotion regulation strategy "Seeking help".

Table 8

Emotion regulation dimensions and strategies

Dimensions and strategies	Example quote
Cognitive strategies	
Addressing understanding: Addressing the misunderstanding by focusing on learning the content.	A: "Why, two 35s?" B: "Because look, one cup has sprinkles."
Adopting a new tactic: Trying a different approach when faced with a problem or are unable to move forward.	A: "Wow! A waffle cone is almost as much as a reg… a kiddie scoop." B: "Yeah but imagine how small a kiddie scoop is."
Reframing: Changing perspective of how the event was interpreted	A: "This is a nightmare. Oh my God." B: "17, 19, 24. 30-, 44. 10, oh wait. Done, $44.57"
Cognitive-Motivational strategies	
Looking ahead: Concentrating on future events rather than attending to the emotion.	A: "Yeah, but that's kinda confusing when you put the two together." B: "Oh ya. So then let's do 0.45 plus 0.35."
Motivational strategies	
Restructuring task: Changing the task to improve emotions experienced in relation to the task.	A: "But you wrote that whole thing!" B: "It doesn't matter!!" A: "Fine."
Behavioural strategies	
Disengagement: Avoidance of emotion or the cause of the emotion.	A: "Why do I not have one?" B: "I don't know" A: "Wait, we're only supposed to have one." B: "Let's ask her."
Interpersonal strategies	
Seeking help: Requesting help from others when required.	A: "Guys! I didn't even do the second thing! You're going too fast!" B: "Sorry!" C: "Ya, sorry!"
Showing empathy: Helping others address their emotions and/or recognizing the emotions of others.	A: But if it makes it easier, you don't have to write the (inaudible)... If it's easier for you, you don't have to write the equation if you don't want to. B: One where you can...

Using humour: Improving emotions using humour/jokes.	C: Well, I don't really know how to add tax, to add stuff. A: Don't worry, I'll uhhh… uhhhh… We have to find fifteen percent of tax and then we add that to X. Get it?
Venting/complaining: Talking about emotions and/or the source or stimulus of emotions with others.	A: Everybody gets something wrong in their life *(laughing)*. B: We do in math, but that's okay. (*giggling*) A: We don't do it anywhere else *(laughing)*. B: Yeah! *(laughing)*. A: Just math (*making a funny voice*) A: I can't do it. I can't do it. B: Ah, help me. C: You guys really need to calm down, it's getting annoying.

Negative socio-emotional interactions were coded using a coding scheme by Bakhtiar et al. (2018). Negative socio-emotional interactions include discouraging participation, low cohesion, and pressuring others. Upon analysis an additional negative socio-emotional interaction, *argument*, was added. An argument was defined as a negative socio-emotional interaction that prevents the group from moving forward because of a disagreement between group members where members are maintaining their perspective without justifying their stance. Arguments are characterized by an overt negative valence in conversations amongst group members. See Table 9 below for the coding schemes and associated examples.

Table 9

Negative socio-emotional interactions

Negative socio-emotional interactions	Definition	Example quote
Discouraging participation/motivation	Criticizing, undermining, ignoring, discouraging, and rejecting the contributions, abilities, work, feedback, questions of group members.	A: "Uh, what are you guys doing?" B: We're finding the tax." A: "I don't know how to do the tax!" C: "Yeah, you're not finding the tax, we are."
Low cohesion	Failing to work as a group or highlighting individual over group work.	B: "What are we doing?" C: "Are you okay, (name)?" B: "She's just mad at us." A: "I'm not mad at you!" B: "Then why are you not talking to us?" A: "Because, I'm focused!" B: "Why? Well, I thought you wanted me to help you because you were confused? But if not, I will not. I'll let you be. So, it's like 50 times zero…"
Pressuring others	Instructing and directing other group members without asking politely. Includes overruling other group members' decisions without conferencing with them.	A: "Can I write them...?" B: "No, you'll write the subtotal and the total."
Argument	Interactions that prevent the group from moving forward because of a disagreement between members. Group members maintain their perspective without justifying their stance. Arguments are characterized by an overt negative valence in conversations amongst group members	A: "So, I'll add them all up here, so…" B: "No, I'm adding them all up already!" A: "Yeah, but we need make sure that we're not wrong…Am I right!?" B: "No." A: "Yeah!" B: "No." A: "Yeah!" B: "No." A: "I'm always right." B: "No, no you're not!"

The primary investigator spent four weeks examining the transcripts to identify instances of metacognitive feelings, judgments, phases of group development, emotion, emotion regulation episodes, negative socio-emotional interactions, and motivation regulation strategies. Inter-rater reliability was achieved by comparing agreement ratings of one randomly selected, re-coded (blind) transcript which was completed by a research assistant. The research assistant was trained on the coding scheme prior to re-coding. Inter-rater agreement was 87% for the 21-page (2904 words) transcript.

Chapter 4

Results

Preliminary Analyses

A summary of the descriptive statistics and zero order correlations are displayed in Appendix I. Values of skewness and kurtosis were examined for normality prior to carrying out a full analysis, using Gravetter and Wallnau's (2014) limits +/-2 for skewness and kurtosis. All person-level and group-level antecedents were within the normal range, but negatively skewed; control (-.56), value (-.85), along with the three dimensions of BPNS, competence (-.60), autonomy (-.57), and relatedness (-.07). For the social emotions and EES scale, shame (5.39), jealousy (4.20), embarrassment (2.70), guilt (4.20), and envy (3.43), as expected, were all outside of the normal range. Empathy (.89) and pride (-.72) were within normal skewness range. Confusion (.67), hopelessness (1.27), surprise (.64), boredom (1.49), curiosity (-.01), frustration (2.08), enjoyment (-.54), and anxiety (.84) were also within the normal range.

For measures of kurtosis, all variables relating to Person- and Group-level conditions were within the normal range; control (-.28), value (1.05), and the three dimensions of BPNS, competence (-.28), autonomy (-.69), and relatedness (-1.59). For the Task x Person x Group-level EES scale, shame (29.00), jealousy (18.09), embarrassment (6.38), guilt (18.09), and envy (12.01), were all outside of the normal range for kurtosis. Empathy (-.32) and pride (-.79) were within normal range for kurtosis. Confusion (-.16), hopelessness (-.25), surprise (-.95), boredom (1.34), curiosity (-.95), enjoyment (-1.10), and anxiety (-.45) were also within the normal range.

Overall, the interviewees expressed a range of emotions, including stress, frustration, boredom, curiosity, pride, and confusion experienced during the collaborative complex problem-solving activity. Some participants described feeling happy and enjoyed working together as a group, while others expressed feeling confused during certain points of the activity. Interviewees expressed feeling proud of their group's accomplishments, particularly

towards the end when they finished the problem. It is important to note that communication and cooperation within the group were affected by these emotions and their intensity varied from person to person.

The think aloud transcripts from the collaborative mathematics problem-solving session revealed that the groups were actively working towards calculating the total bill for four families at the ice cream shop. The groups expressed confusion and curiosity about how to calculate the subtotal and the tax for each of the bills. Approaches to the calculations for bill totals differed amongst group members. Most of the groups relied on group member knowledge to work their way through the calculations. Some of the groups sought help and clarification from their teacher. Emotions expressed upon the submission of their collaborative work were varied but comprised of experiences including emotions like pride, enjoyment, curiosity, and confusion.

RQ1: What Kinds of Relations Exist Between Person- and Person x Group-level Affect and Other Conditions?

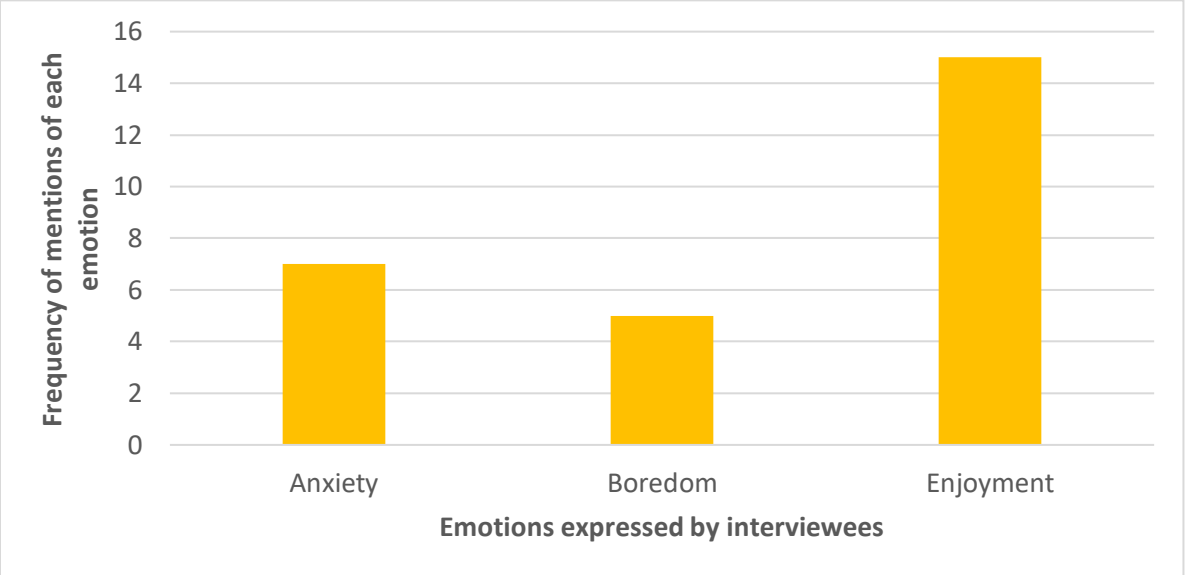
To answer the first research question, I began by examining the associations between Person-level conditions related to affect, motivation, and control beliefs. A Pearson correlation coefficient was computed to assess the linear relationship between self-reported Person-level emotions normally experienced during mathematics class, namely boredom, anxiety, and enjoyment, and Person-level motivation conditions which include value for the learning task and control over learning mathematics. Enjoyment experienced during mathematics class positively significantly correlated to value for learning mathematics ($r(27) = .775$, $p < .001$), while boredom experienced during mathematics class negatively correlated to value for learning mathematics ($r(27) = -.571$, $p < .001$).

Figure 2 displays the relative frequency of the same emotions reported at the Person-level (i.e., boredom, anxiety, and enjoyment) that interviewees described experiencing during

the collaborative complex mathematics problem solving session. The category, *emotion,* was established by interviewees explicit reference to emotion and affective states experienced in the collaborative problem-solving context and during the collaborative problem-solving process. For example, "I was happy that we could solve [the problem] together" was coded as *enjoyment.*

Figure 2

Frequency of emotions anxiety, boredom and enjoyment expressed by interviewees.



All interviewees mentioned experiencing the three emotions (i.e., enjoyment, boredom, or anxiety) to varying degrees in relation to the collaborative problem-solving session. Specifically, interviewees mentioned experiencing enjoyment 15 times, anxiety seven times, and boredom five times during the interviews. I then examined interviewees' emotions in relation to Person- and Person x Group-level conditions including, self-concept, ability, metacognitive knowledge, and motivation. Additionally, I examined the antecedent events that led to emotional responses (i.e., answers/responses, approach/strategy, complexity, task context, low cohesion and working with friends) in relation to enjoyment, anxiety, and boredom.

Interviewees described experiencing enjoyment in relation to their group-ability, metacognitive knowledge, and motivation beliefs. For example, Matthew described how they experienced enjoyment knowing that their group would be able to solve the problem (group-ability) and persevere (motivation). In the interview, they explained that they were, "…happy when we started, wh-, when we started because I knew we were going to solve it and that we wouldn't give up." Blair described how enjoyment experienced within the collaborative context seemed to mediate metacognitive knowledge associated with a general dislike for mathematics at the Person-level. For instance, they explained that "When we were doing the problem and doing the math, I usually don't like math that much but it, it was pretty fun to do the problem as a group." The collaborative context, or working with friends, appeared to be an important antecedent related to the task context that brought about enjoyment for other interviewees. As described by Matthew, "I think we thought… we were also happy that we could solve it together. That, and that we don't always like have to do it alone. Like at our desks." In relation to experiences of boredom, Declan described experiencing a low degree of boredom associated metacognitive knowledge related to a general dislike for mathematics at the Person-level. However, the student added that despite experiencing boredom, the collaborative problem-solving session was still enjoyable.

144 Interviewer: So, you felt bored?
146 Declan: A little bit.
148 Interviewer: Okay.
150 Declan: Well, it was still like sort of fun but still sort of boring.
152 Interviewer: Okay.
154 Declan: Yeah.
156 Interviewer: Do you think that influenced how you worked as a group in any way? That feeling of boredom.
159 Declan: Ummm. No, not really 'cause we always have to do math problems, and even though they're boring, we still have to do them, so. Yeah.

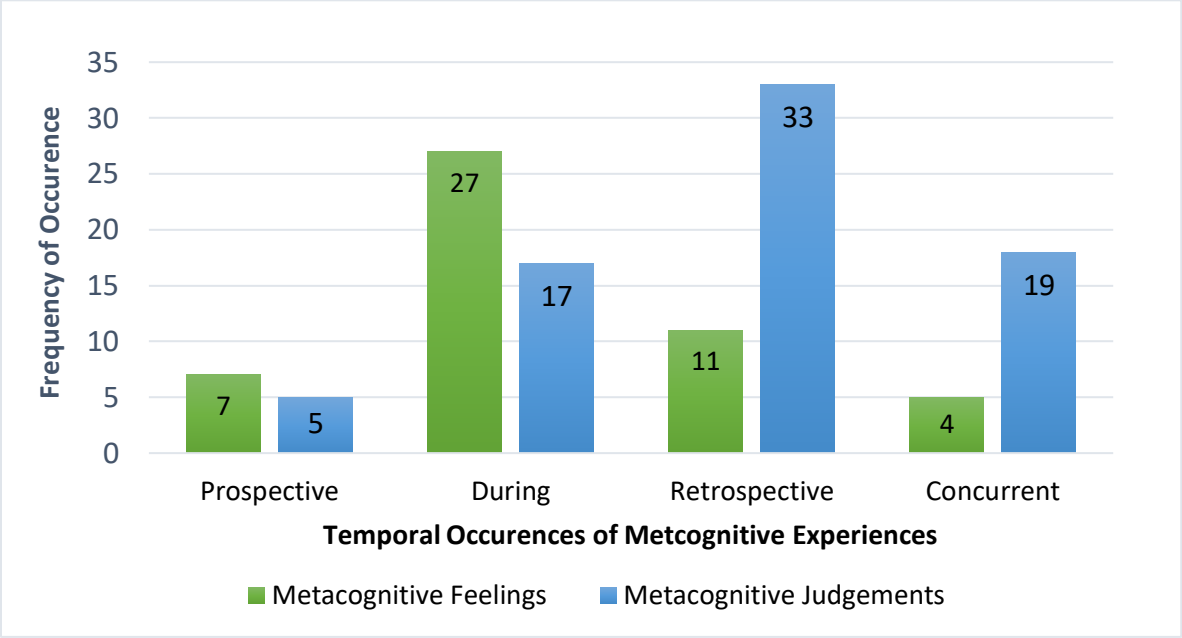
RQ2: What Kinds of Metacognitive Experiences Related to Group Dynamics Arise at the Task x Person x Group-level?

Metacognitive Feelings and Judgements at the Task x Person x Group-level

Metacognitive experiences occurred prospectively, during, retrospectively and concurrently as students collaboratively worked their way through the problem-solving session. A total of 123 instances of metacognitive experiences in the form of feelings and judgments were expressed across the eight transcribed collaborative complex mathematics problem-solving sessions. Specifically, I identified 51 metacognitive feelings (about 41% of total metacognitive experiences) and 72 metacognitive judgements (about 59% of total metacognitive experiences) that took place as students collaboratively solved the complex problem. The largest proportion, approximately 72% (88 occurrences), of all metacognitive experiences occurred *during* the task and *retrospectively* in relation to the task. Specifically, 36% (44 occurrences) of all metacognitive experiences took place during cognitive processing, and approximately 36% (44 occurrences) of all metacognitive experiences occurred while retrospectively considering performance. Approximately 61% of those metacognitive experiences that occurred during the cognitive processing phase were metacognitive feelings, while 75% of metacognitive experiences that took place retrospectively in relation to task performance were metacognitive judgments. Concurrent metacognitive experiences related to group dynamics at the Task x Person x Group-level made up the third largest proportion of metacognitive experiences, that is, about 19% of the total metacognitive experiences occurred concurrently; specifically, 8% of the total metacognitive feelings and 26% of the total metacognitive judgments. Therefore, concurrent metacognitive experiences were not only identifiable from other metacognitive experiences, but they made up about one-fifth of the metacognitive experiences identified in the transcripts. See Figure 3 for a frequency count of prospective, during, retrospective and concurrent metacognitive judgements and feelings.

Figure 3

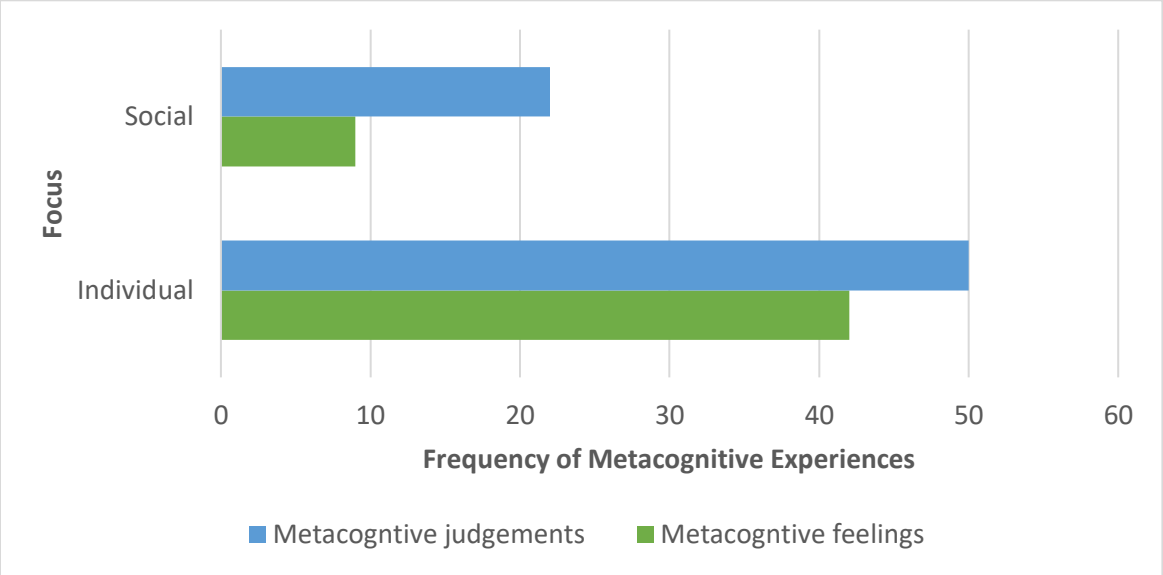
Metacognitive experiences at the Task x Person x Group-level



Metacognitive experiences were either individually focused (i.e., feelings or judgements related to self) or social in nature (i.e., feelings or judgments related to another group member or the group at large). Most of the metacognitive experiences were individually focused (74.7%), while about one quarter of all experiences were socially focused (25.2%). Eighty two percent of the metacognitive feelings were related to the self while 69% of the metacognitive judgements were related to the self.

Figure 4

Socially versus individually focused metacognitive experiences.



Concurrent Metacognitive Feelings and Judgements Related to the Task x Person x Group-level.

Phases of group development (i.e., forming, storming, norming, performing and adjourning) were assigned to the episodes that included concurrent metacognitive experiences. Storming was the most commonly occurring phase of group development experienced by the collaborative groups (11 instances) followed by norming (six instances), performing (three instances), forming (two instances), and lastly, adjourning with only one instance. Therefore, groups mainly functioned within or oscillated between the storming, norming and performing phase of group development. Most of the concurrent metacognitive experiences attributed to storming, or the second phase of group development, were judgments (82%) and most of those instances occurred in relation to the pace at which the group or members of the group were progressing through various activities associated with the task. For example, 78% of the occurrences of concurrent metacognitive judgements were made in relation to monitoring the fast work pace of the group or some of the group members (e.g., “Guys, you’re going too fast. I’m still not there.”). Other instances of concurrent

judgments focused group member's answer correctness (e.g., "…you got the wrong answer"), judgements about the effectiveness of strategy approaches decided on by the group (e.g., "This is not working."), judgement about the group as an entity (e.g., this is not the best of groups."), or group members' behaviours (e.g., "You guys really need to calm down…".). Instances of concurrent metacognitive feelings related to the storming phase focused on how group member actions were making the task more difficult (e.g., "This is harder for us to check!"), or implored group members to develop and engage in a work strategy to make the task easier (e.g., "Guys this is going to be very easy if we just work and have a way to figure this out.".).

