Emotion Regulation and Self-Regulated Learning During Mathematics Problem Solving

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Abstract

Emotion regulation (ER) and self-regulated learning (SRL) are crucial to learners' academic achievements. To date, little research has considered the dynamic relations between ER and SRL in elementary-aged children. To address this gap, we examined relations between ER, the four macro phases of SRL (task definition, planning/goal setting, enactment of learning strategies, monitoring/evaluation), and mathematics problem solving achievement in a sample of 134 elementary students from grades 3 through 6. Path analysis revealed that ER positively predicted all four phases of SRL. Task definition predicted enactment and monitoring/evaluation, while planning/goal setting positively predicted monitoring/evaluation. Analysis further revealed that task definition and planning/goal setting mediated relations between ER, enactment of learning strategies, and mathematics achievement, which suggests a sequenced nature to SRL in mathematics problem solving. Finally, enactment predicted mathematics problem solving achievement. These findings have implications for learners' academic outcomes and suggest that researchers and educators must consider how instructional practices facilitate or curtail elementary-aged students' engagement in adaptive and effective forms of ER and SRL. Interventions should be implemented in schools at a global level to help students learn how to regulate their emotions to improve SRL and learning outcomes.

Keywords: emotion regulation, self-regulated learning, mathematics achievement, elementary-aged students

Résumé

La régulation émotionnelle et l'apprentissage autorégulé sont d'une importance primordiale à la réussite scolaire des élèves. À ce jour, peu de recherches ont exploré les relations entre la régulation émotionnelle et l'apprentissage autorégulé chez les enfants d'âge scolaire. Afin de combler cette lacune, nous avons examiné les relations entre la régulation émotionnelle, les quatre grandes phases de l'apprentissage autorégulé (c'est-à-dire la définition de tâches, la planification et l'établissement d'objectifs, l'adoption de stratégies d'apprentissage, le monitoring et l'évaluation) et la résolution de problèmes mathématiques auprès d'un échantillon de 134 élèves de la 3ème à la 6ème année du primaire. Les analyses ont révélé que la régulation émotionnelle prédit les quatre phases de l'apprentissage autorégulé. Plus précisément, la définition de la tâche est un prédicteur la mise en œuvre de stratégies d'apprentissage, le monitoring et l'évaluation, tandis que la planification et l'établissement d'objectifs sont prédicteurs de monitoring et d'évaluation. De plus, les analyses ont révélé que la définition de la tâche, la planification et l'établissement d'objectifs favorisent les relations entre la régulation émotionnelle, la mise en œuvre de stratégies d'apprentissage et la réussite en mathématiques, ce qui suggère que l'apprentissage autorégulé lors de résolution de problèmes mathématiques se déroule de manière séquentielle. Enfin, la mise en œuvre de stratégies d'apprentissage s'est révélée être un prédicteur de la performance des élèves lors de la résolution de problème mathématique. Ces observations ont des implications importantes pour la réussite scolaire des élèves. Notamment, il est suggéré que les chercheurs et les éducateurs devraient porter attention à la manière dont les pratiques pédagogiques encouragent ou découragent les élèves d'âge primaire à adopter des formes adaptatives et efficaces de régulation émotionnelle et d'apprentissage autorégulé. De plus, il est suggéré que des interventions devraient être mises en œuvre afin d'aider les élèves à apprendre à réguler leurs émotions, à améliorer l'apprentissage autorégulé et la réussite scolaire.

Mots-clés: régulation émotionnelle, apprentissage autorégulé, réussite en mathématiques, élèves du primaire

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CHAPTER 1

Introduction

Academic success, lifelong learning, and healthy social and emotional functioning are important educational goals. One factor that predicts these outcomes includes individuals' ability to self-regulate (Blair & Razza, 2007; Diamond, Barnett, Thomas, & Munro, 2007; Whitebread, Bingham, Pasternak, & Sangster, 2007). Self-regulation is defined as individuals who control their thoughts, feelings and actions to achieve goals and respond to environmental stimuli (Zimmerman, 2008). Individuals who are effective at self-regulating are able to do so across a wide range of processes, including cognition, emotion, motivation and behavior (Gross, 1998; Hutchinson, 2013; Zimmerman & Schunk, 2011). As theorists have argued, regardless of what is being targeted during self-regulation (e.g., learning, emotion, motivation), the same basic executive functions like working memory, inhibitory control, and attention focusing, and higher order processes like metacognition, motivation, and strategic action underlie self-regulation (Diamond, 2013; Hutchinson, 2013; Perry, Hutchinson, Yee, & Määttä, 2018; Winne, 2018; Winne & Perry, 2000; Zimmerman & Schunk, 2011). Despite this overlap in basic and higher order functions among the various targets of self-regulation, research that has explored the role that emotion regulation, motivation regulation, or self-regulated learning play in academic achievement rarely take two or more of these targets simultaneously into consideration (cf. Wolters, 1998, 2003).

Additionally, given the complex cognitive and metacognitive processes that self-regulation relies on, researchers in educational psychology have underestimated the abilities of younger children to engage in emotion regulation and self-regulated learning. Rather, researchers have focused their efforts primarily in understanding emotion regulation and self-regulated learning in university students and adults (Perry, 1998; Whitebread, et al., 2007), though this trend is beginning to shift. That is, a growing body of research demonstrates that children can engage in emotion regulation and self-regulated learning, both of which are critical for early academic success (Graziano, Reavis, Keane, & Calkins, 2007; Perry et al., 2018). However, to our knowledge, no research has simultaneously taken into consideration potential relations between emotion regulation and self-regulated learning during complex learning with young children. Our research addresses this gap in the literature.

Why focus on emotion regulation and self-regulated learning? Emotions serve important personal and social functions like facilitating decision making, scripting social behaviors, and providing ongoing feedback about the match between environmental demands and the individual's goals and abilities (Gross, 1998; Gross & Thompson, 2007). As such, it is evident that learners must be able to regulate how they experience and express emotions to pursue their learning goals. Emotion regulation (ER) is defined as a learner's ability to employ adaptive and effective strategies to control emotions and pursue goals (Gross, 1998). To engage in ER, students must employ their metacognition (e.g., identify their emotions), motivation (e.g., to sustain positive emotions/reduce negative emotions), and strategic action (e.g., enact and monitor strategies to address emotional challenges to maintain their learning; Hutchinson, 2013; Perry et al., 2018). Individuals who engage in effective forms of ER experience more positive emotions and achieve better academic outcomes, whereas individuals whose ER is poorly developed experience more negative emotions, demonstrate difficulties with intrapersonal and social functioning, and have poor academic outcomes (Gross & Thompson, 2007; Richards & Gross, 2000; Strain & D'Mello, 2015).

Like ER, self-regulated learning (SRL) is defined as the ability to adaptively and effectively choose from a repertoire of skills to pursue learning goals and meet environmental demands. In other words, students who self-regulate their learning are aware of their learning strengths and weaknesses (metacognitive), are motivated to learn, and effectively employ and monitor strategies to pursue learning goals (Hutchinson, 2013; Muis, 2007; Perry, 2013; Perry et al., 2018; Zimmerman & Schunk, 2011). Effective engagement in SRL is a strong and reliable predictor of academic success across the life span (Blair & Razza, 2007; Diamond et al., 2007; Zimmerman, 2008). Unfortunately, students whose SRL is poorly developed face a host of negative outcomes including engaging in ineffective patterns of cognition and metacognition, and poor academic achievement (Graziano, Reavis, Keane, & Calkins, 2006; Perry, 1998, 2013).

Although some theorists propose that ER and SRL are conceptually distinct processes that are theoretically united through their reliance on metacognition, motivation and strategic action (Hutchinson, 2013; Perry et al., 2018), most of the research that has explored ER or SRL has not taken into consideration how the two may work together to facilitate or constrain learning outcomes. Furthermore, much of the research on young children's ER and SRL has been conducted in labs, often using tasks that do not easily translate to typical classroom activities (c.f., Muis, Psaradellis, Lajoie, Di Leo, & Chevrier, 2015a; Perry, 2013; Rimm-Kaufman & Chiu, 2007; Whitebread et al., 2007). Accordingly, research is needed to explore how ER and SRL dynamically unfold and relate to learning outcomes during classroom-based tasks, particularly during complex tasks like mathematics problem solving.

As previous research has shown, complex mathematics problem solving presents an emotionally laden and strategically challenging learning activity for younger students as they often struggle with it emotionally (Di Leo, Muis, & Singh, 2017) and strategically (Muis et al., 2015a). Indeed, the most frequently experienced emotions that young students express during complex mathematics problem solving are confusion and frustration (Di Leo et al., 2017).

Positive emotions, like curiosity and enjoyment, have been shown to facilitate self-regulatory processes during mathematics problem solving. However, negative emotions, like confusion, frustration, anxiety, and boredom are of particular concern as they have been associated with limited self-regulatory processes during complex mathematics problem solving (Muis et al., 2015a).