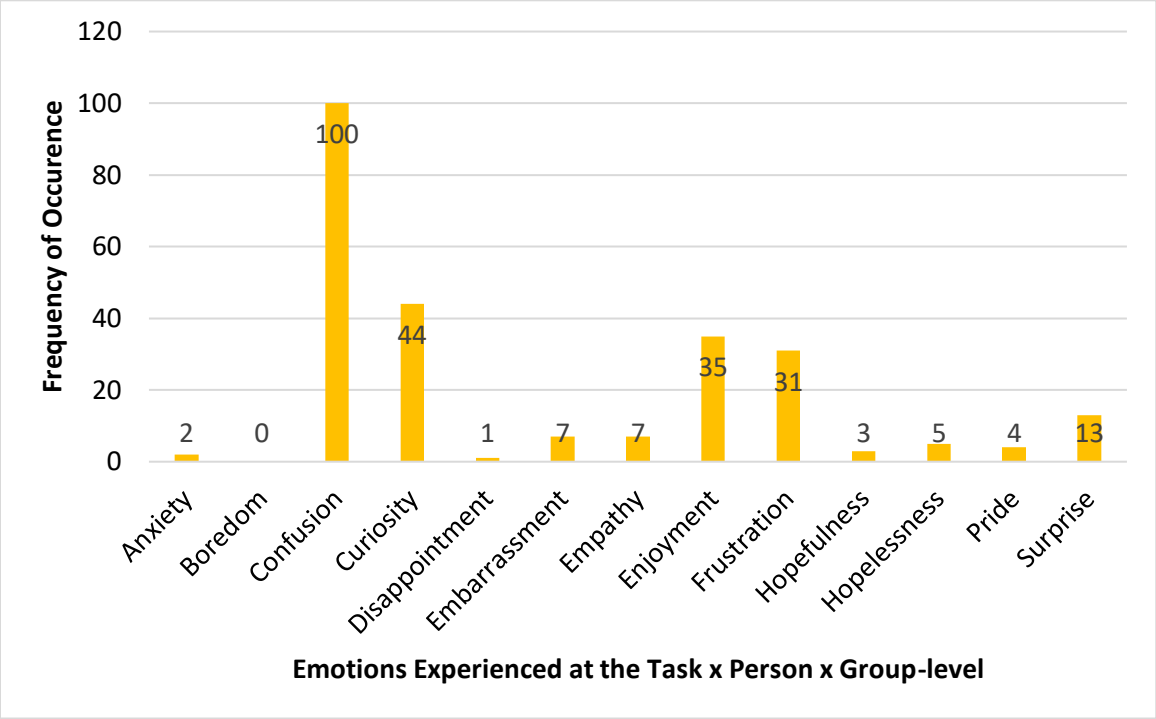
Phase three, *norming*, saw the second highest expressions of concurrent feelings and judgements. Feelings and judgements expressed during this phase generally centered around observing and accepting group members' abilities and aptitudes related to group-level group-concept (e.g., "Math isn't our strong suit.") and accepting the work pace of the group related to person-level and person x group-level focused on self- and group member-concept (e.g., "Well you're a really fast writer, I am really slow.").

Emotions and Concurrent Metacognitive Feelings and Judgements at the Task x Person x Group-level

Two hundred fifty-two instances of emotional expressions were identified across twelve different emotion categories (see Figure 5) amongst the eight groups engaged in the collaborative complex mathematics problem-solving session. Of the 12 emotion categories, confusion occurred most often during the collaborative complex problem-solving session (100 instances), followed by curiosity (44 instances), enjoyment (35 occurrences) and frustration (31 occurrences).

Figure 5

Occurrences of emotions at the Task x Person x Group-level



A code co-occurrence analysis was performed to establish whether emotions experienced at the Task x Person x Group-level occurred in relation to concurrent metacognitive feelings and judgements. Sixteen episodes were identified where a concurrent metacognitive experience was closely associated with instances of emotion. Specifically, nine episodes contained instances of a concurrent metacognitive experience and an emotion that either co-occurred or closely occurred with a concurrent metacognitive feeling or judgement. Seven concurrent metacognitive experiences were found to closely occur, that is closely follow or precede, an instance of emotion. Emotions that more frequently co- or closely occurred with concurrent metacognitive experiences were frustration, followed by happiness. Other emotions that co- or closely occurred with concurrent metacognitive experiences included anxiety, confusion, embarrassment, and empathy. The following two cases are presented to depict co-occurrences and close occurrences of concurrent metacognitive

experiences and emotion to provide specific examples of how emotions occurred in relation to metacognitive experiences during the collaborative problem-solving session.

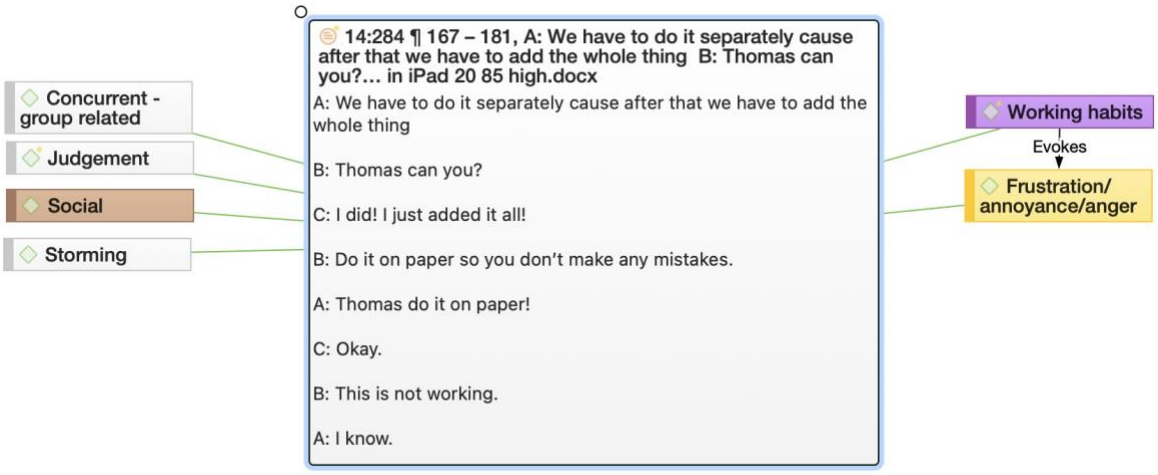
Example 1 - Co-occurring Concurrent Metacognitive Experiences and Emotion. Declan, Istvan and Thomas. A group comprised of students Declan, Istvan and Thomas experienced mostly instances of confusion and frustration during the collaborative problem-solving session; 71% of total instances of emotion experienced by this group were coded as either confusion or frustration. This group also demonstrated 69 instances of SRL, and just over half (52%) of their co-regulatory strategies involved a single member, or multiple group members, co-regulating a single peer's understanding or performance (CoRL – peer), as opposed to a co-regulatory strategy where one or more group members regulate multiple group members' understanding or performance. In relation to group dynamics, this group's phase of group development would be characterized as being at the storming stage, as their collaborative problem-solving session was described mainly by instances of intergroup conflict and a general absence of unity and cohesion. Group members experienced emotional responses to the task and appeared to resist the formation of the group considering the high division of labour employed throughout the problem-solving session. The group members captured in this exchange were students of average ability (e.g., math grades between 75% and 85%).

Figure 6 provides an episode network where group members experienced socially experienced frustration. This episode begins with Declan co-regulating a group plan to do calculations separately so they can add all calculations at the end. When Istvan asks Thomas if he is able to perform a task in relation to the co-regulated plan, Thomas frustratingly responds with, "I did! I just added it all!" followed by Istvan telling Thomas, "Do it [the calculations] on your own paper so you don't make any mistakes". The episode concludes with a social concurrent metacognitive judgement related to confidence in the group's work

habits when Istvan states, “This is not working.”, followed by Declan acknowledging Istvan’s judgement, “I know.”

Figure 6

Co-occurring concurrent metacognitive experiences (judgement) and emotion (confusion).



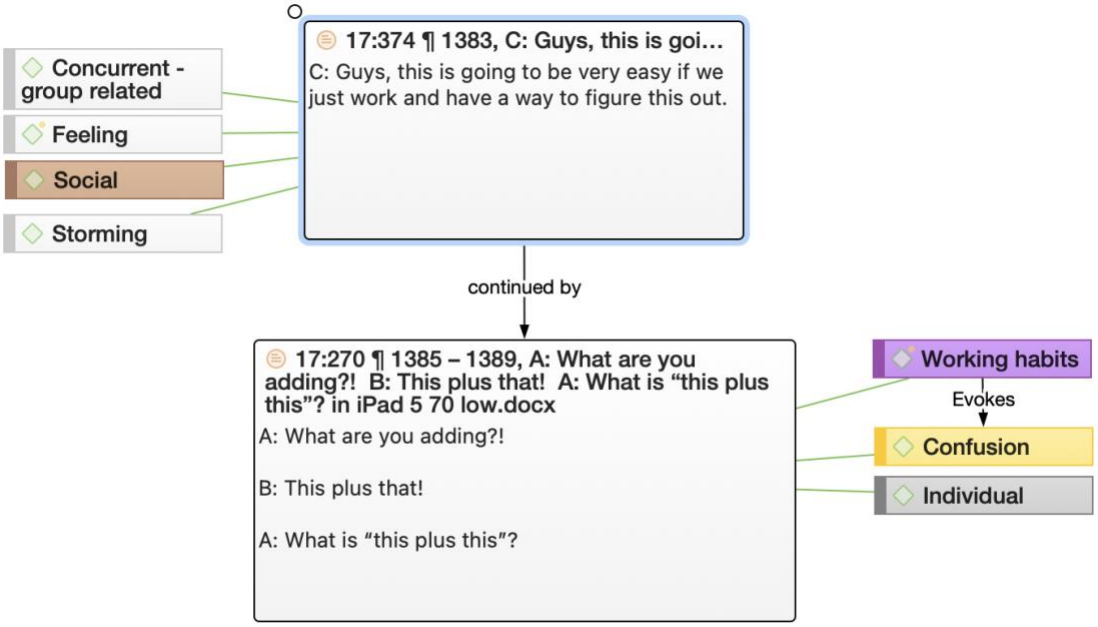
Example 2 - Close-occurring Concurrent Metacognitive Experiences and Emotion. Heather, Chloe, and Melody. A group comprised of students Heather, Chloe, and Melody’s group is composed of students of average to high ability (e.g., math grades between 70% and 95%). During the problem-solving session, the group mostly experienced instances of confusion and curiosity; 68% of total instances of emotion experienced by this group were coded as either confusion or curiosity. This group demonstrated 127 instances of SRL, and 57% of their co-regulatory strategies involved single, or multiple group members, co-regulating a single peer’s understanding or performance (CoRL – peer), as opposed to a co-regulatory strategy where one or more group members regulate multiple group members’ understanding or performance. In relation to group dynamics, this group’s phase of group development would be characterized as being at the storming stage described mainly by instances of intergroup conflict and a general lack of group cohesion during the collaborative problem-solving session. Group members experienced emotional responses to the task and

appeared to resist the formation of the group considering the high division of labour employed throughout the problem-solving session.

Figure 7 displays the network analysis performed to establish the kinds of emotions experienced in proximity to, either occurring shorty before or after, concurrent metacognitive feelings and judgements. In the following network, Melody expresses a concurrent metacognitive feeling expressed about the group's work habits when they state, "Guys, this is going to be very easy if we just work and have a way to figure this out." This utterance was closely followed by Heather experiencing individual confusion in close occurrence to Melody's concurrent metacognitive feeling about group member work habits when they ask Chloe, "What are you adding?", to which Chloe responds, "This plus that!" Heather's confusion persists as she then asks, "What's 'this plus that'?"

Figure 7

Close-occurring concurrent metacognitive experiences (judgement) and emotion (confusion).



Therefore, results conclude that concurrent metacognitive experiences were found to co-occur or occur close to emotions. Additionally, these emotions were found to be spurred by, related to, or occur in relation to the concurrent metacognitive experience.

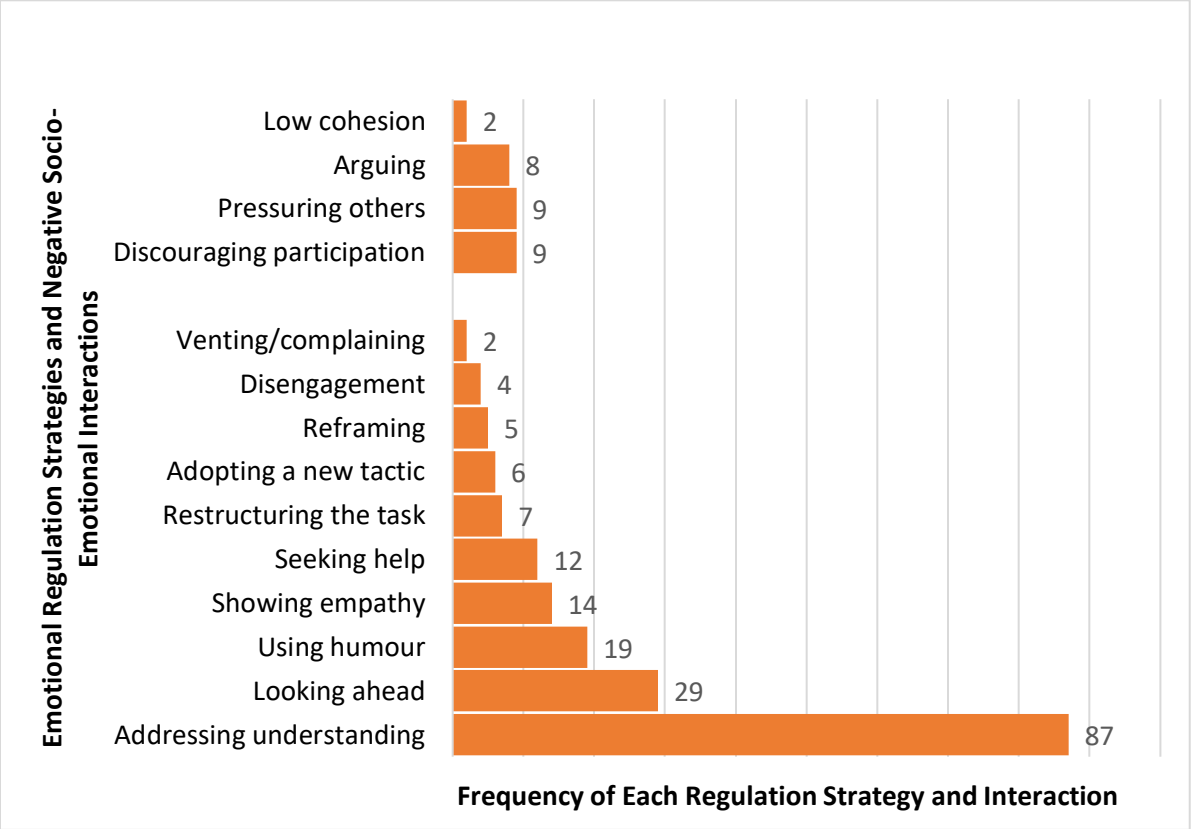
RQ3: What Emotions and Subsequent Emotion Regulation Strategies or Negative Socio-Emotional Interactions Took Place in Response to Concurrent Metacognitive Experiences Related to Group Dynamics at the Task X Person X Group-Level?

Stimulus Events, Emotion Regulation Strategies, and Negative Socio-emotional Interactions

Of the 252 instances of emotion expressed during the collaborative complex mathematics problem solving session, most (54%) were stimulated by the content and task followed by the working habits (23%). Emotions that occurred in relation to the content and task most often included 70 instances of confusion and 34 instances of curiosity. Frustration was most often stimulated by work habits (17 instances). Two hundred thirteen of the 252 emotions were followed by either an emotion regulation strategy (i.e., addressing understanding, adopting a new tactic, disengagement, looking ahead, reframing, restructuring the task, seeking help, showing empathy, using humour, or venting/complaining), or a negative socio-emotional interaction (i.e., arguing, discouraging participation, low cohesion, or pressuring others). Figure 8 displays the frequency of occurrences of emotion regulation strategies and negative socio-emotional interactions.

Figure 8

Frequencies of emotion regulation strategies and negative socio-emotional interactions

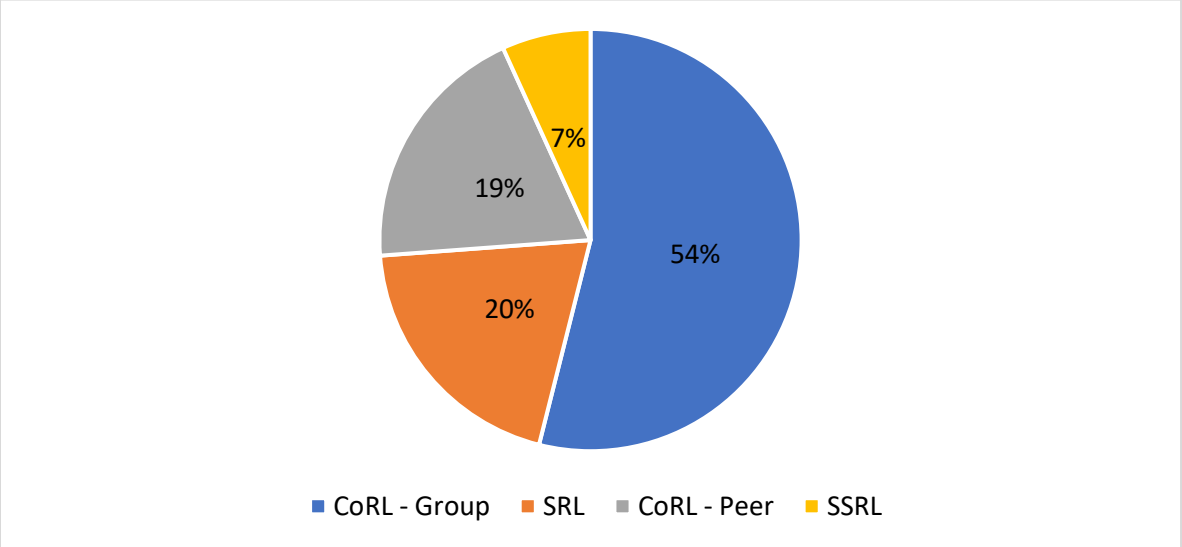


Addressing understanding was the most frequently occurring emotion regulation strategy employed by group members, followed by looking ahead and using humor. Of the 28 negative socio-emotional interactions, discouraging participation and pressuring others occurred most often. Forty-three instances of emotion were met with neither an emotion regulation nor a negative socio-emotional interaction. Emotion regulation strategies were most often co-regulated by one or more group members regulating a peer's emotion (CoRL – peer with 103 instances) followed by a group member self-regulating their own emotions (SRL with 38 instances), one or more group members supporting the regulation of other group members' emotions (CoRL - group with 37 instances) and the group collectively or sharing the regulating of emotion (SSRL with 13 instances). See figure 9 for the relative frequency of regulation modes in relation to emotion regulation strategies. Most instances of SSRL related

to emotion regulation could be attributed to socially experienced confusion stimulated by the content and task. SSRL related to emotion regulation strategies used in relation to socially experienced confusion was addressing understanding characterized by the group communally reviewing what they understood about the problem at hand or engaging in communally calculating results to mediate their confusion, or adopting a new tactic characterized by the group agreeing that a new approach is required. All instances of SSRL related to emotion regulation were precipitated by either a peer or group co-regulation of learning.

Figure 9

Relative frequency of regulation modes in relation to emotion regulation strategies



Concurrent Metacognitive Experiences, Emotion Regulation Strategies, and Negative Socio-emotional Interactions

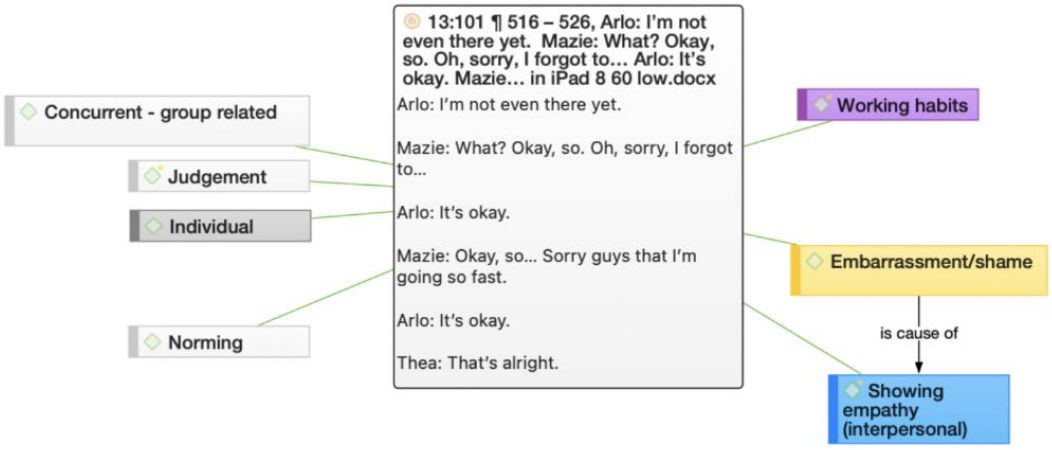
In relation to metacognitive experiences, 67 out of 123 metacognitive experiences co-occurred, or occurred closely, to an emotion that resulted in an emotion regulation strategy or negative socio-emotional interaction. Specific to concurrent metacognitive feelings and judgements, 13 of the 16 concurrent metacognitive experiences that co-occurred or occurred in proximity to emotions were emotionally regulated or met with a negative socio-emotional interaction. The most frequently employed emotion regulation strategy enacted in relation to

a concurrent metacognitive experience was showing empathy, followed by using humor. To depict the unfolding of Task x Person x Group-level emotions, concurrent metacognitive experiences, and emotion regulation strategies/negative socio-emotional interactions, three examples from three different groups have been provided. Subsequently, a case study has been provided to demonstrate how a concurrent metacognitive judgement preceded and concluded the close occurrence of emotions and a resulting emotion regulation strategy across a few episodes.

Example 1 – Arlo, Mazie, and Thea: Embarrassment/Shame, Concurrent Metacognitive Judgment and Showing Empathy. The following group experienced issues with some of the members' fast work pace. The episode begins with a self-regulatory monitoring statement made by Arlo, "I'm not even there yet.", to which Mazie apologized, "Okay… oh, sorry.", for the pace at which they were working (see Figure 10). That is Mazie expressed shame in relation to their fast-paced work habits. Arlo responded to Mazie by saying, "It's okay.", to which Mazie further apologized for the speed at which they were working, "Sorry guys that I'm going so fast.", expressing a concurrent metacognitive judgement about their work speed in relation to other group member's work pace. The group responds to Mazie by showing empathy in the face of their admission of a faster work-pace by responding with, "That's okay.", "That's alright.".