What is currently missing in the literature is consideration of whether younger students regulate these emotions during learning, and how ER facilitates or constrains SRL. Additionally, the work that has been conducted in SRL has modeled the various phases of learning as working in parallel, rather than in sequence. That is, research that has explored relations between SRL and learning outcomes has modeled relations using path analysis with the phases of self-regulated learning working simultaneously rather than in serial fashion (Muis et al., 2015) or have predicted learning outcomes using regression analysis (e.g., Greene & Azevedo, 2009; Pintrich & De Groot, 1990). However, it may be the case that younger students approach learning in a more serial fashion given their limited cognitive resources (Zimmerman, 2000) and the emotional and academically challenging nature of complex mathematics problem solving (Di Leo et al., 2017; Muis et al., 2015a). That is, during complex learning, younger students may engage in task understanding and planning and goal setting first prior to enactment of strategies or evaluation of progress and products. Task understanding and planning and goal setting may be better modeled as antecedents to the enactment and evaluation phases of SRL.

As such, the objectives of the current research are to examine the roles and dynamic relationships between ER and SRL during complex mathematics problem solving with a sample of elementary students from grades 3 through 6. We also assessed whether the phases of SRL were better modeled as serial, rather than in parallel, during mathematics problem solving. Prior to describing our research, we delineate relevant theoretical and empirical work from developmental and educational psychology.

CHAPTER 2

Theoretical Frameworks and Review of Literature

Emotion Regulation

As previously noted, emotion regulation (ER) refers to the process wherein individuals influence the emotions they experience, when they experience them, and how they express them (Gross, 1998). ER processes can be automatic or controlled, conscious or unconscious, and can occur prior to an emotion being elicited (called antecedent-focused ER) or after an emotion is elicited (called response-focused ER) (Gross, 1998). Within the ER literature, researchers have focused on the effects of using two of these ER strategies –cognitive reappraisals and expressive suppression – on memory recall, interpersonal interactions, and well-being (Richards & Gross, 2000). Cognitive reappraisal is antecedent focused and involves changing one's appraisals of the environment to alter or reframe the experience and expression of affect to support goal pursuits (Gross, 1998; Gross & Thompson, 2007). Researchers have demonstrated that the use of cognitive reappraisals are an effective form of ER as they are related to the experience and expression of more positive emotions, less negative emotions, and more engagement in learning (Gross & John, 2003; Richards & Gross, 2000; Strain & D'Mello, 2015). Moreover, the use of reappraisals is related to better memory recall on several tasks (e.g. self-reported and objective memory tasks), which supports learning and achievement outcomes (Richards & Gross, 2000; Strain & D'Mello, 2015).

In contrast, emotion suppression is response focused and is defined as an individual's conscious efforts to inhibit behavioral, physical, and experiential response-tendencies elicited by their emotions (Gross, 1998; Gross & Thompson, 2007). Individuals who engage in emotion suppression experience less positive emotions, more negative emotions, and poor executive functioning (Richards & Gross, 2000). Emotion suppression is also related to poor interpersonal functioning and well-being, and poor performance on memory tasks, which may curtail learning and achievement outcomes (Graziano et al., 2006; Gross & Thompson, 2007; Perry 1998, 2013; Richards & Gross, 2000). As such, emotion suppression is considered an ineffective form of ER.

Moreover, researchers have suggested that learners who employ emotion suppression are more cognitively taxed, as the systems required to consciously inhibit their emotional response-tendencies (i.e., inhibitory control) interfere with their ability to engage in the self-regulation processes (i.e., metacognition, motivation, strategic action) necessary to employ effective strategies and pursue learning and achievement goals (Gross & John, 2003; Richards & Gross, 2000; Hutchinson, 2013; Tice, Baumeister & Zhang, 2004). For example, investigations of kindergarten students' ER and their academic success has demonstrated that students who engage in adaptive and effective forms of ER: 1) yield higher teacher ratings of academic success and classroom productivity; 2) have higher quality teacher-student relationships; and, 3) are more successful on standardized mathematics and literacy tests (Blair & Razza, 2007; Graziano et al., 2006). These findings suggest that young students who effectively engage in ER have significant learning and achievement advantages compared to students with poorly developed ER.

Additionally, researchers have demonstrated that during complex mathematics problem solving, students experience a wide range of emotions, including joy, confusion, frustration, and anxiety, and that these emotions predict students' engagement in learning strategies and academic achievement (Muis et al., 2015a; Pekrun & Stephens, 2012). Specifically, researchers have established that, with young students, confusion and frustration are most often experienced during complex mathematics problem solving (Di Leo et al., 2017), both of which negatively predict the use of learning strategies (Muis et al., 2015a). The inverse relationship between negative emotions, like confusion and frustration, and effective learning strategies is likely due to the cognitive resources that ER and SRL share (Hutchinson, 2013; Perry et al., 2017) being consumed by these negative emotions (Pekrun, 2006). As such, effective ER, like cognitive reappraisal, is likely a key antecedent to successful SRL.