Figure 10

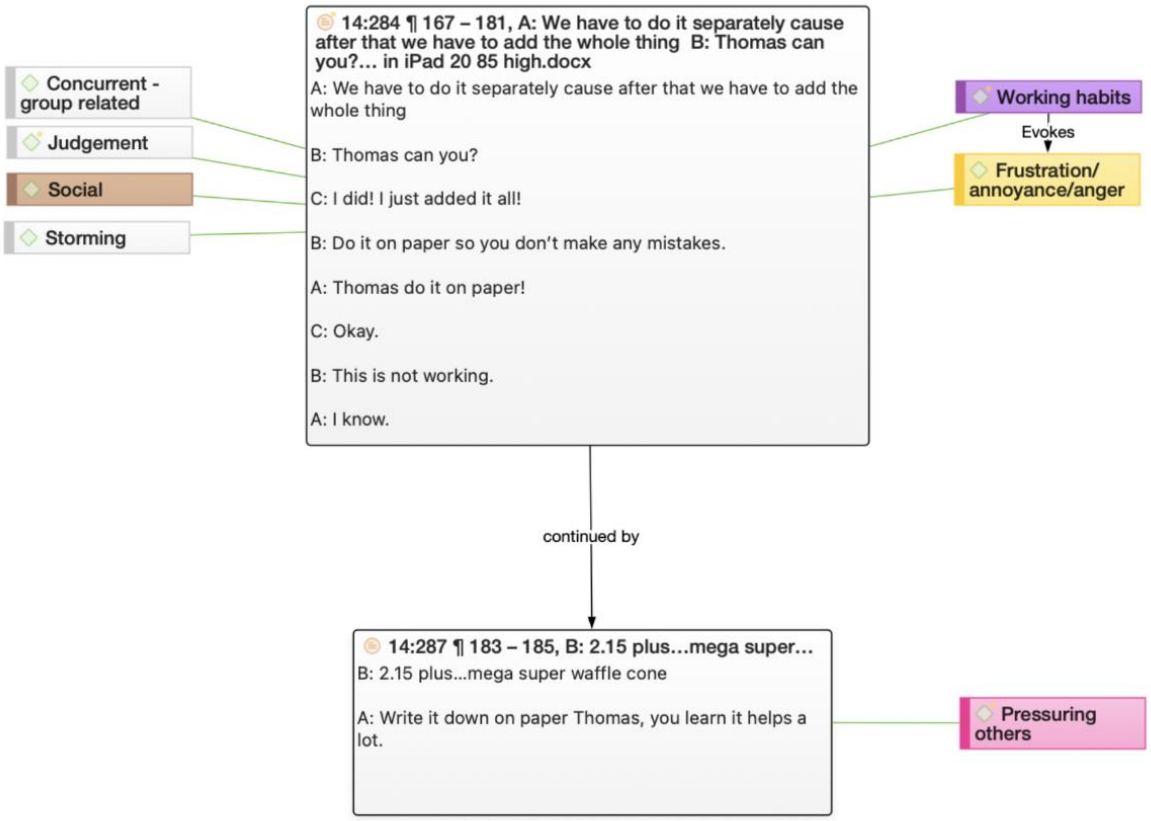
Embarrassment/shame, concurrent metacognitive judgment and showing empathy



Example 2 - Declan, Istvan and Thomas: Frustration, Concurrent Metacognitive Judgment, and Pressuring Others. Declan, Istvan and Thomas' group exhibited a co-occurring concurrent metacognitive experience and emotion as described in relation to the research question 2 (refer to Figure 6). That is, Istvan utters a concurrent metacognitive judgement related to work habits ("This isn't working") followed by Declan responding, "I know". These exchanges were experienced in relation to an emotion, in this case, frustration. Within the first exchange, the earliest instance of pressuring others is evident when Istvan tells Thomas, "Do it on paper so you don't make any mistakes". However, in the exchange that proceeds, Declan is more forceful in pressuring Thomas to write everything down. That is Declan tells Thomas what to do, "Write it down on paper, Thomas, you learn it helps a lot.", without being polite, asking, or making a suggestion (See Figure 11).

Figure 11

Frustration, concurrent metacognitive judgment, and pressuring others

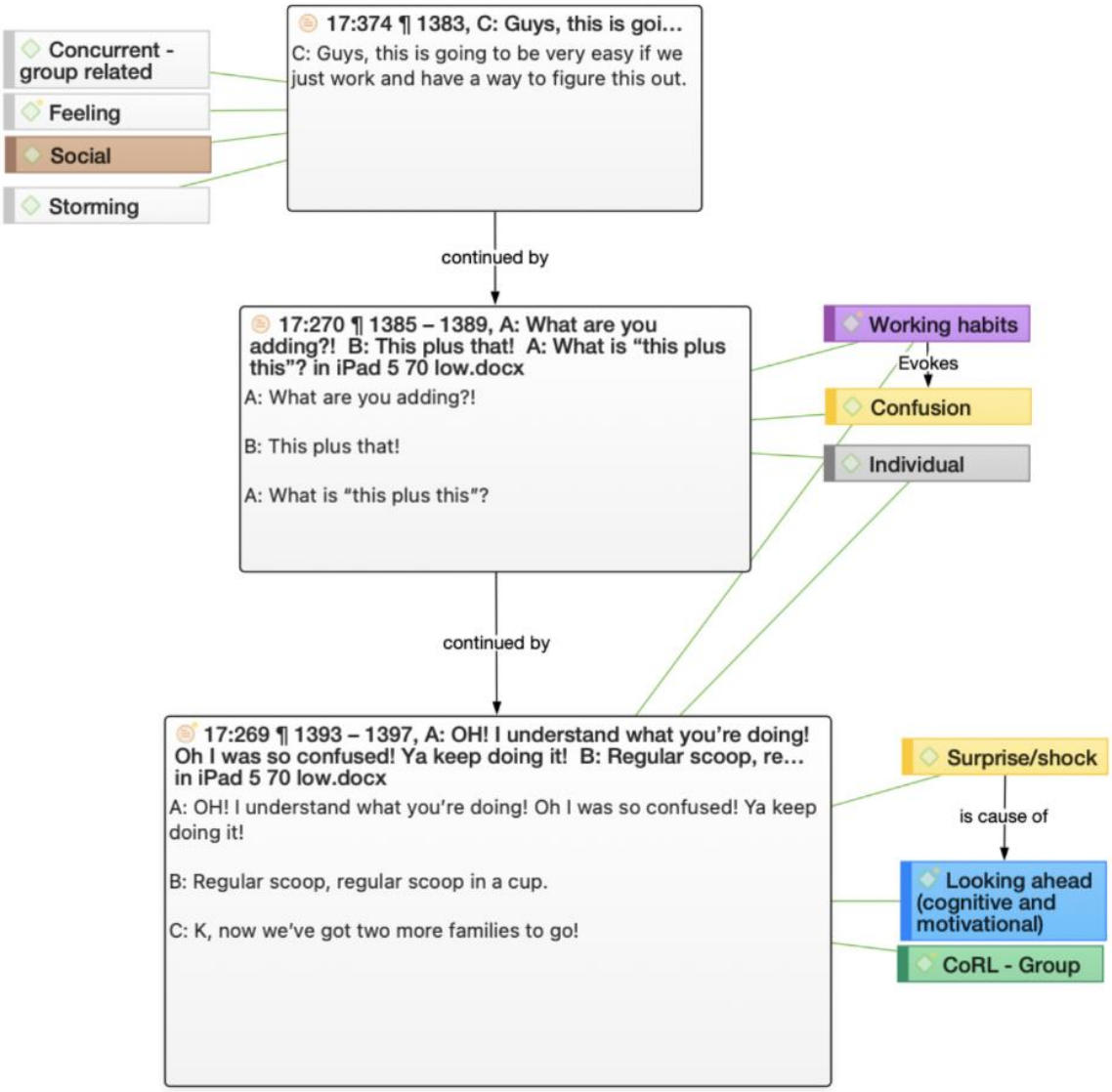


Example 3 - Heather, Chloe, and Melody: Confusion, Surprise, Concurrent Metacognitive Feeling, and Looking Ahead. Recall that Heather, Chloe, and Melody exhibited a close-occurring concurrent metacognitive experience and emotion (refer to Figure 7). A concurrent metacognitive feeling was closely followed by individually experienced confusion in relation to group member work habits. Heather then experiences surprise and that their confusion had been mediated, "Oh ya! I understand what you are doing! Oh, I was so confused." (See Figure 12 below). As a result of the surprise, Heather encourages the group to continue moving forward in the task, "…Keep doing it!". A co-regulatory group emotion regulation strategy is then shared by the other group members as they continue moving on in the learning task. Specifically, Chloe continues to move forward with their calculations "Regular scoop, regular scoop in a cup.", followed by Melody monitoring next

steps, “Okay, now we’ve got two more families to go!”.

Figure 12

Confusion, surprise, concurrent metacognitive feeling, and looking ahead



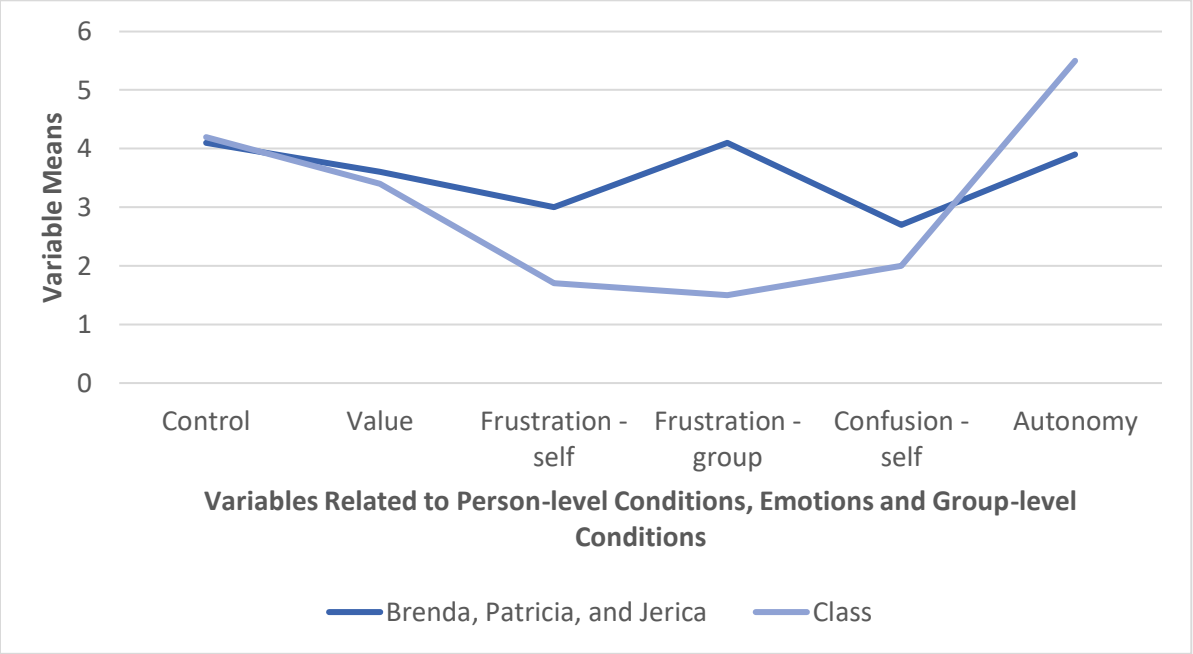
Case study - Brenda, Patricia, and Jerica: Interplay Between Concurrent Metacognitive Experiences, Emotion, Emotion Regulation and Negative Socio-emotional Interactions. Brenda, Patricia, and Jerica are a group of somewhat mixed ability (two students with math grades between 60% and 70% and one student with a math grade between 80% and 95%, for an average group math grade of 70%). An analysis of the descriptive statistics of pre-measures reveal that Brendan, Patrick, and Jeremy hold similar

perceptions of control (*M* = 4.1, *SD* = .1) and value (*M* = 3.6, *SD* = .3) as compared to the class (control *M* = 4.2, *SD* = .5 and value *M* = 3.4, *SD* = .8). During the problem-solving session, the group mostly experienced instances of confusion followed by frustration and embarrassment. Specifically, 17 out of the 24 total instances of emotion experienced by this group were coded as either confusion, frustration, or embarrassment. An analysis of the descriptive statistics revealed that Brenda, Patricia, and Jerica reported experiencing more average frustration (frustration with self *M* = 3, *SD* = 2, and frustration with group *M* = 4.1, *SD* = 1) as compared to the class (frustration with self *M* = 1.7, *SD* = 1.3, and frustration with group *M* = 1.5, *SD* = .9), and slightly more average individual confusion (*M* = 2.7, *SD* = 2.1) as compared to the class (*M* = 2, *SD* = 1.3).

Brenda, Patricia, and Jerica demonstrated 59 instances of SRL in relation to learning or emotion regulation strategies, and 70% of their co-regulatory strategies involved a single, or multiple group members, co-regulating a single peer's understanding or emotion regulation, as opposed to a co-regulatory strategy where one or more group members regulate multiple group members' understanding or emotion regulation. In relation to group dynamics, this group's phase of group development would be generally characterized as being at the storming stage described mainly by instances of intergroup conflict and a general lack of group cohesion during the collaborative problem-solving session. Brenda, Patricia, and Jerica experienced emotional responses to the task and appeared to resist the formation of the group considering the high division of labour employed throughout the problem-solving session. Analysis of the descriptive statistics reveal that the group members experienced lower feelings of autonomy in the group context as compared to the class (*M* = 3.9, *SD* = 1.7 and *M* = 5.5, *SD* = 1.3 respectively) (see Figure 13). Their final score on the complex problem was a 60% as compared to the class average of a 72% achievement score.

Figure 13

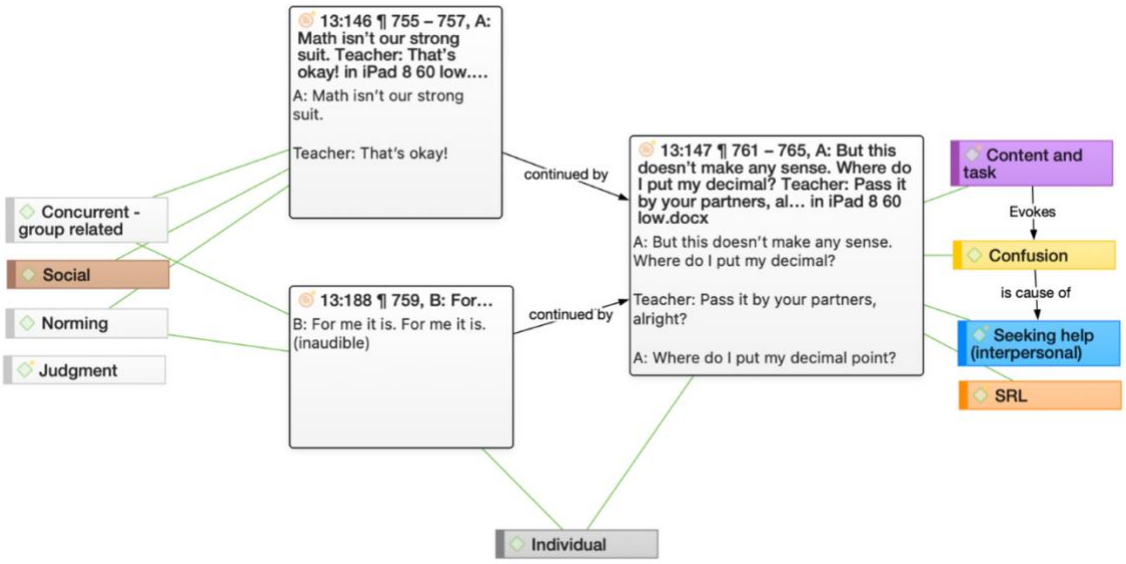
Comparison of means between Brenda's group and the class.



In episode 1 (see Figure 14), Brenda, Patricia, and Jerica exhibited a close-occurring concurrent metacognitive experience and emotion. A concurrent metacognitive judgement reflecting confidence in group-ability at the group-level is made by Brenda, "Math isn't our strong suit.", was followed by Patricia's disagreement in the form of an individual concurrent metacognitive judgment of confidence, "For me it is, for me it is.". The concurrent metacognitive judgements related to confidence in group-ability and self in relation to the group is followed by Brenda's individually experienced confusion in relation to the content and task when they say, "But this doesn't seem to make any sense." and subsequently self-regulates their own emotion with an interpersonal help-seeking strategy directed at the teacher, "Where do I put my decimal?.", and then directed at group members, "Where do I put my decimal point?".

Figure 14

Case study: Episode 1 – Concurrent metacognitive judgements, confusion, seeking help



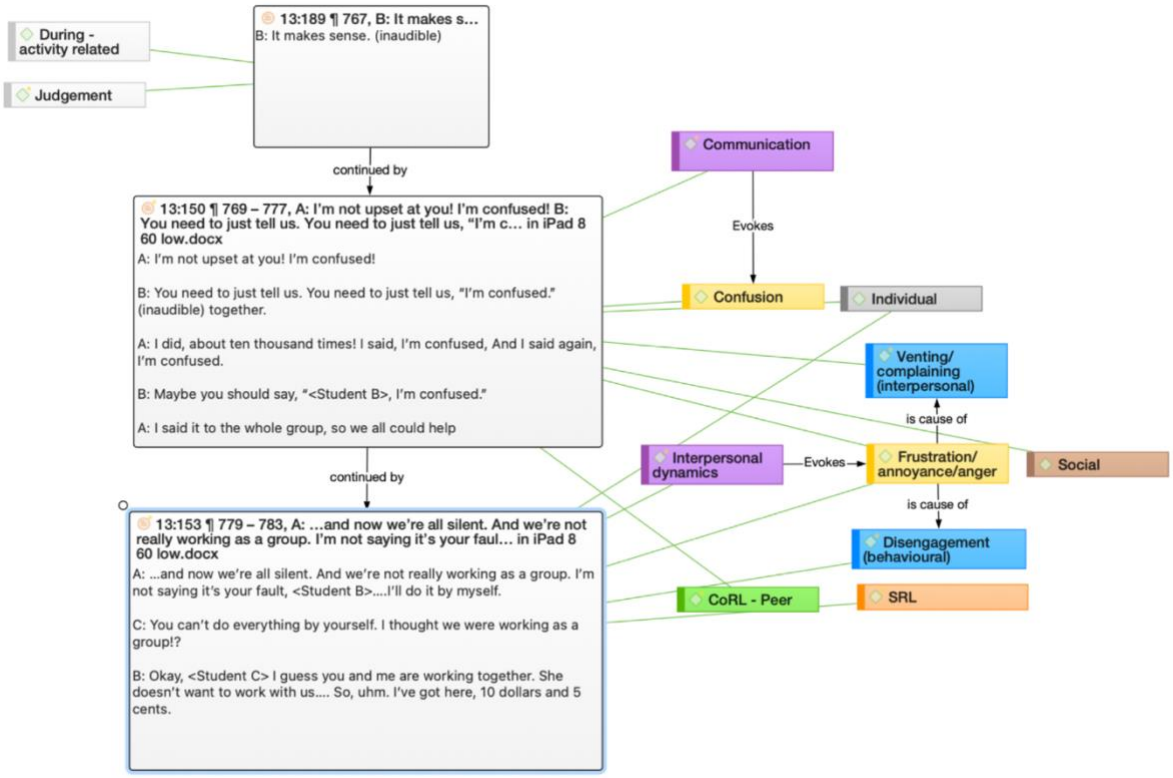
Episode 2 (see Figure 15), which occurred directly after episode 1, begins with a metacognitive judgement, "It makes sense", made by Patricia during the activity. After the metacognitive judgement takes place, a non-audio exchange appears to have spurred a resulting conversation surrounding communication issues. In the second episode block in Figure 13, Brenda explicitly verbalizes their state of confusion when they say, "I'm not upset at you! I'm confused!", to which Patricia explains to Brenda how they should be more transparent in their communication (i.e., "You need to just tell us. You need to just tell us, "I'm confused.""). Socially experienced frustration ensues, and Brenda and Patricia engage in co-regulatory venting and complaining about communication issues where Patricia discusses the source or stimulus of emotions with Brenda, "Maybe you should say, "Patricia", I'm confused!".

In the third episode block in Figure 15, Brenda describes how interpersonal dynamics have broken down and now group members are working independently, "…and now we're all silent. And we're not really working as a group. I'm not saying it's your fault, Patricia.

I'll do it by myself.". At this point, Brenda no longer communicates during the rest of the episode and Patricia confirms that they and Jerica will continue to work together, "Okay, Jerica, I guess you and me are working together. She doesn't want to work with us…. So, uhm. I've got here, 10 dollars and 5 cents.", thus avoiding the emotion that Brenda initially experienced (i.e., confusion in relation to the content and task).

Figure 15

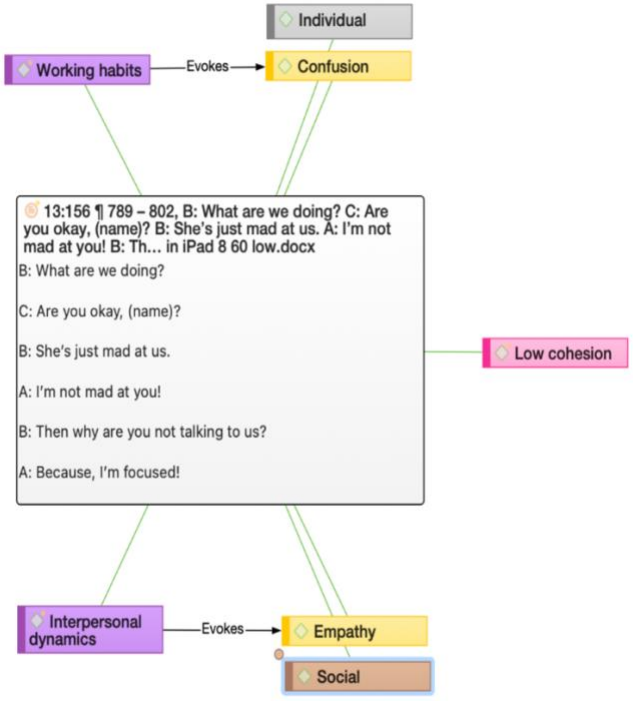
Case study: Episode 2 – During metacognitive judgement, confusion, frustration, venting and disengagement.



In episode 3 (Figure 16), Patricia becomes confused because of work habits, "What are we doing?", while Jerica expresses concern or empathy for Brenda, "Are you okay, Brenda?". An exchange ensues where the group, at this point, is demonstrating negative socio-emotional interactions through low cohesion characterized by group members deliberately not working together.