However, as Muis and colleagues (2015a) argued, some students may lack the skills needed to regulate their emotions during problem solving, which can negatively impact achievement. That is, it seems logical to assume that individuals who are better at regulating their emotions may also be better able to regulate their learning. To our knowledge, no research has explored the roles of both ER and SRL during complex problem solving in young learners. We describe SRL next.

Self-Regulated Learning

Recall that SRL is defined as an event that unfolds during learning that is goal directed and includes cognitive, metacognitive, motivational, behavioral, and environmental components (Muis, 2007; Hutchinson, 2013; Perry et al., 2017, Zimmerman, 2008). Indeed, most models of SRL propose three or four cyclical phases of learning and include several areas for regulation (Muis & Singh, 2018; Pandero, 2017; Perry et al., 2018; Zimmerman & Labuhn, 2012). For example, Muis (2007; Muis & Singh, 2018) proposed four phases of learning that entail task definition, planning and goal setting, enactment, and evaluation; and five areas for regulation including cognition (e.g., knowledge activation), motivation (e.g., achievement goals, self-efficacy), affect (e.g., achievement emotions), behavior (e.g., time on task, effort expenditure), and context (e.g., resources, instructional cues).

During task definition, learners define the task based on instructional cues, task structure and activation of their prior knowledge and emotions. Learners' definition of that task in turn predicts the types of plans and goals learners set. Enactment occurs when learners begin to carry out a task by employing tactics from their repertoire of learning strategies. In every phase, students may evaluate the successes or failures of their strategies and/or task outcomes. As these evaluations feed into one another, directly or indirectly, feedback becomes accessible to learners who may then adjust their SRL strategies to meet environmental demands and pursue goals (Muis, 2007). Finally, in the last phase, several types of reactions and reflections are conducted to evaluate the successes or failures of each phase or products created for the task, or perceptions about the self or context.

As noted above, numerous theoretical frameworks highlight the cyclical nature of SRL, and suggest that its' employment is not a linear process (Hutchinson, 2013; Muis, 2007; Perry, 1998, Pintrich, 2000, Zimmerman, 2008). In other words, theorists have argued that SRL is weakly sequenced (Winne & Hadwin, 1998) as information procured in one phase can feed into other phases or back into itself. However, it is possible that during learning, there is a sequenced nature to the four phases of SRL, which is reflected in most theoretical models of SRL. For example, to effectively and correctly solve a complex mathematics problem a learner must understand the parameters of the problem (i.e., engage in task definition). Then a learner can set goals – perhaps regarding performance, mastering the problem, or completing their work in an allotted amount of time – and subsequently form plans to pursue these goals. Logically, only then is the learner able to adaptively and effectively choose from their repertoire of skills to enact their plans and goals based on their understanding of the task at hand. Learners become aware of how the enactment of their chosen learning strategies promotes or curtails their pursuits by monitoring and evaluating their understanding of the task, their performance, and the attainability of their goals. Depending on the feedback provided to the learner during this phase, they may cycle back into whichever phase of SRL is most appropriate to strategically adjust their learning (e.g., adjusting their plans or changing their strategy).

Interestingly, most researchers have not statistically modeled SRL as a linear progression during learning. For example, in Muis et al.'s (2015a) research on mathematics problem solving, emotions that students experienced were antecedents to the four phases of SRL, which were modeled as occurring in parallel. We argue that it is plausible that the task definition and planning/goal setting phases occur prior to the enactment and evaluation phases of learning, and should be modeled as such.

In summary, it is clear that younger students are able to regulate their learning (Muis, Ranellucci, Trevors, & Duffy, 2015b; Perry & Vandekamp, 2000). However, given that students also experience a wide range of emotions during learning, and that emotions subsequently predict the kinds of strategies learners use during learning (Muis et al., 2015a; Op't Eynde, De Corte, & Verschaffel, 2007; Pekrun, Goetz, Titz, & Perry, 2002), students must also be able to regulate their emotions to engage in effective SRL (Di Leo et al., 2017). That is, to our knowledge, no research has examined relations between young learners' engagement of ER and SRL processes and academic achievement (Mega, Ronconi & De Beni, 2014). Given the link between the underlying mechanisms (i.e., metacognition, motivation, strategic action; Hutchinson, 2013; Perry et al., 2018), ineffective approaches to ER can exhaust learners' cognitive, behavioral, and motivational resources (Richards & Gross, 2000), which in turn may interfere with learners' abilities to engage in effective forms of self-regulation (Tice et al., 2004). By extension, it is reasonable to assume that SRL processes may mediate relations between ER and achievement. However, research has not yet taken this potential relationship into consideration. Our research addresses this gap in the literature.

The Current Study

To date, much of the research has focused on how ER or SRL processes separately predict achievement outcomes in adults and university students (Whitebread et al., 2007). As such, little is known about relations between ER, SRL, and academic achievement with elementary-aged students. The current study extends previous literature by examining how SRL processes mediate the relationship between elementary-aged students' employment of effective ER strategies and their mathematics achievement. Moreover, we modeled SRL phases as sequential, rather than in parallel, to delineate the natural order within which the phases occur during complex mathematics problem solving (Di Leo et al., 2017). Accordingly, our research questions were as follows: (1) What is the relationship between emotion reappraisal and the four phases of self-regulation (task definition, planning/goal setting, enactment of learning strategies, monitoring/evaluation)? (2) Do the four phases of SRL mediate relations between ER and complex mathematics problem solving achievement? (3) Is there a sequenced nature to the four phases of SRL during mathematics problem solving?

Based on theoretical and empirical work (Di Leo et al., 2017; Gross, 1998; Hutchinson, 2013; Muis, 2007; Muis et al., 2015a; Pekrun & Stephens, 2012; Perry et al., 2018), we hypothesized that emotion reappraisal strategies would positively predict the four phases of SRL: task definition, planning/goal setting, enactment of learning strategies, and monitoring/evaluation; and positively predict mathematics achievement. Moreover, we hypothesized that the four phases of SRL would mediate relations between emotion reappraisal and complex mathematics problem solving achievement. Additionally, task definition and planning and goal setting should mediate relations between emotion reappraisal, enactment, monitoring and evaluation, and achievement, demonstrating a sequenced nature to learners' engagement in SRL during complex mathematics problem solving. Our hypothesized model is presented in Figure 1.

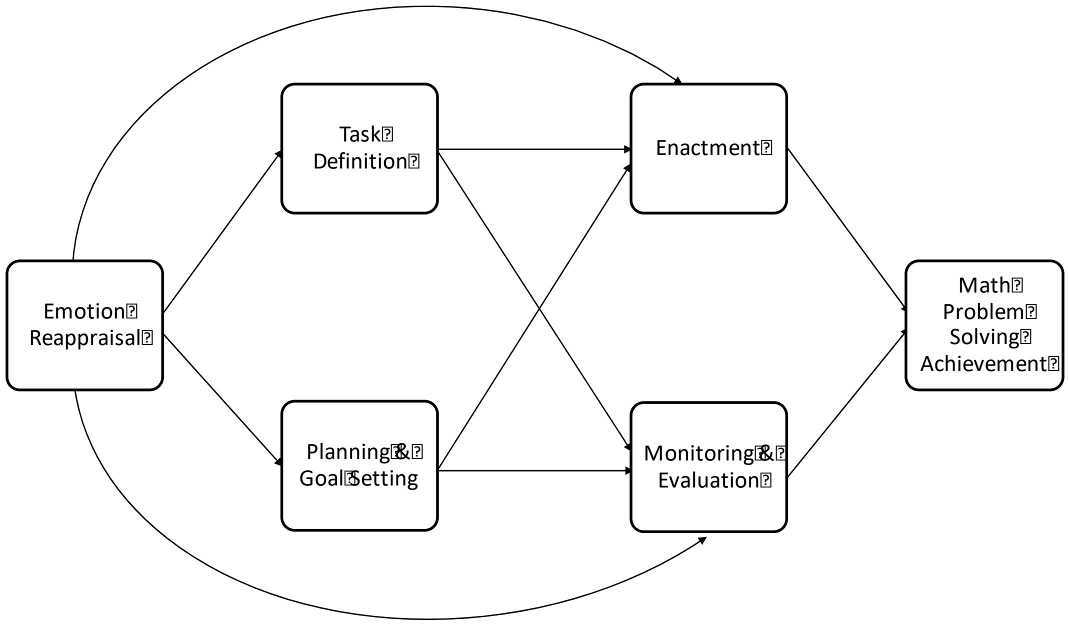

Figure 1. *Hypothesized model.*

CHAPTER 3

Methodology

Participants

One hundred thirty-four students (54 males, 88 females) from grades 3 to 6 (average age = 9.85 years old, SD = 2.10) from one elementary school participated (see Table 1). Given the small sample size by grade level, and that nested analyses were not necessary (see results section), participants' data were aggregated across grades. Parents provided consent for their child, and students provided their assent to participate in the study. From grades 3 through to 6, the languages of instruction at this school include English and French wherein students spend 50% of their time learning in English and the other 50% learning in French. From this sample, most students spoke English as their first language, while the remainder were first-language French speakers but were fully fluent in English. All mathematics problems were completed in the English language, which is the language of instruction for mathematics. Nineteen students were identified as having individualized education plans (IEP) and were given modified problems based on their individual learning needs (i.e., simplified versions of the problems).