Figure 16

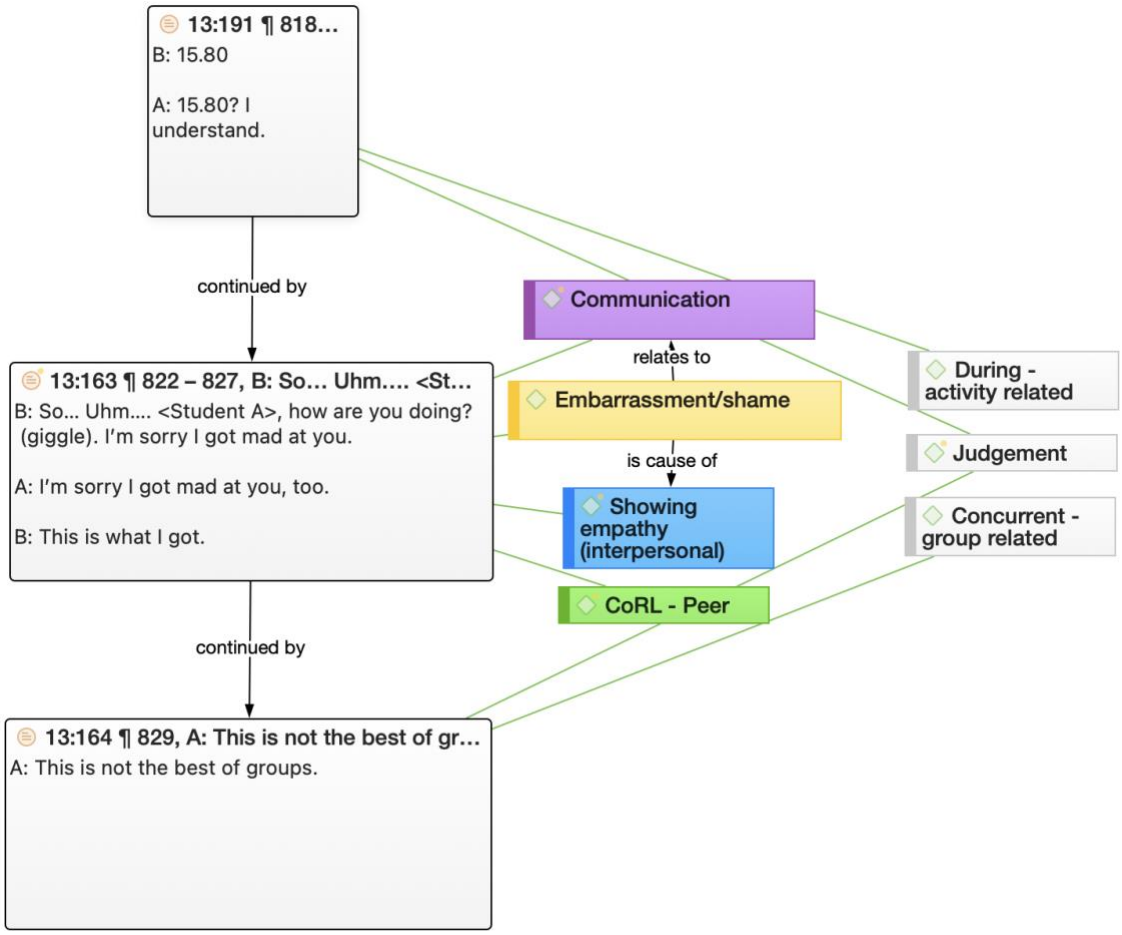
Case study: Episode 3 – Confusion, empathy, low cohesion



In the fourth and final episode (Figure 17), which occurred shortly after episode 3 and directly after an episode of self-regulated calculating took place by Patricia (not shown in Figure 16), Brenda expresses a judgement of learning in relation to an activity-related calculation, “15.80? I understand”. At this point, Brenda’s initial confusion seems to have been addressed through the calculating process. Patricia checks in with Brenda to see how they are doing after which, Patricia seems to feel a sense of embarrassment because of earlier communications and apologizes for becoming angry as witnessed in excerpt 2 (Figure X). Brenda reciprocates the apology by saying, “I’m sorry I got mad at you, too.”. At this point, Brenda concludes the exchanges depicted through excerpts one through four with a concurrent judgement about group dynamics that provides insight into group-level group-concept, “This is not the best of groups”.

Figure 17

Case study: Episode 4 – Embarrassment, showing empathy and concurrent metacognitive judgement.



For Brenda, Patricia, and Jerica, continued instances of un-addressed confusion and issues with communication resulted in unsuccessful interpersonal and behavioural self- and co-regulated emotion regulation strategies and subsequently, a negative socio-emotional interaction. Confusion was preceded by a concurrent metacognitive judgement about group-level group-ability. Interactions spurred by unaddressed confusion that were eventually addressed concluded with a metacognitive judgement about group-level group-concept. This metacognitive judgement was made by the same student who made the initial concurrent

judgment about group-level, group- ability and experienced the un-addressed confusion.

Overall, results from the qualitative analysis reveal that emotions that co-occur or closely-occur with concurrent metacognitive experiences are met with instances of emotion regulation or a negative socio-emotional interaction when solving a complex mathematics problem.

RQ4: How do Task x Person x Group-level Experiences Inform Person-, Person x Group-, and Group-level Conditions?

Task x Person x Group-level Emotions and Group-level Conditions

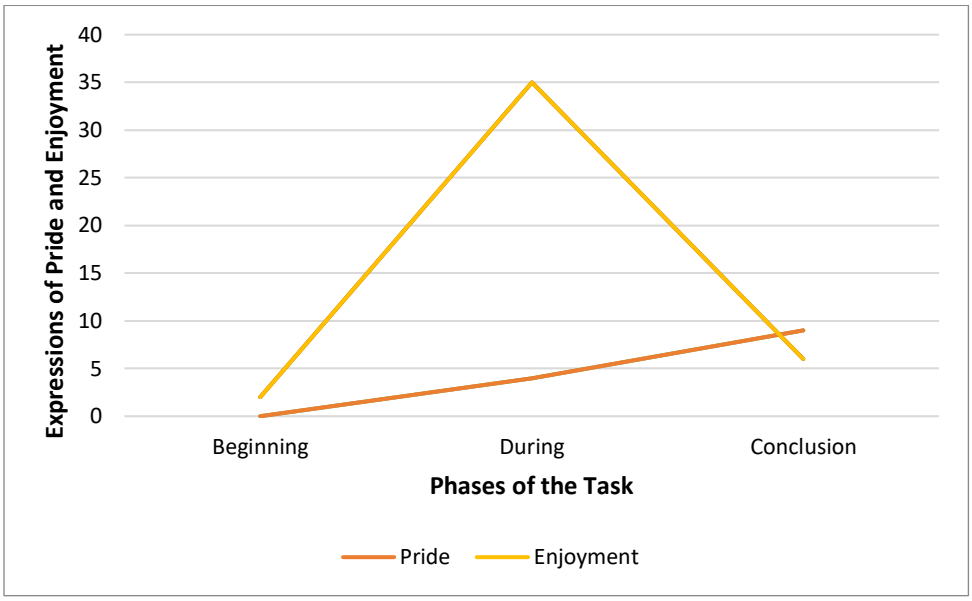
To address the final research question, I started by examining the associations between Task x Person x Group-level emotions and Group-level conditions. A Pearson correlation coefficient was computed to assess the linear relationship between Task x Person x Group-level emotions experienced during the collaborative complex mathematics problem solving session (e.g., socially experienced boredom, anxiety, and enjoyment, and social emotions, pride, shame, empathy, guilt, jealousy, envy, and embarrassment) and Group-level feelings of relatedness or feeling valued by group members. Socially experienced enjoyment and the social emotion, pride, ($r(27) = .528$, $p < .001$) and ($r(27) = .534$, $p < .001$) respectively, positively significantly correlated to feelings of relatedness experienced in the group learning context. Therefore, feelings of enjoyment related to the group, and pride experienced at the Task x Person x Group-level are correlated to groups feeling more related to their group members, which informs Group-level conditions related to motivation.

Interestingly, the experience of pride appears to be a retrospectively expressed emotion as pride was expressed on four occasions at the Task x Person x Group-level or during the collaborative complex mathematics problem solving session. However, as previously mentioned, results from the retrospective EES self-report measure found that pride and enjoyment positively significantly correlated to feelings of relatedness. Additionally,

pride was expressed on 14 occasions and enjoyment expressed 15 times across the 6 interviewees during the retrospective interview. A co-occurrence analysis of interviewees experience of pride found that pride was exclusively mentioned nine times in relation to the completion of the task whereas enjoyment was mentioned twice in relation to the beginning of the task and six times in relation to the completion of the task (see Figure 18 below).

Figure 18

Expressions of pride and enjoyment related to phases of the task



Task x Person x Group-level Experiences Informing Person- and Group-level Conditions

To get a more fine-grained understanding of the correlation, a co-occurrence analysis was performed between affect and Person- and Group-level conditions to ascertain the kinds of emotions that were experienced in relation to self- and group-concept, and self- and group-ability. Specifically, pride experienced while working in a collaborative group context was described as mediating Person-level negative perceptions of ability in relation to mathematics. For example, Camille described being proud of their group towards the end of the problem-solving session and expressed, “I know I’m not really good at doing math equations and I was like, proud, because I was able to do them, and I mostly got them right!”. In Camille’s case, they acknowledged their Person-level ability prior to the collaborative

problem-solving session; however, pride at the Group-level as experienced through processes at the Task x Person x Group-level reinformed this student's Person-level conditions related to ability.

Concurrent Metacognitive Experiences at the Task x Person x Group-level Informing Person-, Person x Group- and Group-level Conditions

As well, concurrent metacognitive experiences expressed at the Task x Person x Group-level provide a glimpse into the quality of conditions forming at the Person-, Person x Group-, and Group-level. For example, in one exchange Kayla expresses their concurrent metacognitive judgements about Michelle's like of mathematics, and then seeks out more information about their peer's preferred kind of mathematics class. These kinds of exchanges, spurred by a concurrent metacognitive experience, could inform Person x Group-level conditions.

Kayla: It's like you enjoy math. (*J*)
Michelle: I like… I like math class. (*J*)
Kayla: Do you like this math class?
Michelle: Yeah. It's kinda like she makes it more like, fun.

Vince made a concurrent judgment in relation to group work habits, "We're all, like, faster than each other.", which could be evidence of the development of Person x Group- or Group-level conditions. Lastly, Twyla expressed a concurrent judgment about their own ability in relation to their peer's ability, "Well, you're a fast writer, I'm really slow.", which could be a sign that new information about the self and a peer is being incorporated into Person-level conditions and Person x Group-level conditions.

Overall, results reveal that pride is an important emotion associated with feeling related to by fellow group members, which could inform Group-level conditions. As well, Group-level conditions may be a powerful mediator of pre-existing Person-level conditions. Lastly, concurrent metacognitive experiences expressed at the Task x Person x Group-level could be indictors of the kinds of information that are being incorporated into Person-, Person

x Group- and Group-level conditions.

Chapter 5

Discussion[4]

[4] Portions of Chapter 5 are under review with Educational Psychology: Singh & Muis (accepted). An integrated model of socially shared regulation of learning: The role of metacognition, affect, and motivation. *Educational Psychologist*

This study explored the conditions and processes involved in the integrated model. Specifically, this study investigated the nature of the relationships between conditions and affect at the Person-, Person x Group-, and Group-level. Additionally, this study explored processes related to group dynamics involving concurrent metacognitive feelings and judgements about self- and group-relations, subsequently experienced emotions, associated emotion regulation strategies and/or negative socio-emotional interactions at the Task x Person x Group-level. Overall, the study found that specific conditions within each condition-level appear to show evidence of being intra- and inter-related. As well, this study found that concurrent metacognitive experiences are observable and that the kinds of concurrent metacognitive feelings and judgements students express at the Task x Person x Group-level may be due to phases of group development. Additionally, this study uncovered that concurrent metacognitive feelings and judgements related to group dynamics appear to be associated with emotions and subsequent emotion regulation strategies and/or negative socio-emotional interactions. Lastly, this study established that Task x Person x Group-level experiences may inform Person-, Person x Group-, and Group-level conditions.

RQ1. Relations Between Person- and Person x Group-level Affect and Other Conditions

Results revealed that Person-level enjoyment of mathematics class relates to valuing mathematics learning, while Person-level boredom experienced during math class relates to a lower value for mathematics learning. Qualitatively, this study illustrated that working collaboratively relates to experiencing enjoyment and could mediate Person-level dislike for mathematics. Research has put forth that there is a conceptual overlap between emotional and motivational concepts. According to Krapp (2005), enjoyment is an important facet of interest and interest is closely associated with value (Eccles & Wigfield, 2020). Therefore, an individual's enjoyment of learning mathematics can be representative of one holding a value

for mathematics and in turn, an intrinsic motivation for math learning. In relation to the integrated model and similar to conjectures made by Schukajlow et al., 2023, Person-level affect associated with enjoyment of mathematics class informs a motivation for learning through value of mathematics.

At the Person x Group-level, interviewees expressed enjoyment in working in a collaborative context. Considering the overlap between emotional and motivational concepts, a Person x Group-level experience of enjoyment would, much like at the individual level, theoretically relate to interest, which relates to intrinsic motivation. Gomez et al., (2010) conducted a study to assess the individual preparedness, perceived learning, team member value, perceived motivation, and perceptions of enjoyment amongst 73 university students who participated in a computer-supported team-based learning context. The authors found that students preferred team-based learning over traditional lecture-style courses and considered working with their team members to be a valuable experience. The authors also found that valuing team members positively impacted enjoyment and motivation, and perceived motivation positively impacted enjoyment for learning. Therefore, working in a collaborative context in a mathematics class may contribute to students developing Person-level positive affect in relation to mathematics, which could in turn impact Person-level motivation in mathematics. Additionally, as per the results, enjoyment experienced in the collaborative context appeared to override an individual dislike for mathematics.

Similar to other research findings (see Pekrun et al., 2014; Vogel-Walcutt et al., 2012) this study revealed that self-reported feelings of boredom experienced in mathematics class was negatively associated with an interest, or in this study's case, value for learning mathematics. However, other research has found that experiences of boredom have a neutral impact on interest related to mathematics (see Schukajlow & Rakoczy, 2016; Schukajlow, 2015). In relation to the current study and as seen with other research findings that compared

associations between enjoyment and boredom and motivation (see Pekrun et al., 2011), the correlation between boredom and value were lower (-.571) compared with the correlation between enjoyment and value (.775). Ainley and Hidi (2014) describe how a possible explanation is that students' interest could be accompanied by both positive and negative emotions. It is my recommendation that future research on the integrated model focus on how group dynamics lead to experiences of positive and negative emotion to better understand the specific context and learning task circumstances that contribute to or mediate Person-, and Person x Group- affect.

RQ 2. Metacognitive Experiences That Took Place During the Collaborative Task

As per this study's findings, a variety of prospective, during, retrospective and concurrent metacognitive experiences arose during the collaborative complex mathematics problem solving session at the Task x Person x Group-level. Specific to cognition of group dynamics, qualitative results from this study reveal that group members expressed concurrent metacognitive feelings and judgements in relation to group dynamics and self- and social-relations thus validating the existence of concurrent metacognitive experiences related to self- and group-relations. As previously mentioned, metacognition has historically been considered an individual process that serves an individual in regulating their cognition (Efklides, 2008). Efklides (2008) states that social-level metacognition is a meta level of personal awareness, which employs metacognitive experiences and metacognitive knowledge to convey our thought processes to, and assess the thinking of, others.

The current study also found that concurrent metacognitive feelings and judgements related to group dynamics were associated with feelings of frustration, which may have been due to groups' current phase of group development and a lack of collaborative training to support SSRL. Research on metacognition in different domains and age groups has found that feelings play a critical role in developing metacognitive judgments (Koriat & Levy-Sadot,

2000). Significant relationships were also reported between emotions and metacognitive judgments in math problem solving among primary school students (Tornare et al., 2015). In relation to Person-level conditions, Webster and Hadwin (2015) studied emotion and use of emotion regulation strategies at the self-regulated level of 111 undergraduate students while studying for a first-year university course on self-regulated learning. The authors studied the intensity of achievement emotions and found that negative emotions were related to decreased confidence judgments about the achievement of individual learning goals. Specifically, the intensity of negative emotions negatively predicted students' self-evaluations. In the integrated model, this would mean that negative emotions, such as instances of frustration, would relate to decreased concurrent judgements related to confidence about the group at the Task x Person x Group-level. As described in the exchanges between Thomas, Istvan and Declan, the instance of frustration experienced by a group member concludes with a social concurrent metacognitive judgement related to confidence in the group's work habits (e.g., Istvan: "This is not working.", Declan: "I know."). Therefore, it may be possible that the same dynamics that exist between negative affect and prospective, during, and metacognitive judgements related to confidence, also exist between negative affect and concurrent metacognitive judgements related to confidence in the group, group members, or a single group member.

Experiences of frustration and concurrent metacognitive experiences may have also been due to the phase of group development and a lack of collaborative learning training. As previously mentioned, many groups were engaged in the storming phase of group development. Bonebright (2009) describes group dynamics that most often describe the second, or storming phase, of group development. This phase is normally characterized by intergroup conflict and a general lack of unity. Group members may have a pronounced emotional reaction to the task and group members especially when the task influences

perceptions of self-concept. The results from this study found that working with friends appeared to be an important antecedent related to the task context that brought about enjoyment, however, these groups did not receive any explicit or formal training in collaborative learning strategies and managing group dynamics. Therefore, the participants in this study, despite holding pre-existing positive social relationships with their group members outside of the collaborative task context, were developing an understanding of group members as work partners during the collaborative complex problem-solving session for perhaps the first time.

In a study by Johnson et al. (2002), the authors describe the community building process of collaborative teams in an online learning context. They studied the group processes and strategies used by 36 graduate students who were enrolled in an online course comprised of nine online classes, as they worked remotely in a collaborative group composed of five or six members. The authors found that issues of team conflicts were most often associated with issues surrounding group members' lack of participation, planning, or disagreements between individuals. Team conflicts did not appear to arise in relation to task difficulty. Additionally, the authors found that unresolved conflicts impeded the development of the collaborative group. In relation to this study, it appears that frustration (a normal affective reaction in the storming phase) in relation to group work habits appears to enact what Efklides (2008) would call *social-level metacognition,* which employs metacognitive experiences (concurrent metacognitive judgements) and metacognitive knowledge to convey thought processes to others. Therefore, based on this study's findings related to RQ2, recommendations for future research include further investigation into the impact of antecedents, consequences, and emotions on the qualities of concurrent metacognitive experiences. Additionally, future research is encouraged to focus on how individuals and the collaborative group regulate their emotions based on the challenges they experience in the

collaborative learning context above and beyond the stimulus events focused on in this study. For example, the adaptive instrument for regulation of emotions (AIRE) (Järvenoja et al., 2013) assess the nature of social challenges (i.e., personal priorities, work and communication, teamwork, collaboration, and external constraint) and how the emotions resulting from these challenges are either self-, co-, or socially regulated. Finally, future research is encouraged to focus on the impact of SSRL and/or collaborative team-building training sessions on positive group development and subsequent group dynamics as they take place in a collaborative complex problem-solving context.

RQ 3. Emotion Regulation Strategies and Interactions Employed by the Collaborative Groups in Response to Concurrent Metacognitive Experiences

Results found that collaborative groups enacted an array of emotion regulation strategies regulated by the self, peers, and the collective and engaged in negative socio-emotional interactions as a consequence of emotions experienced at the Task x Person x Group-level. Results also demonstrated that some of the emotions experienced during the collaborative complex problem-solving task co-occurred or closely occurred in relation to concurrent metacognitive feelings and judgements about group dynamics described by the integrated model. According to Efklides (2006), metacognitive experiences monitor the progress that one is making in relation to the goals they have set for the learning task; the higher the discrepancy between the goal for the learning task and the outcome in relation to the goal, the higher the likelihood of experiencing negative affect. A secondary feedback loop monitors the rate at which the discrepancy between goals and the progress towards those goals are reduced. The size of the discrepancy could initiate feelings of difficulty as an individual, or group, may lack the cognitive resources to overcome the discrepancy. It is the contention of the integrated model that concurrent metacognitive experiences may influence the kinds of expectations the group has for completing the learning task. Therefore, when

group members, or the group, notices a large discrepancy between the goals for their group (based on Group-level conditions) in relation to the group dynamics and task performance at the Task x Person x Group-level, concurrent metacognitive feelings of difficulty associated with group dynamics may theoretically bring about, or reflect the occurrence of negative affect.

It is the contention of the integrated model that concurrent metacognitive experiences, or the metacognitive experiences that focus on self- and social-relations as they occur alongside cognition related to the task, activity, and outcome, monitor the progress of social-relations as the task unfolds. Metacognitive experiences in turn trigger affect, and consequently, may trigger emotion regulation. Findings by Dang et al. (2023) found that collaborative groups tended to switch to metacognitive interactions after a cognitive trigger related to cognitive task-solving processes took place and engaged in socio-emotional interactions after an emotional trigger took place. Similarly, the current study found similar findings related to collaboration and group dynamics. That is, group member work habits triggered, or were associated with, concurrent metacognitive experiences expressed by collaborative group members, which co-occurred or closely occurred with an emotion and after which an emotion regulation strategy was employed.

The current study found that, although instances of SSRL related to emotion regulation did occur, instances of SSRL were rare and were representative of only 13 out of a total of 191 regulation instances, or just under 7%, of total emotion regulation modes related to emotion regulation. It is important to note that the collaborative groups in this study did not receive any SSRL training or support prior to engaging in, or during the collaborative complex problem-solving session. Hogenkamp et al. (2021) studied how SSRL related to a task was demonstrated in a cooperative learning context. One hundred four, fourth, fifth and sixth grade students working in collaborative groups of four team members were included in

the study. Results revealed that SSRL rarely occurred in the cooperative learning context (just under 6% of total learning regulation codes). The authors found that the absence of SSRL contributed to less structured collaboration. The authors also found that there was no significant difference in the enactment of SSRL between cooperative groups who were supported by being provided with a strategy to help group members distribute the work equally amongst members versus groups who were unsupported in establishing equal work distribution. The frequency of SSRL use found by Hogenkamp et al. (2021) is comparable to the frequency of SSRL use in response to an emotion in the current study. It appears from results of the Hogenkamp et al. (2021) study that equal work distribution did not contribute to the occurrence of SSRL. Similarly, in the current study, equal work distribution did not come up as a significant issue related to instances of SSRL.

RQ 4. Relations Between Task x Person x Group-Level and Person-, Person x Group-, and Group-Level Conditions.

Pride has been described as an emotion mainly experienced in association with appraisals made by others and in relation to social standards (Tangney & Fischer, 1995). Additionally, enjoyment occurs from high control and high value and low cost (Pekrun, 2019). Specifically, the expression of pride stems from others when their high ability or effort led to successful outcomes (Hareli & Weiner, 2002). Pride can also act as a means of ego enhancement. That is, an individual who experiences pride may look to maintain pride by continuing to demonstrate effort and ability (Ryan & Deci, 2000). For example, Tracy and Robins (2007) investigated the structure and processes of pride amongst 99 undergraduate students enrolled in psychology courses across seven studies. The authors found that pride appears to have two facets with one facet of pride appearing to be more state-like and linked with achievement and self-esteem and the other being more trait-like in nature and related to hubris. In relation to the current study, socially experienced states of enjoyment and the pride

positively correlated to feelings of relatedness experienced at the Task x Person x Group-level. The students who participated in this research study had spent at minimum 8 months learning together in the classroom environment and interviewees expressed friendships existing amongst group members despite being grouped by the teacher who did not consider pre-existing friendships in the formation of groups. Relatedness is an important facet in the formation of friendships according to attachment theory (Rubin et al., 2006) and increases the likelihood that one would engage in self-improvement to increase social relationships (Chen et al., 2015; Saeki & Quirk, 2015). Recall that in this study Camille described being proud of their group towards the end of the problem-solving session and expressed that despite a weak self-concept in math, she was proud as she was able to complete the math equations successfully. It may be that a group member's experience of pride is sustained through a demonstration of effort and pre-existing friendships in the group additionally support the engagement in self-improvement in mathematics during the collaborative complex mathematics problem solving session. These affective and social experiences may then contribute to improvement in Person, and Person x Group-level conditions related to self- and group-concept and thus lead to increased feelings of relatedness at the Group-level.

It is the contention of the integrated model that concurrent metacognitive feelings and judgements may inform Person x Group-level metacognitive knowledge about self- and group-concept, and self and the group-ability. In the case study of Brenda, Patricia, and Jerica, concurrent metacognitive experiences, emotion, and emotion regulation and negative socio-emotional interactions took place across several episodes. In the case study of Brenda's group, the individual expression of confusion in relation to the content and task is preceded by a concurrent metacognitive judgment associated with their confidence in their group's math ability based on experiences that took place in context (i.e., "Math isn't our strong suit.") and the subsequent episodes concluded with a concurrent metacognitive judgement

about the group-concept, again, based on in-context experiences (i.e., “This is not the best of groups). At the Task x Person x Group-level, this student is expressing, through a verbalization of their concurrent metacognitive experiences (namely metacognitive judgements), their assessment of the group in-context which may inform their Person x Group-level conditions. According to the integrated model, an individual’s metacognitive experiences, based on the thoughts on the thinking of others, are integrated into their metacognitive knowledge of group concept and ability at the Person x Group-level and may depend on subsequent experiences taking place at the Task x Person x Group-level.

Research has shown that students’ perceptions of group dynamics may relate to the development of self-concept and group member-concept (see Theobald et al., 2017). In the integrated model these are conditions that align with the Person-, and Person x Group-level. In a study by Theobald et al. (2017), students ages 18 to 24 years of age enrolled in a second-year university biology course worked collaboratively with peers in a 2-hour per week laboratory class. Students were surveyed three times over the course of the semester on their perceptions of the group dynamics that took place within their collaborative groups. Participants reported that in some of the collaborative groups a single group member dominated group processes. Specifically, in subsequent focus group discussions students demonstrated that they were able to self-identify and identify others as those who dominated a group. Therefore, based on results from this study, it appears that students were able to develop a Person-, and Person x Group-level awareness of self and group-member concept. Lobczowski et al. (2021a) qualitatively compared how groups of pharmacy graduate students working in collaborative groups constructed metacognitive experiences, knowledge, and skills. Their study examined differences in the socially shared metacognition processes between groups who rated themselves as high versus low for metacognitive experiences. They found that, despite finding little difference in the frequency of socially shared

metacognitive processes between the low and high self-rated groups, high self-rated groups were more deliberate, targeted, and cohesive in their enactment of strategies by using learning supports that facilitated sharing, capitalizing on the time they had to collaborate, and targeting the individual strengths of group members as compared to low self-rated groups. High self-rated groups also described how regulation was led by a specific individual in the group, a role that was appreciated by other group members, which supported the group in their regulation efforts. Therefore, self- and group member-concept at the Person- and Person x Group-level seems to be informed by affective experiences at the Task x Person x Group-level. Thus, it appears that the experiences that occurred in this research study during the Task x Person x Group-level may have indeed informed an understanding of the Person-level and Person x Group-level conditions as described by the integrated model.

Limitations and Future Direction

Sample Size and Demographic Diversity

This study explored facets of the various levels involved in the integrated model and provided some promising evidence that supports theoretical assumptions associated with aspects of the conditions and processes involved in the integrated model. However, the current study has several limitations that are worth noting. The first limitation is the small sample size used in this exploratory study. According to Daniel (2011), the recommended number of participants for an exploratory study is suggested to be between n = 20 to 150; however, correlational research should have a minimum n = 30. Small sample sizes are susceptible to experiencing low statistical power and in turn, may conclude a false positive (Faber & Fonesca, 2014). As well, small sample sizes (e.g., n = 20), may contain a larger number of outliers when compared to larger sample sizes (e.g., n = 60), which could influence parameter estimates and standard errors (Creedon & Hayes, n.d.). Therefore, correlational results from this study should be interpreted with caution. Larger sample sizes,

especially if using a quantitative analysis, should be used when conducting future research studies on the conditions and processes associated with the integrated model. Additionally, the current study was conducted in a single fifth-grade classroom of a private school in the Montreal area characterized by a high socio-economic status (SES). It is therefore suggested that future research compare the kinds of conditions and processes involved in integrated model at different grade levels. As well, it is suggested that the demographic diversity of the sample be considered by conducting this study in various classrooms, across several elementary schools of diverse SES.

Intra- and Inter-Motivation and Motivation Regulation

This study focused on exploring the dynamics between Person, Person x Group and Group-level affect, self- and group-ability and concept, and motivation as well as metacognitive experiences, emotion, and emotion regulation at the Task x Person x Group-level. However, there are important facets of the conditions and processes involved in the integrated model that were not explored in the current study. Firstly, motivation regulation related to any of the cognitive phases (i.e., task representation, cognitive processing, performance, and group dynamics) was not explored in this study. Emotions experienced when engaged in the collaborative context not only affect regulatory processes, but additionally affect the motivation to pursue regulatory processes, learning, and further collaboration (Hadwin & Oshige, 2011; Volet & Vauras, 2013). Conversely, the role of emotions in collaborative contexts is influenced by one's motivation for learning (Meyer & Turner, 2002). For motivation, the following can be concluded in relation to the operationalization of motivation in the integrated model. Sociocultural considerations of motivation in collaborative contexts align well with Efklides' MASRL model and *intra-motivation in collaboration* because they involve the sharing of individual metacognitive processes to influence group motivation. Specifically, theoretical assumptions about the

manifestation of motivation at the Person-level of the MASRL model cite that motivation is the result of preceding metacognitive processes that namely involve considerations of affect and cognitive representations of the self. Therefore, motivation is not spontaneous, but rather the result of metacognitive experiences and knowledge of the self that subsequently influence metacognitive strategies and metacognitive knowledge. Appropriately, much of the empirical work in this area reflects the aforementioned notion by having studied the interplay of socially shared regulation of emotion and motivation in tandem (see Järvenoja & Järvelä, 2005; Järvenoja & Järvelä, 2009; Järvenoja et al., 2019; Järvenoja et al., 2020). I suggest that future empirical work in this area use the integrated model as a framework to explore the interplay between factors such as self-concept, affect, metacognitive knowledge, metacognitive strategies and motivation and the influence these factors have on socially shared regulation of motivation. Additionally, I suggest that a three-tiered analysis of motivation regulation that focuses on the interplay of individual metacognitive processes manifesting into instances of co-regulated motivation that influence socially shared regulation of motivation would reinforce theoretical assumptions.

Reciprocal and Temporal Dynamics

In relation to affect at the individual level, metacognitive experiences influence motivation, and emotions experienced in a group context, which set the stage for the regulation of emotions (Iiskala et al., 2011). As well, metacognitive experiences appear to precede instances of socially shared metacognition (see Iiskala et al., 2011). Therefore, affective experiences require regulation but are also instrumental in bringing about shared instances of metacognitive thought, which suggests a dynamic and cyclical relationship. This dynamic relationship has been explored at the individual level wherein Muis et al. (2018) proposed that emotions constrain or facilitate SRL processes and the quality of those processes. Specifically, surprise, curiosity, and confusion should result in increased instances

of metacognitive strategy use and an increase in cognitive effort as they arise as a result of high novelty or cognitive disequilibrium. In contrast, anxiety and frustration that may arise when cognitive disequilibrium cannot be resolved may reduce the amount of effort exerted but may also increase the use of shallow strategies due to cognitive resources being consumed by those emotions (see Pekrun et al., 2011; Pekrun & Stephens, 2012).

Based on the aforementioned, a fruitful area of future inquiry would be to consider the interplay of affective experiences between the conditions and regulatory processes associated with the collaborative task. Specifically, future research should further explore the reciprocal and temporal dynamics between Person-, Person x Group-, and Group-level conditions and Task x Person x Group-level processes. Additionally, future research is encouraged to investigate how conditions at the individual and social level influence the occurrence of concurrent metacognitive experiences, emotion, emotion, and motivational regulation, and how concurrent metacognitive experiences, emotion, emotion and motivational regulation in turn influence individual and social level conditions. Lastly, future research that examines the temporal, or sequential, dynamics of concurrent metacognitive experiences and emotion could help to identify critical points at which interventions could be aimed at supporting emotion regulation would be most beneficial in supporting group dynamics. For example, Zheng et al. (2022) examined the temporal shifts in emotions of 98 medical students across three phases of SRL while engaged in a problem-solving task. The authors found that initial instances of curiosity and enjoyment predicted student performance. Additionally, the authors were able to profile students into emotion profiles, which proved to be either stable or transitional over the time the students spent engaged in the learning task. Examinations that considered the emotion profiles of collaborative groups and how the temporal shifts in emotion impact group performance and achievement would be a fruitful area for further research and contribute to an understanding of how emotion influences group functioning and

subsequent learning.

Measurements

Although this study used a combination of pre- and post- self-report measures, audio transcriptions and semi-structured interviews, it is suggested that future studies use an increased array of data collection tools. Specifically, this study used pre- and post-measure self-reports. Self-reports run the risk of memory-bias (see Goetz et al., 2013) and only measure conscious emotional processes (Pekrun, 2016). A possible validity bias associated with the self-reports used in this study is the potential that participants may bias their reports of emotion because of social desirability (Pekrun, 2016). For example, students who worked in collaborative group with their friends may downplay reporting feelings of frustration associated with their group members. Conversely, students who did not work with their friends in the collaborative group or worked with peers with whom they had negative associations with may have inflated reports of frustration or boredom and underreported feelings of pride.

Multimodal approaches to measuring emotions and the quality of collaboration has been suggested and described by various researchers (Järvelä et al., 2021; Praharaj et al., 2023; Zheng et al., 2023). Specifically, using a combination of subjective (e.g., self-reports) and objective data (e.g., physiological measures) to increase the validity of participants perceptions of various experiences (e.g., emotion, cognitive appraisals, and task difficulty) has been put forth (Järvelä et al., 2019) (For a review of measurement techniques for measuring emotions see Zheng et al., 2023). Also including indirectly objective data, such as observational data in the form of video recordings of the students engaged in the collaborative learning context, is also suggested for future studies. A triangulation of subjective, objective, and indirect objective data would support future research in exploring the temporal and reciprocal nature of conditions and processes in the integrated model and

uncover the stimulation of regulatory patterns (Järvelä et al., 2021).

Educational Implications

As previously mentioned, educational institutions at all levels are ever-increasing their focus on developing students' future-proof learning, in particular, their ability to engage in collaborative problem-solving (Hesse et al., 2015). Collaborative learning is associated with the development of stronger social support networks, effective conflict resolution, increased understanding of diversity, higher level thinking and communication skills, increased perseverance when faced with a challenge, deeper learning, and an increase in active involvement in the learning process (Cohen & Willis, 1985; Johnson & Johnson, 1990; Swing & Peterson, 1982; Yager, et al., 1985). Poon et al. (2015) discussed how a major challenge associated with supporting students in the development of skills that include collaboration is due to a lack of clarity on how to teach and measure such competencies. The integrated theoretical framework provides a model from which teaching practices and assessment of effective SSRL in collaborative learning may be derived.

Hesse et al. (2015) described three fundamental social skills involved in effective collaboration: participation, perspective-taking, and social regulation. Specifically, perspective-taking is a multidimensional construct that is linked to affective phenomena such as social achievement emotions, and emotional understanding (Hesse et al., 2015). Cognitively, perspective-taking requires individuals to consider understandings from various points of view (Zuckerman et al., 1983). Johnson and Johnson (2009) described five principles required for cooperation to take place within a cooperative or collaborative group learning context: positive interdependence (i.e., pursuing common goals), responsibility and accountability, promotive interaction (i.e., trust building, communication, sharing of resources, providing encouragement, elaborating on ideas, modelling, and peer assessment), effective social skills, and group processing. Therefore, it is recommended that tasks be

structured so that collaboration is a requirement for success (Esmonde, 2009). For example, research has found that the quantity and quality of interactions between collaborative members increased during ill-structured, complex, and open-ended learning tasks as compared to single-solution, procedurally oriented tasks (Chizhik, 2001). As well, tasks that supported interdependence through group rewards and supported independence through individual accountability were found to be most effective in supporting collaboration (Slavin, 1996). Additionally, these principles are better practiced and perfected during planned, and carefully structured learning tasks, as opposed to spontaneous, spur-of-the-moment episodes of collaboration (Butera & Buchs, 2019).

The integrated framework provides teachers with a conceptual way to organize and investigate the social processes involved in SSRL. Considering the ability of independent observers to measure collaborative learning and instances of SSRL (see Hesse et al., 2015; Iiskala et al., 2011), it is also our suggestion that pre-service teaching programs increase their focus on, and training in, setting up and assessing collaborative learning contexts and the regulatory processes that bring about productive and effective SSRL. In a study by Manlove et al. (2006), the authors found that the supportive directives that collaborative groups received during collaborative work had a positive impact on learning regulation. Therefore, teacher training should focus on providing teachers with a theoretical understanding of the processes involved in SSRL so that they can effectively support SSRL in the classroom.

For example, teachers should be trained in identifying, monitoring, and responding to behaviours related to student disengagement in group processes. As the frequency of socially shared metacognition between low and high self-rated collaborative groups on metacognitive experiences appears to be an unreliable method to evaluate the quality of collaboration (see Lobczowksi et al., 2021), teachers must rely on other kinds of analyses to determine the calibre of SSRL taking place in their classrooms. As previously mentioned, teachers should

look for instances of students engaged in sustained episodes of independent work during collaborative learning sessions as this may be an indicator that students are underutilizing possible collaborative mediums and/or using their time to collaborate in an inefficient way (Lobczowksi et al., 2021). As well, teachers are encouraged to scaffold planning approaches and ask collaborative groups to submit a plan of action as it has been found that groups that engaged in unproductive planning also struggled with monitoring task performance (Lobczowksi et al., 2021). It is also suggested that teachers monitor the phases in which groups are in throughout the collaborative process through observation techniques and group check-ins. Identifying and addressing signs of confusion and student boredom as well as providing students with strategies that they can independently use to mediate feelings of confusion, and apathy when engaged in a collaborative learning task could reduce the possibility of social loafing (see Luo et. al., 2021). Checking the affective climate of the group through self- and group-reporting, question-and-answer periods or group conferences, and observation would support teachers in responding to possible SSRL challenges that emanate from emotions related to the task, learning and/or other group members.

Additionally, Esmonde (2009) encourages teachers to engage their students in collaborative learning training sessions before facilitating collaborative learning situations (Buchs et al., 2016; Farivar & Webb, 1994; Gillies & Ashman, 1998). Some studies found little effect on collaborative training (Ross et al., 1996); however, others have found students who received collaborative training experienced higher achievement on, and participation in, collaborative tasks (Buchs et al., 2016; Gillies & Ashman, 1997; Webb & Farivar, 1994) particularly when it is coupled with feedback and reflection on collaborative interactions (Ross, 1995). Buchs et al. (2016) studied the effects of a training intervention to promote cooperative learning. The researchers provided students in the cooperative interactions condition with a text describing the value of cooperation and asked students to explain the

cooperative skills that they used throughout the cooperative learning situation. Results showed that feelings of competence and learning outcomes were the highest amongst students in the cooperative interactions condition as compared to students who worked individually. Accordingly, collaborative training sessions may assist students in developing their metacognitive knowledge of the self and others and improve metacognitive judgements by helping students fine-tune their estimates of effort, time, and appropriateness of responses. Additionally, having students reflect on the feedback they are provided with may support students and collaborative groups in their self and socially shared regulation of learning.

The integrated framework incorporates cognitive and metacognitive regulatory processes that take place at both the Person-, Person x Group- and Group-level. In a study by Hogenkamp et al. (2021), the researchers found that not all group members engage in SSRL equally and that uncoordinated SRL processes could lead to ineffective SSRL. Considering that the integrated framework focuses on metacognitive, motivational, and affective processes at the individual and group level in relation to the learning task, the framework could be used to uncover how group members' individual cognitive and metacognitive regulatory processes relate to SSRL in relation to the learning task. Research conducted using the integrated framework would contribute to framing and organizing the cognitive and social processes that collaborative groups, and the individuals in those groups engage in, in collaborative learning contexts. Effective supportive directives could be developed and accurately target groups' needs. As well, the results from research conducted based on the framework could be used to inform teachers about how to structure and sequence collaborative learning tasks so that they initiate and support effective SSRL.

Lastly, success in collaboratively solving complex problems involves more than understanding and applying processes (Esmonde, 2009). Organization and communication skills are other non-academic aptitudes vital to collaboration. From this perspective, multiple

abilities are required to effectively collaborate above and beyond subject-specific understandings. In relation to the current study, high instances of confusion and low instances of SSRL related to emotion regulation may have been due to group members' undeveloped social awareness. That is, they may have had trouble identifying and diagnosing important information about how the group was functioning and verbalizing their needs as a consequence of the emotions experienced in relation to the task and group dynamics. For example, referring to the case study of Brenda's group and the emotional episodes spurred by a concurrent metacognitive judgement, Brenda does not explicitly verbalize that she is confused until she becomes frustrated and tells Patricia, "I'm not upset at you! I'm confused!" At this point, Patricia explains how Brenda should be clearer in their communication, "You need to just tell us. You need to just tell us, "I'm confused. Maybe you should say, 'Patricia", I'm confused!'". It could be that Brenda felt as if she was expressing her confusion to her group members despite her failure to explicitly articulate her emotions. To increase the value of organization and communication skills and the likelihood of their occurrence, these qualities should be explained, supported, celebrated, and modelled by the teacher through direct instruction and feedback. Additionally, teacher presence, monitoring, and observation are imperative when students are working collaboratively. This way, if a group member is perhaps being marginalized, it is the teacher's role to assign competence to the marginalized student by publicly acknowledging their academic contribution(s) to the group. Explicitly celebrating and supporting students' collaborative skills when they are engaged in a collaborative problem-solving context may assist them in developing a more positive Person-level self-concept, metacognitive experiences, and perceptions of ability.

Conclusion

The foundational organization of the integrated framework is based on results from

research conducted on individual metacognitive and SRL processes (see Efklides, 2011). Up until very recently, research conducted on metacognition has largely neglected the social aspects of metacognition (Iiskala et al., 2011). As well, little research has considered the environmental and pedagogical factors that bring about effective SSRL (Panadero & Järvelä, 2015). This dissertation aimed to propose an integrated framework for operationalizing social level metacognitive conditions (i.e., Person- Person x Group- and Group-level) and processes (i.e., Task x Person x Group level) that lends itself to a more situated perspective of metacognition in shared regulation of learning. This study considered calls to consider the role of the social context in SSRL (Dowson & McInery, 2003; Hickey & McCaslin, 2001; Volet & Järvelä, 2001). Therefore, the aim of this study was to investigate the conditions of affect and motivation at the Person-, Person x Group- and Group-level and metacognitive experiences, emotions, emotion regulation and interactions experienced at the Task x Person x Group level. Additionally, this study explored how Task x Person x Group-level group dynamics inform Person-, Person x Group- and Group-level conditions. The results of this study revealed important relations between affect and Person- and Person x Group-level conditions, the existence of concurrent metacognitive experiences, and that concurrent metacognitive experiences occurred or closely occurred with emotions. As well, concurrent metacognitive experiences that occurred or closely occurred with emotions were emotionally regulated by the group. Lastly, experiences at the Task x Person x Group-level appeared to inform Person-, Person x Group- and Group-level conditions.

My hope is that the presentation of the integrated model of SSRL provides a theoretical scaffolding for empirical explorations beyond the current study. More specifically, future theoretical and empirical work in this area is needed to fully understand metacognitive processes in relation to SSRL and in relation to metacognition, affect, and motivation, to solidify the conceptual ground on which SSRL is built. Such a line of inquiry would not only

extend the understanding of the salient, as well as subtle features of SSRL, but also serve to reinforce theoretical conjectures that pertain to the relationship between metacognition and learning regulation at the social level. Additionally, the field requires contemplation of the kinds of methodological considerations that would be most appropriate to study metacognitive processes involved in SSRL.

Coming together to share thoughts, speculations, and understandings is an age-old tradition in the development of critical thinking and the advancement of understanding. With the evolution of technology and the multitude of new methods and avenues for communication, paired with the uncertainty of the workforce landscape facing society, it is not surprising that the factors that contribute to effective collaboration are ever-increasingly important to examine. I aspire to add to the conversation surrounding issues relating to the factors and processes involved in collaboration and bring attention to the importance of validating the individual and shared learning experiences and communal learning process. I hope that the integrated model encourages and informs future pedagogical approaches and interventions to support collaboration.