Table 1.

Gender and age of students by grade.

Grade	Male	Female	Total	Age	SD
Grade 3	20	7	27	8.7	.53
Grade 4	21	17	38	9	2.21
Grade 5	19	19	38	10.3	1.85
Grade 6	20	11	31	11.3	2.16
Total (134)	80	4		9.9	2.10

Materials

Demographics. Information regarding students' age (by date of birth) and sex (male or female) was obtained from the parental consent forms (see Appendix A).

Emotion Regulation. An adapted 3-item version of the Emotion Regulation Questionnaire (ERQ; see Appendix B; Gross & John, 2003) was used to measure students' employment of emotion reappraisal (e.g., "When I want to feel happy, I think about something that makes me happy"). Students responded to each item using a 5-point Likert-scale where 1 is "Strongly Disagree" and 5 is "Strongly Agree." Responses were summed then averaged for an overall ER score. Reliability for this scale was $\alpha = .83$.

Self-Regulatory Processes. Following recommendations by Muis et al. (2015a), SRL processes were captured using a concurrent think aloud protocol. Students wore Apple Ear Pods with remote and microphone to capture their voices on digital recording devices. Think alouds ranged in length from 4.3 minutes (grade 3) to 61.5 minutes (grade 6), which were transcribed verbatim. Once transcribed, think alouds were segmented into meaningful units, which consisted of a clause or sentence that enclosed a thought or idea. Segments were then coded by seven trained research assistants using a coding scheme developed specifically for mathematics problem solving (Muis et al., 2015a). Twenty-three micro-level SRL strategies were identified and coded through an initial iterative process (e.g., prior knowledge activation, planning, calculating, self-correcting; see Table 2 for a complete list of codes). Specifically, the principal investigator (the second author) spent four months training the research assistants to ensure an acceptable level of inter-rater agreement. In the first phase, four segmented transcripts were coded together as a group. Two of the transcripts chosen were ones that were deemed challenging to code, whereas the other two were considered more straight forward. Coding and discussion of those four transcripts continued until an acceptable level of agreement was reached (90%). Following the initial training, the research assistants and principal investigator then coded an additional four transcripts individually. Inter-rater agreement was established at 65%. The principal investigator and research assistants again worked collaboratively on the second set of four transcripts to reach an acceptable level of inter-rater agreement, after which two more segmented transcripts were chosen and coded separately. In the last phase, an acceptable level of agreement was achieved at 78% across another 10% of the transcripts. The seven trained coders then coded the remaining transcripts.

Following Greene and Azevedo's (2009) protocol, once all micro-level codes were identified, micro-level frequencies were then summed and computed into four macro-level SRL strategies: task definition, planning/goal setting, enactment, and monitoring/evaluation. To control for time on task and verbosity, raw frequencies for each micro-level code were proportioned by taking the raw frequency and dividing it by the student's raw total code frequency (i.e., frequency of calculating / total frequency of codes). Given that think-aloud protocols yielded some zeros, zero values were substituted with the following formula to correct for skewness ($y=1/4n$, where $y = 0$ and n = total frequency of codes; see Bohn-Gettler & Rapp, 2011; Sheskin, 2004; Tabachnick & Fidell, 2013).

Mathematics Problem Solving Achievement. Students were given a complex mathematics problem appropriate for their grade, which was chosen by their teacher and taken from the regular curriculum (see Appendices C, D, E and F). These complex problems are characterized by the need for students to identify the goals of the problem, carry out the task, and find the solution. To achieve this, students must engage in reasoning, research and the use of strategies to come to a solution. Students must perform a series of operations to decode, model, verify, explain and validate their solution (Gouvernement du Québec, 2018). As such, each problem consisted of three interconnected components including analysis, worth 30%, application, worth 50%, and justification, worth 20%. For the analysis component, students were asked to identify important information including what they knew (in terms of the information provided in the problem) and what they had to solve or figure out. The application component included students' calculations for solving the problem. Finally, the justification component required students to justify their answers. Students with IEP's were provided adapted problems that maintained the same grading components and structure, but were simplified versions of the problems. The standardized provincial grading scheme for each problem was used to grade achievement (see Appendix G). Full points were awarded to students for successful completion/accuracy, half points awarded for partial completion/accuracy, and zeros were awarded for incomplete/inaccurate components. Given that the total raw score values for each problem varied by grade, scores were computed into weighted percentiles and subsequently summed into a total percent. The first author graded all problems. Subsequent inter-rater agreement with the second author was 100% for 10% of the problems from each grade.