References

Ainley, M. (2007). Being and feeling interested: Transient state, mood, and disposition. In P. A. Schutz & R. Pekrun (Eds.), *Emotion in Education*, 147–163. New York: Elsevier. https://doi.org/10.1016/B978-012372545-5/50010-1

Ainley, M., & Hidi, S. (2014). Interest and enjoyment. In R. Pekrun & L. Linnenbrink-Garcia (Eds.), *International Handbook of Emotions in Education* (pp. 205-227). New York: Routledge.

Ainley, M., Hidi, S., & Berndorff, D. (2002). Interest, learning, and the psychological processes that mediate their relationship. *Journal of Educational Psychology*, *94*, 545. https://doi.org/10.1037/0022-0663.94.3.545

ATLAS.ti Scientific Software Development GmbH. (2023). ATLAS.ti Mac (version 23.2.1) [Qualitative data analysis software]. https://atlasti.com

Azevedo, R., Guthrie, J. T., & Seibert, D. (2004). The role of self-regulated learning in fostering students' conceptual understanding of complex systems with hypermedia. *Journal of Educational Computing Research*, *30*, 87-111. https://doi.org/10.2190/DVWX-GM1T-6THQ-5WC7

Bandura, A. (1994). Self-efficacy. In V. S. Ramachaudran (Ed.), *Encyclopedia of human behaviour, Vol. 4*, (pp. 71-81). New York: Academic Press.

Bandura, A. (2001). Social cognitive theory: An agentic perspective. *Annual Review of Psychology*, *52*, 1-26. https://doi.org/10.1111/1467-839X.00024

Barron, B. (2003). When smart groups fail. *Journal of the Learning Sciences, 12*, 307–359. https://doi.org/10.1207/S15327809JLS1203_1

Bakhtiar, A., Webster, E. A., & Hadwin, A. F. (2018). Regulation and socio-emotional interactions in a positive and a negative group climate. *Metacognition and Learning*, *13*, 57-90. https://doi.org/10.1007/s11409-017-9178-x

Boekaerts, M. (2006). Self-regulation and effort investment. In K. A. Renninger & I. E. Sigel (Eds.), *Handbook of child psychology volume 4: child psychology in practice, 6 ed*., (pp. 345-377). New York, NY: Wiley.

Bonebright, D. A. (2010). 40 years of storming: a historical review of Tuckman's model of small group development. *Human Resource Development International*, *13*, 111-120. https://doi.org/10.1080/13678861003589099

Borge, M., & White, B. (2016). Toward the development of socio-metacognitive expertise: An approach to developing collaborative competence. *Cognition and Instruction*, *34*, 323-360. https://doi.org/10.1080/07370008.2016.1215722

Buchs, C., Gilles, I., Antonietti, J. P., & Butera, F. (2016). Why students need to be prepared to cooperate: A cooperative nudge in statistics learning at university. *Educational Psychology*, 36, 956–974. https://doi.org/ 10.1080/01443410.2015.1075963

Butera, F., & Buchs, C. (2019). Social interdependence and the promotion of cooperative learning. In *Social psychology in action* (pp. 111-127). Springer, Cham. https://doi.org/10.1007/978-3-030-13788-5_8

Chen, B., Vansteenkiste, M., Beyers, W., Boone, L., Deci, E. L., Kaap-Deeder, Duriez, V., Lens, B., Matos, W., & Mouratidis, A. (2015). Basic psychological need satisfaction, need frustration, and need strength across four cultures. *Motivation and Emotion, 39*, 216–236.

Chizhik, A. W. (2001). Equity and status in group collaboration: Learning through explanations depends on task characteristics. *Social Psychology of Education*, *5*, 179-200. https://doi.org/10.1023/A:1014405118351

Corrégé, J. B., & Michinov, N. (2021). Group size and peer learning: Peer discussions in different group size influence learning in a biology exercise performed on a tablet with stylus. In *Frontiers in Education, 6*, 1-13. https://doi.org/10.3389/feduc.2021.733663

Creedon, P. S., & Hayes, A. F. (n.d.). Small Sample Mediation Analysis: How Far Can We Push the Bootstrap? Department of Psychology, The Ohio State University. Retrieved from http://afhayes.com/public/aps2015ch.pdf

Creswell, J. W., & Clark, V. P. (2011). *Mixed methods research*. SAGE Publications. https://doi.org/10.1023/A:1014405118351

Dang, B., Vitiello, R., Nguyen, A., Rosé, C., & Järvelä, S. (2023). How Do Students Deliberate for Socially Shared Regulation in Collaborative Learning? A Process-Oriented Approach. In *Proceedings of International Conference on Computer-Supported Collaborative Learning (CSCL)*.

Daniel, J. (2011). Sampling Essentials: Practical Guidelines for Making Sampling Choices. SAGE.

De Backer, L., Van Keer, H., & Valcke, M. (2015). Exploring evolutions in reciprocal peer tutoring groups' socially shared metacognitive regulation and identifying its metacognitive correlates. *Learning and Instruction*, *38*, 63-78. https://doi.org/10.1016/j.learninstruc.2015.04.001

De Backer, L., Van Keer, H., & Valcke, M. (2021). Examining the relation between students' active engagement in shared metacognitive regulation and individual learner characteristics. *International Journal of Educational Research, 110*. https://doi.org/10.1016/j.ijer.2021.101892

De Grave, W. S., Boshuizen, H. P. A., & Schmidt, H. G. (1996). Problem based learning: Cognitive and metacognitive processes during problem analysis. *Instructional Science*, *24*, 321–341. https://doi.org/10.1007/BF00118111

Deci, E. L., & Ryan, R. M. (1985). The general causality orientations scale: Self-determination in personality. *Journal of Research in Personality*, *19*, 109-134. https://doi.org/10.1016/0092-6566(85)90023-6

Deci, E. L., & Ryan, R. M. (2010). Self-determination. In Weiner, I. B., & Craighead, W. E. (2010). *The Corsini Encyclopedia of Psychology*. Hoboken, N.J: John Wiley. https://doi.org/10.1016/0092-6566(85)90023-6

Dindar, M., Järvelä, S., & Haataja, E. (2020). What does physiological synchrony reveal about metacognitive experiences and group performance?. *British Journal of Educational Technology*, *51*, 1577-1596. https://doi.org/10.1111/bjet.12981

Dowson, M., & McInerney, D. M. (2003). What do students say about their motivational goals?: Towards a more complex and dynamic perspective on student motivation. *Contemporary educational psychology*, *28*, 91-113. https://doi.org/10.1016/S0361-476X(02)00010-3

Eccles, J. S., & Wigfield, A. (2020). From expectancy-value theory to situated expectancy-value theory: A developmental, social cognitive, and sociocultural perspective on motivation. *Contemporary Educational Psychology*, *61*, https://doi.org/10.1016/j.cedpsych.2020.101859

Efklides, A. (2002). Feelings and judgments as subjective evaluations of cognitive processing: How reliable are they? *Psychology: The Journal of the Hellenic Psychological Society, 9*, 163–184.

Efklides, A. (2006). Metacognition and affect: What can metacognitive experiences tell us about the learning process?. *Educational research review*, *1*, 3-14. https://doi.org/10.1016/j.edurev.2005.11.001

Efklides, A. (2008). Metacognition: Defining its facets and levels of functioning in relation to self-regulation and co-regulation. *European Psychologist*, *13*, 277. https://doi.org/10.1027/1016-9040.13.4.277

Efklides, A. (2009). The role of metacognitive experiences in the learning process. *Psicothema*, *21*, 76-82.

Efklides, A. (2011). Interactions of metacognition with motivation and affect in self-regulated learning: The MASRL model. *Educational Psychologist*, *46*, 6-25. https://doi.org/10.1080/00461520.2011.538645

Efklides, A. (2017). Affect, Epistemic Emotions, Metacognition, and Self-Regulated Learning. *Teachers College Record*, *119,*1-22. https://doi.org/10.1177/01614681171190130

Efklides, A., Samara, A., & Petropoulou, M. (1999). Feeling of difficulty: An aspect of monitoring that influences control. *European Journal of Psychology of Education*, *14*(4), 461–476. http://www.jstor.org/stable/23420265

Efklides, A., Schwartz, B. L., & Brown, V. (2018). Motivation and affect in self-regulated learning: Does metacognition play a role? In, D. H. Schunk & J. A. Greene (Eds.), *Self-regulated learning and performance*, (pp. 64-82). NY: Routledge. https://doi.org/10.4324/9781315697048

Ericsson, K. A., & Simon, H. A. (1998). How to study thinking in everyday life: Contrasting think-aloud protocols with descriptions and explanations of thinking. *Mind, Culture, and Activity*, *5*, 178-186. https://doi.org/10.1207/s15327884mca0503_3

Esmonde, I. (2009). Ideas and identities: Supporting equity in cooperative mathematics learning. *Review of Educational Research*, *79*, 1008-1043. https://doi.org/10.3102/003465430933256

Faber, J., & Fonseca, L. M. (2014). How sample size influences research outcomes. *Dental Press Journal of Orthodontics*, *19*, 27-29. https://doi.org/10.1590/2176-9451.19.4.027-029.ebo

Farivar, S., & Webb, N. M. (1994). Helping and getting help—essential skills for effective group problem solving. *The Arithmetic Teacher*, *41*, 521-525. https://doi.org/10.5951/AT.41.9.0521

Flavell, J. H. (1979). Metacognition and cognitive monitoring: A new area of cognitive–developmental inquiry. *American Psychologist*, *34*, 906-911. https://doi.org/10.1037/0003-066X.34.10.906

Forgas, J. P. (1994). The role of emotion in social judgments: An introductory review and an Affect Infusion Model (AIM). *European Journal of Social Psychology*, *24*, 1-24. https://doi.org/10.1002/ejsp.2420240102

Frijda, N. H. (1986). *The emotions*. Cambridge University Press.

Furrer, C., & Skinner, E. (2003). Sense of relatedness as a factor in children's academic engagement and performance. *Journal of educational psychology*, *95*, 148. https://doi.org/10.1037/0022-0663.95.1.148

Gillies, R. M., & Ashman, A. F. (1997). The effects of training in cooperative learning on differential student behaviour and achievement. *The Journal of Classroom Interaction*, 1-10. http://www.jstor.org/stable/23870790

Gillies, R. M., & Ashman, A. F. (1998). Behaviour and interactions of children in cooperative groups in lower and middle elementary grades. *Journal of Educational Psychology*, *90*, 746. https://doi.org/10.1037/0022-0663.90.4.746

Goetz, T., Bieg, M., Lüdtke, O., Pekrun, R., & Hall, N. C. (2013). Do girls really experience more anxiety in mathematics? *Psychological Science, 24*, 2079–2087. https://doi.org/10.1177/0956797613486

Gomez, E. A., Wu, D., & Passerini, K. (2010). Computer-supported team-based learning: The impact of motivation, enjoyment and team contributions on learning outcomes. *Computers & Education*, *55*, 378-390. https://doi.org/10.1016/j.compedu.2010.02.003

Grau, V., & Whitebread, D. (2012). Self and social regulation of learning during collaborative activities in the classroom: The interplay of individual and group

cognition. *Learning and Instruction*, *22*, 401–412. https://doi.org/10.1016/j.learninstruc.2012.03.003

Gravetter, F., & Wallnau, L. (2014). *Essentials of statistics for the behavioral sciences (8th ed.)*. Belmont, CA: Wadsworth.

Griffen, P., & Care, E. (Eds.). (2014). *Assessment and teaching of 21st century skills: Methods and approach*. Springer. https://doi.org/10.1007/978-94-017-9395-7

Haataja, E., Dindar, M., Malmberg, J., & Järvelä, S. (2022). Individuals in a group: Metacognitive and regulatory predictors of learning achievement in collaborative learning. *Learning and Individual Differences*, *96*, 102146. https://doi.org/10.1016/j.lindif.2022.102146

Hadwin, A., Järvelä, S., & Miller, M. (2018). Self-regulation, co-regulation, and shared regulation in collaborative learning environments. In D. H. Schunk & J. A. Greene (Eds.), *Self-regulated learning and performance,* (pp. 83 – 106). NY: Routledge. https://doi.org/10.4324/9781315697048

Hadwin, A., & Oshige, M. (2011). Self-regulation, co-regulation, and socially shared regulation: Exploring perspectives of social in self-regulated learning theory. *Teachers College Record*, *113*, 240-264. https://doi.org/10.1177/016146811111300204

Hareli, S., & Weiner, B. (2002). Social emotions and personality inferences: A scaffold for a new direction in the study of achievement motivation. *Educational Psychologist*, *37*, 183-193. https://doi.org/10.1207/S15326985EP3703_4

Hesse, F., Care, E., Buder, J., Sassenberg, K., & Griffin, P. (2015). A framework for teachable collaborative problem solving skills. In *Assessment and teaching of 21st century skills* (pp. 37-56). Springer, Dordrecht. https://doi.org/10.1007/978-94-017-9395-7_2

Hickey, D. T., & McCaslin, M. (2001). A comparative, sociocultural analysis of context and

motivation. In S. Volet & S. Järvelä (Eds.), *Motivation in learning contexts: Theoretical advances and methodological implications* (pp. 33–55). Oxford, UK: Pergamon.

Hofmann, S., & Doan, S. (2018). *The social foundations of emotion: Developmental, cultural, and clinical dimensions*. Washington, DC: American Psychological Association. https://doi.org/10.1037/0000098-000

Hogenkamp, L., Van Dijk, A. M., & Eysink, T. H. (2021). Analyzing socially shared regulation of learning during cooperative learning and the role of equal contribution: A grounded theory approach. *Education Sciences*, *11*, 512. https://doi.org/10.3390/educsci11090512

Hurme, T. R., Järvelä, S., Merenluoto, K., & Salonen, P. (2015). *What makes metacognition as socially shared in mathematical problem solving?*. In Metacognition: Fundaments, Applications, and Trends (pp. 259-276). Springer, Cham. https://doi.org/10.1007/978-3319-11062-2_10

Hurmerinta-Peltomäki, L., & Nummela, N. (2006). Mixed methods in international business research: A value-added perspective. *Management International Review*, *46*, 439-459. https://doi.org/10.1007/s11575-006-0100-z

Iiskala, T., Vauras, M., & Lehtinen, E. (2004). Socially-shared metacognition in peer learning? *Hellenic Journal of Psychology, 1*, 147-178.

Iiskala, T., Vauras, M., Lehtinen, E., & Salonen, P. (2011). Socially shared metacognition of dyads of pupils in collaborative mathematical problem-solving processes. *Learning and Instruction*, *21*, 379-393. https://doi.org/10.1016/j.learninstruc.2010.05.002

Iiskala, T., Volet, S., Lehtinen, E., & Vauras, M. (2015). Socially shared metacognitive regulation in asynchronous CSCL in science: Functions, evolution and participation. *Frontline Learning Research*, *3*, 78-111.

Ito, T., & Umemoto, T. (2022). Socially Shared Regulation and Performance in Group Work on Creativity Tasks: Analyzing Regulation Utterances. *Journal of Education and Learning*, *11*, 74-83. https://doi.org/10.5539/jel.v11n4p74

Janssen, J., Erkens, G., Kirschner, P. A., & Kanselaar, G. (2012). Task-related and social regulation during online collaborative learning. *Metacognition and Learning*, *7*, 25-43. https://doi.org/10.1007/s11409-010-9061-5

Järvelä, S., & Hadwin, A. F. (2013). New frontiers: Regulating learning in CSCL. *Educational psychologist*, *48*, 25-39. https://doi.org/10.1080/00461520.2012.748006

Järvelä, S., & Järvenoja, H. (2011). Socially constructed self-regulated learning and motivation regulation in collaborative learning groups. *Teachers College Record*, *113*, 350-374. https://doi.org/10.1177/016146811111300205

Järvelä, S., Järvenoja, H., & Malmberg, J. (2019). Capturing the dynamic and cyclical nature of regulation: Methodological Progress in understanding socially shared regulation in learning. *International journal of computer-supported collaborative learning*, *14*, 425-441. https://doi.org/10.1007/s11412-019-09313-2

Järvelä, S., Kirschner, P. A., Panadero, E., Malmberg, J., Phielix, C., Jaspers, J., ... & Järvenoja, H. (2015). Enhancing socially shared regulation in collaborative learning groups: Designing for CSCL regulation tools. *Educational Technology Research and Development*, *63*, 125-142. https://doi.org/10.1007/s11423-014-9358-1

Järvelä, S., Lehtinen, E., & Salonen, P. (2000). Socio-emotional orientation as a mediating variable in the teaching–learning interaction: Implications for instructional design. *Scandinavian Journal of Educational Research, 44*, 293-306. https://doi.org/10.1080/713696677

Järvelä, S., Malmberg, J., Haataja, E., Sobocinski, M., and Kirschner, P. A. (2021). What multimodal data can tell us about the students' regulation of their learning process. *Learning and Instruction, 72*, 1-9. https://doi.org/10.1016/j.learninstruc.2019.04.004.

Järvelä, S., Volet, S., & Järvenoja, H. (2010). Research on motivation in collaborative learning: Moving beyond the cognitive–situative divide and combining individual and social processes. *Educational Psychologist*, *45*, 15-27. https://doi.org/10.1080/00461520903433539

Järvenoja, H., & Järvelä, S. (2005). How students describe the sources of their emotional and motivational experiences during the learning process: A qualitative approach. *Learning and Instruction*, *15*, 465-480. https://doi.org/10.1016/j.learninstruc.2005.07.012

Järvenoja, H., & Järvelä, S. (2009). Emotion control in collaborative learning situations: Do students regulate emotions evoked by social challenges. *British Journal of Educational Psychology*, *79*, 463-481. https://doi.org/10.1348/000709909X402811

Järvenoja, H., Järvelä, S., & Malmberg, J. (2020). *Learning and Instruction*, *70*, 101090. https://doi.org/10.1016/j.learninstruc.2017.11.004

Järvenoja, H., Näyakki, P., & Törmänen, T. (2019). Emotion regulation in collaborative student learning: when do higher education students activate group level regulation in the face of challenges? *Studies in Higher Education, 44,* 1747-1757. https://doi.org/10.1080/03075079.2019.1665318

Järvenoja, H., Volet, S., & Järvelä, S. (2013). Regulation of emotions in socially challenging learning situations: An instrument to measure the adaptive and social nature of the regulation process. *Educational Psychology*, *33*, 31-58. https://doi.org/10.1080/01443410.2012.742334

Jin, Q., & Kim, M. (2018). Metacognitive regulation during elementary students'

collaborative group work. *Interchange*, *49*, 263-281. https://doi.org/10.1007/s10780-018-9327-4

Johnson, D. W., & Johnson, R. T. (2009). An educational psychology success story: Social interdependence theory and cooperative learning. *Educational researcher*, *38*, 365-379. http://dx.doi.org/10.3102/0013189X09339057

Johnson, D. W., Johnson, R. T., & Stanne, M. B. (1990). Impact of group processing on achievement in cooperative groups. *The Journal of Social Psychology, 130*, 507–516. https://doi.org/10.1080/00224545.1990.9924613

Johnson, S. D., Suriya, C., Yoon, S. W., Berrett, J. V., & La Fleur, J. (2002). Team development and group processes of virtual learning teams. *Computers & Education*, *39*, 379-393. https://doi.org/10.1016/S0360-1315(02)00074-X

Khosa, D. K., & Volet, S. E. (2014). Productive group engagement in cognitive activity and metacognitive regulation during collaborative learning: can it explain differences in students' conceptual understanding?. *Metacognition and Learning*, *9*, 287-307. https://doi.org/10.1007/s11409-014-9117-z

Kirschner, F., Paas, F., & Kirschner, P. A. (2009). A cognitive load approach to collaborative learning: United brains for complex tasks. *Educational Psychology Review*, *21*, 31-42. doi:10.1007/s10648-008-9095-2.

Kirschner, F., Paas, F. Kirschner, P. A., & Janssen, J. (2011). Differential effects of problem-solving demands on individual and collaborative learning outcomes. *Learning and Instruction*, *21*, 587-599. https://doi.org/10.1016/j.learninstruc.2011.01.001

Kirschner, P. A., & Stoyanov, S. (2020). Educating Youth for Nonexistent/Not Yet Existing Professions. *Educational Policy*, *34*, 477–517. https://doi.org/10.1177/0895904818802086

Koriat, A. (2007). Metacognition and consciousness. In P. D. Zelazo, M. Moscovitch & E.

Thompson (Eds.), *The Cambridge Handbook of Consciousness* (pp. 289–325). Cambridge, UK: Cambridge University Press. https://doi.org/10.1017/CBO9780511816789.012

Koriat, A., & Levy-Sadot, R. (2001). The combined contributions of the cue-familiarity and accessibility heuristics to feelings of knowing. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *27*, 34-53. DOI:10.1037/0278-7393.27.1.34

Krapp, A. (2005). Basic needs and the development of interest and intrinsic motivational orientations. *Learning and Instruction*, *15*, 381–395. https://doi.org/10.1016/j.learninstruc.2005.07.007

Kreijns, K., Kirschner, P. A., & Jochems, W. (2003). Identifying the pitfalls for social interaction in computer-supported collaborative learning environments: a review of the research. *Computers in Human Behavior*, *19*, 335-353. https://doi.org/10.1016/S0747-5632(02)00057-2

Kuusela, H., & Pallab, P. (2000). A comparison of concurrent and retrospective verbal protocol analysis. *The American journal of psychology*, *113*, 387-404. https://doi.org/10.2307/1423365

La Guardia, J. G., Ryan, R. M., Couchman, C. E., & Deci, E. L. (2000). Within-person variation in security of attachment: a self-determination theory perspective on attachment, need fulfillment, and well-being. *Journal of personality and social psychology*, *79*, 367. DOI: 10.1037//0022-3514.79.3.367

Latané, B., Williams, K., & Harkins, S. (1979). Many hands make light the work: The causes and consequences of social loafing. *Journal of Personality and Social Psychology*, *37*, 822-832. https://doi.org/10.1037/0022-3514.37.6.822

Levine, J. M., & Moreland, R. L. (2004). Collaboration: The social context of theory development. *Personality and Social Psychology Review*, *8*, 164-172. https://doi.org/10.4324/9780203764473

Lewis, K. (2003). Measuring transactive memory systems in the field: scale development and validation. *Journal of Applied Psychology*, *88*, 587. https://doi.org/10.1037/0021-9010.88.4.587

Li, J., Liu, J., Yuan, R., & Shadiev, R. (2022). The Influence of Socially Shared Regulation on Computational Thinking Performance in Cooperative Learning. *Educational Technology & Society*, *25*, 48–60. https://www.jstor.org/stable/48647029

Lobczowski, N. G. (2020). Bridging gaps and moving forward: Building a new model for socioemotional formation and regulation. *Educational Psychologist*, *55*, 53-68. https://doi.org/10.1080/00461520.2019.1670064

Lobczowski, N. G. (2022). Capturing the Formation and Regulation of Emotions in Collaborative Learning: The FRECL Coding Procedure. *Frontiers in Psychology*, *13*, https://doi.org/10.3389/fpsyg.2022.846811

Lobczowski, N. G., Allen, E. M., Firetto, C. M., Greene, J. A., & Murphy, P. K (2020). An exploration of social regulation of learning during scientific argumentation discourse. *Contemporary Educational Psychology, 63*, 101925. https://doi.org/10.1016/j.cedpsych.2020.101925

Lobczowski, N. G., Lyons, K., Greene, J. A., & McLaughlin, J. E. (2021a). Socially shared metacognition in a project-based learning environment: A comparative case study. *Learning, Culture and Social Interaction*, *30*, 100543. https://doi.org/10.1016/j.lcsi.2021.100543

Lobczowski, N. G., Lyons, K., Greene, J. A., & McLaughlin, J. E. (2021b). Socioemotional

regulation strategies in a project-based learning environment. *Contemporary Educational Psychology*, *65*, 101968. https://doi.org/10.1016/j.cedpsych.2021.101968

Luo, Z., Marnburg, E., Øgaard, T., & Okumus, F. (2021). Exploring antecedents of social loafing in students' group work: A mixed-methods approach. *Journal of Hospitality, Leisure, Sport & Tourism Education*, *28*, 1-11. https://doi.org/10.1016/j.jhlste.2021.100314

Malmberg, J., Haataja, E. & Järvelä, S. (2022). Exploring the connection between task difficulty, task perceptions, physiological arousal and learning outcomes in collaborative learning situations. *Metacognition Learning* 17, 793–811. https://doi.org/10.1007/s11409-022-09320-z

Manlove, S., Lazonder, A. W., & De Jong, T. (2006). Regulative support for collaborative scientific inquiry learning. *Journal of Computer Assisted Learning, 22*, 87–98. https://doi.org/10.1111/j.1365-2729.2006.00162.x

McCrudden, M. T., Marchand, G., & Schutz, P. (2019). Mixed methods in educational psychology inquiry. *Contemporary Educational Psychology*, *57*, 1-8. https://doi.org/10.1016/j.cedpsych.2019.01.008

McGrath, J. E. (1991). Time, interaction, and performance (TIP). *Small Group Research, 22*, 147–174. https://doi.org/10.1177/1046496491222001

McKim, C. A. (2017). The value of mixed methods research: A mixed methods study. *Journal of mixed methods research*, *11*, 202-222. https://doi.org/10.1177/15586898156070

Metallidou, P., & Efklides, A. (2001). The effects of general success-related beliefs and specific metacognitive experiences on causal attributions. In A. Efklides & J. Kuhl (Eds.). *Trends and prospects in motivation research*, (pp. 325-347). Springer, Dordrecht. https://doi.org/10.1007/0-306-47676-2_17

Meyer, D. K., & Turner, J. C. (2002). Discovering emotion in classroom motivation research. *Educational psychologist*, *37*, 107-114. https://doi.org/10.1207/S15326985EP3702_5

Michinov, N., & Michinov, E. (2009). Investigating the relationship between transactive memory and performance in collaborative learning. *Learning and Instruction*, *19*, 43-54. doi: 10.1016/j.learninstruc.2008.01.003.

Miele, D. B., & Scholer, A. A. (2018). The role of metamotivational monitoring in motivation regulation. *Educational Psychologist*, *53*, 1-21. https://doi.org/10.1080/00461520.2017.1371601

Miller, M., & Hadwin, A. (2015). Scripting and awareness tools for regulating collaborative learning: Changing the landscape of support in CSCL. *Computers in Human Behavior*, *52*, 573-588. https://doi.org/10.1016/j.chb.2015.01.050

Moreland, R. L., & Argote, L. (2003). Transactive memory in dynamic organizations. In R. Peterson, & E. Mannix (Eds.), *Understanding the Dynamic Organization* (pp. 135-162). Mahwah, NJ: Erlbaum.

Muir, T. (2019). *The collaborative classroom: Teaching students how to work together now and for the rest of their lives*. Dave Burgess Consulting

Muis, K. R., Chevrier, M., & Singh, C. A. (2018). The role of epistemic emotions in personal epistemology and self-regulated learning. *Educational Psychologist*, *53*, 165-184. https://doi.org/10.1080/00461520.2017.1421465

Muis, K. R., Psaradellis, C., Lajoie, S. P., Di Leo, I., & Chevrier, M. (2015). The role of epistemic emotions in mathematics problem solving. *Contemporary Educational Psychology*, *42*, 172-185. https://doi.org/10.1016/j.cedpsych.2015.06.003

Nolen, S. B., & Ward, C. J. (2008). Sociocultural and situative approaches to studying motivation. In Maehr, M., Karabenick, S., & Urdan, T. (Eds.), *Social psychological*

perspectives (Vol. 15, pp. 425-460). Bingley, U.K.: JAI.

Norman, E., & Furnes, B. (2016). The concept of "metaemotion": What is there to learn From research on metacognition? *Emotion Review*, *8*, 187–193. https://doi.org/10.1177/1754073914552913

Norman, E., Price, M. C., & Duff, S. C. (2010). Fringe consciousness: A useful framework for Clarifying the nature of experience-based feelings. In A. Efklides & P. Misailidi (Eds.), *Trends and Prospects in Metacognition Research* (pp. 63–80). New York, NY: Springer. https://doi.org/10.1007/978-1-4419-6546-2_4

Nurmi, J. E., & Aunola, K. (2005). Task-motivation during the first school years: A person-oriented approach to longitudinal data. *Learning and Instruction*, *15*, 103-122. https://doi.org/10.1016/j.learninstruc.2005.04.009

Nguyen, A., Järvelä, S., Rosé, C., Järvenoja, H., & Malmberg, J. (2023). Examining socially shared regulation and shared physiological arousal events with multimodal learning analytics. *British Journal of Educational Technology*, *54*, 293-312. https://doi.org/10.1111/bjet.13280

Nguyen, A., Järvelä, S., Wang, Y., & Rosé, C. P. (2022). Exploring socially shared regulation with an AI deep learning approach using multimodal data. In *Proceedings of the 16th International Conference of the Learning Sciences-ICLS 2022, pp. 527-534*. International Society of the Learning Sciences. https://repository.isls.org//handle/1/8836

Onwuegbuzie, A. J., & Leech, N. L. (2004). Enhancing the interpretation of "significant" findings: The role of mixed methods research. *The Qualitative Report*, *9*, 770-792.

Panadero, E., & Järvelä, S. (2015). Socially shared regulation of learning: A review. *European Psychologist, 20*, 190-203. DOI:10.1027/1016-9040/a000226

Papadopoulos, P. M., Obwegeser, N., & Weinberger, A. (2021). Concurrent and retrospective metacognitive judgements as feedback in audience response systems: Impact on

performance and self-assessment accuracy. *Computers and Education Open*, *2*, 1-11. https://doi.org/10.1016/j.caeo.2021.100046.

Pekrun, R. (2006). The Control-Value Theory of Achievement Emotions: Assumptions, Corollaries, and Implications for Educational Research and Practice. *Educational Psychology Review, 18*, 315-341. https://doi.org/10.1007/s10648-006-9029-9

Pekrun, R. (2016). *Using Self-Report to Assess Emotions in Education*. In: Zembylas, M., Schutz, P. (Eds) Methodological Advances in Research on Emotion and Education. Springer, Cham. https://doi.org/10.1007/978-3-319-29049-2_4

Pekrun, R. (2019). *Self-appraisals and emotions: A control-value approach*. In T. Dicke, F. Guay, HW Marsh, RG Craven, & DM McInerney (Eds). Self – a multidisciplinary concept.

Pekrun, R., Goetz, T., Frenzel, A. C., Barchfeld, P., & Perry, R. P. (2011). Measuring emotions in students' learning and performance: The Achievement Emotions Questionnaire (AEQ). *Contemporary Educational Psychology*, *36*, 36-48. https://doi.org/10.1016/j.cedpsych.2010.10.002

Pekrun, R., Goetz, T., Titz, W., & Perry, R. P. (2002). Positive emotions in education. In E. Frydenberg (Ed.), *Beyond coping: Meeting goals, visions, and challenges* (pp. 149–173). Konstanz: Bibliothek der Universität Konstanz. urn:nbn:de:bsz:352-139080

Pekrun, R., Hall, N. C., Goetz, T., & Perry, R. P. (2014). Boredom and academic achievement: Testing a model of reciprocal causation. *Journal of Educational Psychology, 106*, 696-710. https://doi.org/10.1037/a0036006

Pekrun, R., Lichtenfeld, S., Killi, U., & Reiss, K. (2007). Achievement Emotions Questionnaire-elementary school users' manual. Munich, Germany: University of Munich.

Pekrun, R., & Meier, E. (2011). Epistemic emotion scales (EES). *Unpublished manuscript.*

Department of Psychology, University of Munich. Munich, Germany.

Pekrun, R., & Stephens, E. J. (2012). Academic emotions. In K. Harris, S. Graham, T. Urdan, S. Graham, J. Royer, & M. Zeidner (Eds.), *Individual differences and cultural and contextual factors. APA educational psychology handbook* (Vol. 2, pp. 3-31). Washington, DC: American. https://doi.org/10.1037/13274-001

Pekrun, R., Vogl, E., Muis, K. R., & Sinatra, G. M. (2016). Measuring emotions during epistemic activities: the epistemically-related emotion scales. *Cognition and Emotion*, 1-9. https://doi.org/10.1080/02699931.2016.1204989

Perry, R. P., Hladkyj, S., Pekrun, R. H., & Pelletier, S. T. (2001). Academic control and action control in the achievement of college students: A longitudinal field study. *Journal of Educational Psychology*, *93*, 776-789. https://doi.org/10.1037/0022-0663.93.4.776

Poon, C. L., Tan, S., Cheah, H. M., Lim, P. Y., & Ng, H. L. (2015). Student and teacher responses to collaborative problem solving and learning through digital networks in Singapore. In *Assessment and teaching of 21st century skills* (pp. 199-212). Springer, Dordrecht. https://doi.org/10.1007/978-94-017-9395-7_9

Praharaj, S., Scheffel, M., Specht, M., & Drachsler, H. (2023). Measuring collaboration quality through audio data and learning analytics. In V. Kovanovic, R. Azevedo, D. Gibson & D. Ifenthaler (Eds.*). Unobtrusive Observations of Learning in Digital Environments.* Springer. doi.org/10.1007/978-3-031-30992-2_2

Reiter-Palmon, R., Sinha, T., Gevers, J., Odobez, J. M., & Volpe, G. (2017). Theories and models of teams and groups. *Small Group Research*, *48*, 544-567. https://doi.org/10.1177/1046496417722841

Rogat, T. K., & Adams-Wiggins, K. R. (2014). Other-regulation in collaborative groups:

Implications for regulation quality. *Instructional Science*, *42*, 879-904. https://doi.org/10.1007/s11251-014-9322-9

Rogat, T. K., & Linnenbrink-Garcia, L. (2011). Socially shared regulation in collaborative groups: An analysis of the interplay between quality of social regulation and group processes. Cognition and Instruction, 29(4), 375–415. doi:10.1080/07370008.2011.607930.

Ross, J. A. (1995). Strategies for enhancing teachers' beliefs in their effectiveness: Research on a school improvement hypothesis. *Teachers College Record*, *97*, 227-251. https://doi.org/10.1177/016146819509700205

Ross, J. A., Cousins, J. B., & Gadalla, T. (1996). Within-teacher predictors of teacher efficacy. *Teaching and teacher education*, *12*, 385-400. https://doi.org/10.1016/0742-051X(95)00046-M

Rubin, K. H., Bukowski, W. M., & Parker, J. G. (2006). Peer inter- actions, relationships, and groups. In N. Eisenberg, W. Damon, & R. M. Lerner (Eds.), *Handbook of Child Psychology: Social, Emotional, and Personality Development* (pp. 571–645). Wiley.

Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist*, *55*, 68. https://doi.org/10.1037/0003-066X.55.1.68

Saab, N., van Joolingen, W., & van Hout-Wolters, B. (2012). Support of the collaborative inquiry learning process: Influence of support on task and team regulation. *Metacognition and learning*, *7*, 7-23. https://doi.org/10.1007/s11409-011-9068-6

Saeki, E., & Quirk, M. (2015). Getting students engaged might not be enough: The importance of psychological needs satisfaction on social-emotional and behavioral

functioning among early adolescents. *Social Psychology of Education, 18*, 355–371. https://doi.org/10.1007/s11218-014-9283-5

Scardmalia, M., & Bereiter, C. (2002). Knowledge building. *Encyclopedia of Education*, 1370-1373.

Schnaubert, L., Krukowski, S., & Bodemer, D. (2021). Assumptions and confidence of others: The impact of socio-cognitive information on metacognitive self-regulation. *Metacognition and Learning, 16*, 855–887. https://doi.org/10.1007/s11409-021- 092695

Schukajlow, S. (2015). Effects of enjoyment and boredom on students' interest in mathematics and vice versa. In *Proceedings of the 39th Psychology of Mathematics Education conference* (Vol. 4, pp. 137-144).

Schukajlow, S., & Rakoczy, K. (2016). The power of emotions: Can enjoyment and boredom explain the impact of individual preconditions and teaching methods on interest and performance in mathematics?. *Learning and Instruction*, *44*, 117-127. https://doi.org/10.1016/j.learninstruc.2016.05.001

Schukajlow, S., Rakoczy, K. & Pekrun, R (2023). Emotions and motivation in mathematics education: Where we are today and where we need to go. *ZDM Mathematics Education, 55*, 249–267. https://doi.org/10.1007/s11858-022-01463-2

Slavin, R. E. (1996). Research on Cooperative Learning and Achievement: What We Know, What We Need to Know. *Contemporary Educational Psychology, 21*, 43-69. https://doi.org/10.1006/ceps.1996.0004

Singh, C. A., & Muis, K. R. (2021). The role of social emotions and co-regulation of learning during complex math problem solving. In *Trends and Prospects in Metacognition Research across the Life Span* (pp. 103-133). Springer, Cham. https://doi.org/10.1007/978-3-030-51673-4_6

Sobocinski, M., Malmberg, J. & Järvelä, S. (2022) Exploring Adaptation in Socially-Shared Regulation of Learning Using Video and Heart Rate Data. *Tech Know Learn, 27*, 385–404. https://doi.org/10.1007/s10758-021-09526-1

Swing, S. R., & Peterson, P. L. (1982). The relationship of student ability and small-group interaction to student achievement. *American Educational Research Journal*, *19*, 259-274. https://doi.org/10.3102/00028312019002259

Tangney, J. P. E., & Fischer, K. W. (1995). Self-conscious emotions: The psychology of shame, guilt, embarrassment, and pride. In *The idea for this volume grew out of 2 pivotal conferences. The 1st conference, on emotion and cognition in development, was held in Winter Park, CO, Sum 1985. The 2nd conference, on shame and other self-conscious emotions, was held in Asilomar, CA, Dec 1988.*. Guilford Press.

Tapola, A., Veermans, M., & Niemivirta, M. (2013). Predictors and outcomes of situational interest during a science learning task. *Instructional Science*, *41*, 1047-1064. https://doi.org/10.1007/s11251-013-9273-6

Theobald, E. J., Eddy, S. L., Grunspan, D. Z., Wiggins, B. L., & Crowe, A. J. (2017). Student perception of group dynamics predicts individual performance: Comfort and equity matter. *PloS one*, *12*. https://doi.org/10.1371/journal.pone.0181336

Thomas, D. R. (2006). A general inductive approach for analyzing qualitative evaluation data. *American journal of evaluation*, *27*, 237-246. https://doi.org/10.1177/1098214005283748

Tindale, R. S., & Kameda, T. (2000). Social sharedness as a unifying theme for information processing in groups. *Group Processes and Intergroup Relations*, *3*, 123-140. https://doi.org/10.1177/1368430200003002002

Tornare, E., Czajkowski, N. O., & Pons, F. (2015). Children's emotions in math problem solving situations: Contributions of self-concept, metacognitive experiences, and

performance. *Learning and Instruction*, *39*, 88-96. https://doi.org/10.1016/j.learninstruc.2015.05.011

Tracy, J. L., & Robins, R. W. (2007). The psychological structure of pride: a tale of two facets. *Journal of personality and social psychology*, *92*, 506-525. DOI:10.1037/0022-3514.92.3.506

Tuckman, B. W., & Jensen, M. A. C. (1977). Stages of small-group development revisited. *Group & organization studies*, *2*, 419-427. https://doi.org/10.1177/105960117700200404

Turner, J. C., & Nolen, S. B. (2015). Introduction: The relevance of the situative perspective in educational psychology. *Educational Psychologist*, *50*, 167-172. https://doi.org/10.1080/00461520.2015.1075404

Vauras, M., Iiskala, T., Kajamies, A., Kinnunen, R., & Lehtinen, E. (2003). Shared-regulation and motivation of collaborating peers: A case analysis. *Psychologia*, *46*, 19-37. https://doi.org/10.2117/psysoc.2003.19

Vlachopoulos, S. P., & Michailidou, S. (2006). Development and initial validation of a measure of autonomy, competence, and relatedness in exercise: The Basic Psychological Needs in Exercise Scale. *Measurement in physical education and exercise science*, *10*, 179-201. https://doi.org/10.1207/s15327841mpee1003_4

Vogel-Walcutt, J. J., Fiorella, L., Carper, T., & Schatz, S. (2012). The definition, assessment, and mitigation of state boredom within educational settings: a comprehensive review. *Educational Psychology Review, 24*, 89-111. https://doi.org/10.1007/s10648-011-9182-7

Volet, S. (2001). Understanding learning and motivation in context: A multi-dimensional and multi-level cognitive-situative perspective. In S. Volet & S. Järvelä (Eds.), *Advances in learning and instruction series. Motivation in learning contexts: Theoretical advances*

and methodological implications, (pp. 57-82). Elmsford, NY, US: Pergamon Press.

Volet, S. E., & Järvelä, S. E. (2001). *Motivation in learning contexts: Theoretical advances and methodological implications*. Pergamon Press.

Volet, S., Summers, M., & Thurman, J. (2009a). High-level co-regulation in collaborative learning: How does it emerge and how is it sustained? *Learning and Instruction*, *19*, 128-143. https://doi.org/10.1016/j.learninstruc.2008.03.001

Volet, S., & Vauras, M. (Eds.). (2013). *Interpersonal regulation of learning and motivation: Methodological advances*. Routledge.

Volet, S., Vauras, M., & Salonen, P. (2009b). Self- and social regulation in learning contexts: An integrative perspective. *Educational Psychologist*, *44*, 215–226. https://doi.org/10.1080/00461520903213584

Vosniadou, S. (2007). The cognitive-situative divide and the problem of conceptual change. *Educational Psychologist, 42,* 55-66. https://doi.org/10.1080/00461520709336918

Walker, R. A. (2010). Sociocultural issues in motivation. In S. Järvelä (Ed.) *Social and emotional aspects of learning,* (Vol. 6, pp. 712-717). Amsterdam: Elsevier.

Webb, N. M. (1984). Sex Differences in Interaction and Achievement in Cooperative Small Groups. *Journal of educational psychology*, *76*, 33. https://doi.org/10.1037/0022-0663.76.1.33

Webb, N. M., & Farivar, S. (1994). Promoting helping behaviour in cooperative small groups in middle school mathematics. *American Educational Research Journal*, *31*, 369-395. https://doi.org/10.2307/1163314

Webb, M., Tracey, M., Harwin, W., Tokatli, O., Hwang, F., Johnson, R., ... & Jones, C. (2022). Haptic-enabled collaborative learning in virtual reality for schools. *Education and Information Technologies*, *27*, 937-960. https://doi.org/10.1007/s10639-021-10639-4

Webster, E. A., & Hadwin, A. F. (2015). Emotions and emotion regulation in undergraduate studying: Examining students' reports from a self-regulated learning perspective. *Educational Psychology*, *35*, 794-818. https://doi.org/10.1080/01443410.2014.895292

Wegner, D. M. (1978). Transactive memory: A contemporary analysis of the group mind. In s-Verlag. https://doi.org/10.1007/978-1-4612-4634-3_9

Wegner, D.M. (1987). Transactive memory: A contemporary analysis of the group mind. In B. Mullen, B., G. R. Goethals (Eds.), *Theories of Group Behavior*. Springer, New York, NY. https://doi.org/10.1007/978-1-4612-4634-3_9

Wigfield, A. (1994). Expectancy-value theory of achievement motivation: A developmental perspective. *Educational Psychology Review*, *6*, 49-78. https://doi.org/10.1007/BF02209024

Wigfield, A., & Eccles, J. S. (2000). Expectancy–value theory of achievement motivation. *Contemporary Educational Psychology*, *25*, 68-81. https://doi.org/10.1006/ceps.1999.1015

Wilson, J. M., Straus, S. G., & McEvily, B. (2006). All in due time: the development of trust in computer-mediated and face-to-face teams. *Organizational Behavior and Human Decision Processes, 99*, 16–33. https://doi.org/10.1016/j.obhdp.2005.08.001

Winne, P. H. (2018). Cognition and metacognition within self-regulated learning. In D. H. Schunk & J. A. Greene (Eds.), *Self-regulated learning and performance,* (pp. 52 – 64). NY: Routledge. https://doi.org/10.4324/9781315697048-3

Winne, P. H., & Hadwin, A. F. (2008). The weave of motivation and self-regulated learning. In D. Schunk & B. Zimmerman (Eds.), *Motivation and self-regulated learning: Theory, research, and applications Vol. 2,* (pp. 297-314). NY: Erlbaum.