Current Mathematics Achievement. Teachers provided ratings of students' current mathematics achievement using two mathematics achievement items from an adapted version of the Self-Regulation in School Inventory (SRISI; see Appendix H; e.g., "What is this child's achievement level in terms of provincial expectations for Mathematics – solves a situational problem?"; Hutchinson & Perry, 2014). These items are rated on a 7-point Likert scale that is anchored at four points, where Achievement Level 1 fails to meet provincial standards and corresponds with a score of 1, Achievement Level 2 approaches the provincial standards and corresponds with a score of 3, Achievement Level 3 meets provincial standard and corresponds with a score of 5, and Achievement Level 4 surpasses provincial standard and corresponds with a score of 7. Scores of teachers' perceptions were summed then averaged for an overall score of each student's current mathematics achievement, which was used as a covariate for all analyses. Reliability for this measure was $\alpha = .96$.

Procedure

This study secured clearance from the McGill University Research Ethics Board. Prior to data collection, teachers provided ratings of students' current mathematics achievement. Data collection took place in each class over two days per class. During regular classroom hours, the second author explained to students how to respond to the items on the ERQ, and then read all items out loud to students. Next, students were trained how to think out loud during mathematics problem solving. This step included playing a practice think-aloud audio file for the students that modeled what not to do followed by an appropriate think out loud example (Muis et al., 2016). Students were then given an iPad with headsets and microphones to record their thought processes during problem solving. Next, students were provided with a grade-appropriate mathematics problem to solve that had been chosen by their teachers in alignment with their current curriculum. Teachers introduced the problem to students and then read the instructions out loud. Barriers were set between each student to ensure they could not see each other's work. The noise level in the classroom was loud enough that students could not clearly hear one another. However, students ($n = 5$) who found the noise level to be distracting were relocated to a researcher-supervised learning space in the school's library. Six to eight trained graduate students and the primary investigator circulated the classroom to ensure students continued to talk out loud and responded to any questions students had while solving the problem. Students were prompted to keep talking if they were silent for more than five seconds. Teachers also remained in the classrooms and answered any questions students had while solving the problem. Students spent a minimum of 5 minutes to a maximum of 60 minutes completing the problem (M = 9.90 minutes for grade 3, SD = 5.09; M = 30.42 minutes for grade 4, SD = 12.67; M = 25.69 minutes for grade 5, SD = 11.11; M = 24.34 minutes for grade 6, SD = 11.46). After solving the problem, students were given a $10 iTunes gift card to compensate them for their time.

Table 2.

Definitions and examples of micro- and macro- level SRL strategies.

Phase (macro)/micro Level	Code	Definition	Examples
Phase 1: Task definition		A learner generates a perception about the task, context, and the self in relation to the task. External and internal conditions play a major role.	Prior knowledge activation, beliefs, motivation, and knowledge of strategies are activated during this level.
Prior knowledge activation	PKA	Searching for or explicitly recalling relevant prior knowledge.	"Well I have to know percentages." "So, I already know one fourth is equal to twenty-five in one hundred".
Identifying important information	I3	Recognizing the usefulness of information.	"Ok, now I have to find, now I have to know that onions and herbs are one half of the area for the beets. "she needs to find the area that she will need to uh, to do her garden." "So that's what I need to figure out."
Reading	R	Reading the problem, or its components, word for word.	"Sarah is planning her kitchen garden. She is planting many root vegetables to last her through the winter. This is the list of the vegetables and the amount of space Sarah has decided to give each one."
Phase 2: Planning and goal setting		The learner begins to devise a plan to solve the problem and sets goals.	e.g., planning to use means-ends analysis, trying trial and error, identifying which part of the problem to solve first, solving it within a specific amount of time.