Winne, P. H., Jamieson-Noel, D., & Muis, K. (2002). Methodological issues and advances in researching tactics, strategies, and self-regulated learning. *Advances in motivation and achievement: New directions in measures and methods*, *12*, 121-155.

Wolcott, M. D., & Lobczowski, N. G. (2021). Using cognitive interviews and think-aloud protocols to understand thought processes. *Currents in Pharmacy Teaching and Learning*, *13*, 181-188. https://doi.org/10.1016/j.cptl.2020.09.005

Wolters, C. A. (2003). Regulation of motivation: Evaluating an underemphasized aspect of self-regulated learning. *Educational Psychologist*, *38*, 189-205. https://doi.org/10.1207/S15326985EP3804_1

Yager, S., Johnson, D. W., & Johnson, R. T. (1985). Oral discussion, group-to-individual transfer, and achievement in cooperative learning groups. *Journal of educational Psychology*, *77*, 60-66. DOI:10.1037/0022-0663.77.1.60

Zheng, J., Lajoie, S. P., Li, S., & Wu, H. (2022). Temporal change of emotions: Identifying academic emotion trajectories and profiles in problem-solving. *Metacognition and Learning*, 1-31. https://doi.org/10.1007/s11409-022-09330-x

Zheng, J., Li, S., & Lajoie, S. P. (2023). A review of measurements and techniques to study emotion dynamics in learning learning. In V. Kovanovic, R. Azevedo, D. Gibson & D. Ifenthaler (Eds*.). Unobtrusive Observations of Learning in Digital Environments.* Springer. doi.org/10.1007/978-3-031-30992-2_2

Zhou, X., & Tsai, C. W. (2022). The Effects of Socially Shared Regulation of Learning on the Computational Thinking, Motivation, and Engagement in Collaborative Learning by Teaching. *Education and Information Technologies*, 1-18. https://doi.org/10.1007/s10639-022-11527-1

Zuckerman, M., Kernis, M. H., Guarnera, S. M., Murphy, J. F., & Rappoport, L. (1983). The ego-centric bias: Seeing oneself as cause and target of others' behaviour. *Journal of Personality, 51*, 621–630. https://doi.org/10.1111/j.1467-6494.1983.tb00869.x

Appendices

Appendix A: Complex problem

Hi, Grade Five!

You're working a shift at St. George's very popular ice cream shop, *The Dragon's Desserts*. Your job is to find the total of each family's bill **and** calculate the tax on the total bill amount (tax rate is 15%). You'll find the orders of four families on page 3.

At the end of your shift, in order to cash-out, you'll have to calculate the total amount that you sold during your shift (taxes included).

Use the price list to help you…

- calculate the amount for each item
- total for each bill

Use the **Cash Out** sheet provided to record your answers for…

- bill totals (subtotals)
- bill totals including taxes
- final cash out

Happy scooping!

The Dragon's Desserts Menu

Regular ice cream	**Cost** (without tax)
Kiddy scoop	$1.25
Regular scoop	$2.15
Soft ice cream	
Small	$1.15
Medium	$1.65
Large	$2.25
Formats	
Cup	$0.35
Regular cone	$0.45
Waffle cone	$1.10
Milkshakes	$3.75
Extras	
Sprinkles	$0.35
Chocolate dipped	$0.75
Whipped cream	$0.85
Doggy ice cream	$2.05

The Orders

The Branston Family 	- 1 kiddy scoop in a cup, with sprinkles - 1 kiddy scoop in a regular cone - 1 regular scoop in a waffle cone - 2 regular scoops in a cup, with sprinkles
The Senecal Family 	- 1 chocolate milkshake, with whipped cream - 1 kiddy scoop in a waffle cone - 1 regular scoop in a cup, with sprinkles
The Coles Family 	- 1 kiddy scoop in a regular cone, with sprinkles - 1 medium soft ice cream in a regular cone - 1 medium soft ice cream in a regular cone, chocolate dipped
The Clarke Family 	- 1 scoop of doggy ice cream - 2 regular scoops in a waffle cone, with sprinkles - 1 regular scoop in a regular cone

Cash out

Families	Items	Cost	Subtotal	Total (tax incl.)
The Branston Family 				
The Senecal Family 				
The Coles Family 				
The Clarke Family 				
	Cash out total:			

A worksheet to help you…

The Branston Family 		
The Senecal Family 		
The Coles Family 		
The Clarke Family 		

Appendix B: Scoring rubric

Dragon's Desserts Rubric

iPad Number: _____ Student IDs: _____

Category	1	2	3	4
Mathematical Concepts	Mathematical explanation shows very limited understanding of the underlying concepts needed to solve the problem(s) OR is not written.	Mathematical explanation shows some understanding of the mathematical concepts needed to solve the problem(s).	Mathematical explanation shows substantial understanding of the mathematical concepts used to solve the problem(s).	Mathematical explanation shows complete understanding of the mathematical concepts used to solve the problem(s).
Mathematical Reasoning	Little evidence of mathematical reasoning.	Some evidence of mathematical reasoning.	Uses effective mathematical reasoning.	Uses complex and refined mathematical reasoning.
Strategy/Procedures	Rarely uses an effective strategy to solve problems.	Sometimes uses an effective strategy to solve problems, but does not do it consistently.	Typically uses and effective strategy to solve the problem(s).	Typically uses an efficient and effective strategy to solve the problem(s).
Mathematical Errors	60% or less error-free solutions.	61%-75% error-free solutions.	76%-84% error-free solutions.	85%-100% error-free solutions.
Completion	25% of the problems are completed.	50% of the problems are completed.	75% of the problems are completed.	All of the problems are completed.

Appendix C: Achievement Emotions Questionnaire (AEQ)

Math-Class

Please color in the circle
that best fits your answer.

	1	2	3	4	5
1 I enjoy math class.	not at all	a little	somewhat	a lot	very much
2 Math class bores me.	not at all	a little	somewhat	a lot	very much
3 Math scares me.	not at all	a little	somewhat	a lot	very much

Math Class

Please color in the circle
that best fits your answer.

4	I look forward to math class.				
				
1 not at all	2 a little	3 somewhat	4 a lot	5 very much

5	When I think about math class, I get nervous.				
				
1 not at all	2 a little	3 somewhat	4 a lot	5 very much

6	Math bores me.				
				
1 not at all	2 a little	3 somewhat	4 a lot	5 very much

Math Class

Please color in the circle
that best fits your answer.

7	When I think about math class, my stomach feels upset.				
				
1 not at all	2 a little	3 somewhat	4 a lot	5 very much

8	Math is fun for me.				
				
1 not at all	2 a little	3 somewhat	4 a lot	5 very much

9	I find doing math boring.				
				
1 not at all	2 a little	3 somewhat	4 a lot	5 very much

Math Class

Please color in the circle
that best fits your answer.

10	During math class, I worry that everything is too difficult for me.				
					
1 not at all	2 a little	3 somewhat	4 a lot	5 very much	

11	I find Math class so boring that I would rather do something else.				
					
1 not at all	2 a little	3 somewhat	4 a lot	5 very much	

12	I enjoy doing math.				
					
1 not at all	2 a little	3 somewhat	4 a lot	5 very much	

Math Homework

Please color in the circle
that best fits your answer.

1 When I do math homework, I am in a good mood.

1	2	3	4	5
not at all	a little	somewhat	a lot	very much

2 Math homework bores me to death.

1	2	3	4	5
not at all	a little	somewhat	a lot	very much

3 I worry so much about not finishing my math homework that I start sweating.

1	2	3	4	5
not at all	a little	somewhat	a lot	very much

Math Homework

Please color in the circle
that best fits your answer.

4	**Math homework bores me so much that I don't want to keep doing it.**				
					
1 not at all	2 a little	3 somewhat	4 a lot	5 very much	

5	**When I do math homework, I worry if I will ever understand it.**				
					
1 not at all	2 a little	3 somewhat	4 a lot	5 very much	

6	**I enjoy math homework so much that I don't want to stop.**				
					
1 not at all	2 a little	3 somewhat	4 a lot	5 very much	

Math Homework

Please color in the circle
that best fits your answer.

7	Math homework scares me so much that I don't want to start doing it.				
					
1 not at all	2 a little	3 somewhat	4 a lot	5 very much	

8	When I do math homework, I get tired quickly because I am bored.				
					
1 not at all	2 a little	3 somewhat	4 a lot	5 very much	

Math Tests

Please color in the circle
that best fits your answer.

1	**I enjoy math tests.**			
1 not at all	2 a little	3 somewhat	4 a lot	5 very much
2	**When I take a math test, I am afraid of getting a bad grade.**			
1 not at all	2 a little	3 somewhat	4 a lot	5 very much
3	**I am so nervous during a math test that I cannot remember properly what I have learned.**			
1 not at all	2 a little	3 somewhat	4 a lot	5 very much

Math Tests

Please color in the circle
that best fits your answer.

4	I look forward to math tests.				
					
1 not at all	2 a little	3 somewhat	4 a lot	5 very much	

5	Math tests scare me so much that I would rather not take them.				
					
1 not at all	2 a little	3 somewhat	4 a lot	5 very much	

6	I am so nervous during a math test that I cannot concentrate properly.				
					
1 not at all	2 a little	3 somewhat	4 a lot	5 very much	

Math Tests

Please color in the circle
that best fits your answer.

7	I get very nervous during math tests.				
					
1 not at all	2 a little	3 somewhat	4 a lot	5 very much	

8	During a math test, I think, "This is going great!"				
					
1 not at all	2 a little	3 somewhat	4 a lot	5 very much	

Appendix D: Academic control questionnaire

Academic Control Scale

The following statements are focused on your beliefs about math. There are no right or wrong answers. Please carefully read each statement and answer it based on your personal experience.

1	2	3	4	5
Strongly Disagree				**Strongly Agree**

1. I have a lot of control over my grades in math.

2. The more effort I put into learning math, the better I do.

3. No matter what I do, I can't seem to do well in math.

4. I am responsible for how well I do in math.

5. How well I do in math is often the "luck of the draw."

6. There is little I can do about my math grade.

7. When I do poorly in math, it's usually because I haven't given it my best effort.

8. My grades are decided by things out of my control, and there is little I can do to change that.

Appendix E: Academic task value questionnaire

Task Value Measure

The following statements are focused on your beliefs about math. There are no right or wrong answers. Please carefully read each statement and answer it based on your personal experience.

1	2	3	4	5
Not at all true of me				**Very true of me**

(a) _____ In general, I find learning about math very interesting.

(b) _____ The amount of effort it takes to understand math is worthwhile to me.

(c) _____ In general, learning about math is useful.

(d) _____ I like reading texts about math.

(e) _____ Compared to my other activities, learning about math is very useful for me.

(f) _____ I feel that, to me, learning more about math is very important.

(g) _____ Learning more about math is useful for my life.

Appendix F: Academic Emotions Scale

Activity Emotions Scale

We are interested in how you feel when working on the math problem. For each emotion, please indicate how strongly you felt that emotion by circling the number that best describes the level of the feeling you experienced when working on the math problem. Also indicate by checkmark whether that emotion was directed at yourself, your group or both

	Not at all	Very little	Moderate	Strong	Very strong	Myself	Group
Curious	1	2	3	4	5	☐	☐
Shame	1	2	3	4	5	☐	☐
Empathy	1	2	3	4	5	☐	☐
Confused	1	2	3	4	5	☐	☐
Hopeless	1	2	3	4	5	☐	☐
Surprised	1	2	3	4	5	☐	☐
Enjoyment	1	2	3	4	5	☐	☐
Anxious	1	2	3	4	5	☐	☐
Frustrated	1	2	3	4	5	☐	☐
Jealousy	1	2	3	4	5	☐	☐
Fearful	1	2	3	4	5	☐	☐
Worried	1	2	3	4	5	☐	☐
Happy	1	2	3	4	5	☐	☐
Embarrassment	1	2	3	4	5	☐	☐
Guilt	1	2	3	4	5	☐	☐
Interested	1	2	3	4	5	☐	☐
Angry	1	2	3	4	5	☐	☐
Envy	1	2	3	4	5	☐	☐
Bored	1	2	3	4	5	☐	☐
Pride	1	2	3	4	5	☐	☐

Appendix G: Basic Psychological Needs Scale (in Relationships)

Basic Need Satisfaction in Relationship Scale

Please answer each statement by indicating how true it is for you. There are no right or wrong answers.

Use the following scale:

1	2	3	4	5	6	7
Not at all true			**Somewhat true**			**Very true**

1. When I was solving the math problems with my group, I felt like I could be myself.
2. When I was solving the math problems with my group, I felt like I can do this problem.
3. When I was solving the math problems with my group, I felt they cared about me.
4. When I was solving the math problems with my group, I often felt like I didn't know how to do the work or can't do the work.
5. When I was solving the math problems with my group, I had a say in what happens, and I could voice my opinion.
6. When I was solving the math problems with my group, I often felt disconnected from the members of the group.
7. When I was solving the math problems with my group, I felt very capable and successful.
8. When I was solving the math problems with my group, I felt a lot of closeness and kindness.
9. When I was solving the math problems with my group, I felt controlled and pressured to do the problems in certain ways.

Appendix H: Retrospective Interview Questions

1. What kinds of feelings did you experience when you were solving the problem together as a group?

2. Did you have any feelings towards someone else in the group or the group as a whole? Can you give examples?

3. While you were solving the math problem as a group, can you give examples of when you felt…
    a. Happy?
    b. Curious?
    c. Bored?
    d. Proud?
    e. Confused?

Appendix I: Descriptive statistics and zero order correlations

	M	*SD*	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17.00	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
Control	4.18	0.51		.42*	0.09	0.32	-0.33	0.20	0.11	0.36	0.24	0.09	0.05	0.17	-0.18	-0.08	-0.15	0.02	-0.11	0.09	0.04	-0.01	0.01	0.14	-.39*	0.00	-0.07	-0.05	-0.14	-0.02	0.04	0.22	-0.24	-0.02	-0.27	-0.14	0.20	0.27
Value	3.42	0.8			0.18	.78**	-.57**	0.00	0.13	0.08	-0.27	0.14	-0.06	-0.02	-0.15	0.09	-0.15	0.03	-0.02	0.09	0.26	0.08	0.26	0.20	0.05	0.11	-0.03	0.07	0.04	-0.02	0.28	0.12	0.18	0.10	-0.34	-0.01	0.18	-0.04
Global Anxiety - Class	1.64	0.61				-0.16	0.15	-0.29	-0.32	-0.17	-0.04	-0.26	-0.13	-0.07	0.28	-0.04	0.14	0.05	0.25	-0.11	-0.06	-0.31	0.19	-0.12	.48**	0.06	-0.02	-.40*	0.12	0.08	-0.02	-0.11	0.21	0.11	0.12	0.12	-0.03	0.02
Global Enjoyment - Class	2.72	1.18					-.84**	0.05	0.05	0.06	-0.36	0.30	-0.03	0.07	-0.11	0.05	-0.25	0.00	-0.04	0.15	0.24	0.19	0.23	0.10	-0.04	0.08	-0.05	0.28	0.02	0.02	0.17	0.17	0.06	0.04	-0.36	0.01	0.06	-0.15
Global Boredom - Class	2.53	1.1						0.08	0.16	0.03	0.28	-0.30	-0.08	-0.06	0.04	-0.04	0.14	-0.18	0.12	0.07	0.07	-0.08	-0.07	-0.05	0.03	0.04	0.23	-0.08	-0.21	-0.13	0.06	-0.01	-0.19	-0.09	0.18	0.06	0.15	0.17
Autonomy	5.46	1.3							.50**	.51**	0.08	.40*	0.20	-0.12	-0.14	-.43*	-0.27	-.38*	0.06	-0.02	0.18	0.24	0.07	-0.27	-.47*	-0.26	0.31	0.15	-0.29	0.00	0.34	-0.18	-.51**	-.46*	-0.07	-0.09	.40*	0.09
Competence	5.83	1								.42*	0.08	0.11	0.13	-0.15	-0.26	-0.28	-0.17	-0.29	-0.15	0.20	0.28	0.21	0.05	-0.22	-0.27	0.01	0.35	0.14	-0.24	-0.16	.39*	-0.03	-0.03	0.04	0.07	-0.28	.48**	-0.14
Relatedness	5.52	1.18									0.10	0.36	-0.12	0.08	0.02	-0.11	-0.11	-0.13	-0.32	-0.09	-0.06	.53**	-0.06	-0.27	-.39*	-0.16	0.01	.46*	-.41*	-0.17	0.23	0.33	-0.30	-0.14	-.39*	-0.35	0.23	.53**
Curious (self)	1,57	0.84										-.43*	-0.14	-0.19	-0.07	-0.20	-0.07	-0.13	-0.03	-0.26	0.12	-0.36	0.11	0.14	-0.11	0.00	0.35	-.47*	-0.18	-0.23	0.06	-0.13	-0.19	-0.13	0.11	0.03	0.01	0.08
Curious (group)	2.04	1.4											0.36	0.36	-0.04	-0.13	-0.05	0.26	-0.19	0.19	-0.32	.64**	-0.20	-0.22	-0.31	0.07	-0.30	.56**	0.06	0.33	-0.05	0.12	-0.21	-0.14	-0.22	-0.05	0.09	0.19
Empathy (self)	1.31	0.71												-0.13	-0.21	-0.30	-0.17	0.04	0.06	-0.28	0.04	-0.05	-0.10	-0.17	-0.26	-0.13	-0.02	0.03	-0.11	0.23	0.08	-0.23	-0.12	-0.08	0.21	-0.19	0.17	-0.11
Empathy (group)	1.83	1.31													0.05	0.28	0.09	0.28	-0.12	.45*	-0.17	0.36	0.10	0.35	-0.20	0.26	-0.19	0.29	0.10	-0.01	-0.13	0.34	-0.17	-0.12	-0.11	-0.11	0.08	.403*
Confused (self)	2.03	1.27														0.33	.57**	0.28	0.32	-0.3	-0.13	0.03	-0.01	-0.14	.59**	-0.11	0.04	-0.16	-0.14	-0.06	0.10	-0.28	0.36	.45*	-0.21	-0.06	0.03	0.02
Confused (group)	2.07	1.28															.37*	.51**	-0.09	0.0	0.06	0.16	-0.16	0.46*	0.17	0.35	0.03	0.12	0.05	0.03	0.01	0.07	0.26	.44*	-.38*	0.28	0.02	0.20
Hopeless (self)	1.24	0.64																.39*	-0.10	0.0	-0.31	-0.03	-0.20	-0.15	.40*	-0.09	-0.33	-0.18	-0.10	-0.13	-0.15	-0.29	.39*	.53**	0.13	-0.17	-0.21	0.03
Hopeless (group)	1.38	0.78																	0.06	-0.1	-.45*	0.20	-0.09	0.24	0.07	0.41*	-0.13	-0.16	0.32	.52**	-0.21	-0.07	0.27	.40*	-0.25	0.21	-0.12	0.08
Surprise (self)	1.46	0.74																		0.0	0.23	-0.19	0.20	0.21	0.25	0.08	.56**	-.44*	-0.17	0.24	.43*	-0.23	-0.17	-0.12	-0.15	0.32	0.28	-0.26
Surprise (group)	1.79	1.13																			0.11	0.28	-0.09	0.33	-0.27	0.44*	0.02	0.30	0.13	0.06	0.02	.39*	-0.19	-0.14	0.10	0.09	0.07	-0.03
Enjoyment (self)	2.41	1.6																				-0.34	0.33	0.22	0.01	0.16	.61**	-0.03	-0.23	-0.21	.72**	-0.15	-0.24	-0.17	-0.19	0.09	.46*	-0.17
Enjoyment (group)	2.28	1.62																					-0.25	0.07	-0.33	0.26	-0.10	.76**	-0.10	0.15	-0.04	.55**	-0.22	-0.15	-.38*	-0.11	0.11	0.33
Anxious (self)	1.41	0.83																						0.08	0.22	-0.09	0.30	-0.30	-0.03	-0.01	0.15	-0.15	0.00	-0.10	-0.12	-0.22	0.17	-0.27
Anxious (group)	1.24	0.64																							-0.23	0.49**	0.33	-0.08	0.18	0.08	0.14	0.24	-0.10	-0.07	-0.22	0.27	0.06	0.10
Frustrated (self)	1.72	1.25																								-0.070	-0.06	-0.36	0.06	-0.09	-0.12	-0.33	.62**	.50**	0.02	0.10	-0.28	-0.28
Frustrated (group)	1.48	0.87																									0.31	0.06	.46*	.50**	0.16	0.12	-0.15	-0.11	-0.16	.45*	0.16	-0.01
Happy (self)	2.59	1.64																										-0.31	-0.24	0.14	.64**	-0.22	-0.25	-0.18	-0.13	0.31	.49**	-0.18
Happy (group)	2.61	1.69																											-0.15	-0.12	-0.04	.64**	-0.27	-0.19	-0.34	-0.20	0.09	0.30
Embarrassment (self)	1.1	0.41																												.56**	-0.29	-0.19	0.22	-0.05	0.12	0.16	-0.31	-0.24
Embarrassment (group)	1.17	0.54																													-0.07	-0.20	-0.09	-0.06	-0.19	0.27	-0.08	-0.18
Interested (self)	2.72	1.53																														-0.25	-0.31	-0.22	-0.26	-0.03	.68**	-0.10
Interested (group)	2.1	1.5																															-0.20	-0.14	-0.32	-0.03	-0.09	.48**
Angry (self)	1.24	0.91																																.79**	0.21	-0.12	-0.33	-0.27
Angry (group)	1.14	0.74																																	-0.11	-0.08	-0.23	-0.13
Bored (self)	1.72	1.28																																		-0.03	-0.13	-0.27
Bored (group)	1.28	0.65																																			-0.04	0.10
Pride (self)	3.03	1.7																																				-0.18
Pride (group)	2.03	1.5																																				

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

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