Making/restating a plan	P/RP	Stating what approach will be taken, what strategy will be used to solve the problem, or what part of the problem will be solved in some sequence. This includes restating plans.	"So, what we have to figure out is, is what 1 quarter of the garden is." "So next, I have to do the uh beets." "Now, how I found the area for each section." "Let's just test that out."
Setting/restating a goal	G/RG	A goal is modeled as a multifaceted profile of information, and each standard in the profile is used as a basis to compare the products created when engaged in the activity. This includes restating goals.	"I'm looking for the space that she needs for her garden." "we need to make the denominator all… we need to make the denominator… the equivalent. Every. Each denominator the same." "I can't spend too much time counting each vegetable"
Phase 3: Enactment		Enactment occurs when the learner begins to work on the task by applying tactics or strategies chosen for the task.	
Hypothesizing	HYP	Making predictions.	[learner is solving calculations] "It could be two. I think. It could be two." "It's either area [in reference to what the learner must calculate] or..." "It's probably the carrots, I did the carrots wrong I bet."
Summarizing	SUM	Summarizing what was just read in the problem statement.	[learner finishes reading] "So you know that potatoes will use one quarter of the garden. Cabbage is one fifth of the garden. Beets ten percent of the garden. Carrots 0.20 of the garden."
Help seeking	HS	Asking for help from a teacher, peer, or other source.	
-Information	-I	Help seeking for information	[calls on teacher] "Um, can I rip the pages apart please?" [referring to a component of the problem] "Do I have to fill it out?" "I have a question. Is this the garden? Just to make sure. Is that the garden?" "What do we do next?"
- Evaluation	- E	VERSUS help seeking for evaluation.	"I'm gonna ask [student], is that right?" [calls on teacher] "Am I doing this right?"
Coordinating informational sources	CIS	Using other sources of information to help solve the problem.	"I'm just going to go back to the thing [legend]"

Highlighting/labeling /coloring/ drawing/writing	HLC	Highlighting information, labeling information as part of the problem-solving process, or taking notes in reference to the problem. Making a drawing to assist learning or as part of solving the problem	"I'm going to get a highlighter and highlight root." [highlighting] "I will write potatoes in that ¼ part of the garden." [labeling] [you can hear the learner's pencil] "I'm going to put the line right here" [drawing]
Calculating/measuring	CAL	Solving equations, measuring, or other similar features.	"So now, 10 divide by 5 is equal to 2. So, it's 5 by 2. Ok. 1, 2, 3, 4, 5" "So 100 divided by 4 is 25." [adding up the squares] "1, 2, 3, 4, 5, 6, 7, 8, 9, 10. 10 by 10. So that's 100 squares."
Re-reading	RR	Re-reading a section of the problem, word for word. Important that it is word for word, otherwise it is summarizing.	"I'm actually just going to reread it to make sure that I understand it completely."
Making inferences	MI	Making inferences based on information read or products created from solving the problem. (self-explanation) Explaining why something was done. Key word is *because*.	"I knew I made a mistake because they wouldn't give you a half there!" "If I end up with a small number like what I got last time, two, then that won't sound right." "Alright I did 100 divided by 4 because I wanted to find out the potatoes." [self-explanation]
Goal directed search	GDS	Intentionally searching for information related to the problem statement or the products created during problem solving.	"I'm looking for how much the beets were so I can figure out the onions and herbs." [learner is looking for information regarding the problem] "Let's look at the other page." [learner gets stuck trying to solve the second component of the problem] "I'm going back to the first one [question] because I don't understand."

Phase 4: Monitoring and evaluation		Various types of reactions and reflections are carried out to evaluate the successes or failures of each level or products created for the task, or perceptions about the self or context. Reaction and reflection also includes judgments and evaluations of performance on a task as well as the attributions for success or failure.	Products created are compared to the standards set via metacognitive monitoring. Monitoring and evaluation can include any facet listed above (e.g., progress, motivation, plans, goals, strategies, products like answers or drawings made).
Self-questioning	SQ	Posing a question.	"So, what do I know right now?" "Why did I do this?" "What should I think about?" "Did I do this wrong?" "Is it cm, m or something else?"
Monitoring	MON	Monitoring something relative to goals.	[learner solves a component of the problem] "I wrote that down so I don't forget." [learner is calculating] "Okay, wait." [referring to the worksheet] "I don't have much space." "Let me check if I went wrong somewhere." "So, let me just count them just in case, I'm just going to count them." "Someone's going to come tell me your spending too much time on this."
Judgement of learning	JOL	Learner is aware that something is unknown, not fully understood, or difficult to do.	"Uh, ok I'm stuck…I'm not sure what is essential to think about." "I'm not sure how I'm gonna show that." "I don't understand this." "I'm going to have a hard time doing this." "I need help." "This doesn't make sense."
Self- correcting	SC	Correcting one's mistakes.	"No! not beets. Sorry. The carrots! I already did beets." [learning is counting the problem space] "And then same with the onion - no, the onions and the herbs are only 5." "I forgot to put an 'a' after the 'c' [referring to labels], so c-a, c-a, c-a, c-a."

Evaluation	EVAL	Judging whether goals have been met, whether a particular strategy is working, whether the answer is correct, whether the work is neat, etc. Judgment of all facets that fall under monitoring.	"I don't need to write that down." [after counting the area of each vegetable] "Perfect! It fits completely in my garden!" "Uh oh, I did it wrong." "Yah so 10, that's the answer." "So, we figured that [part of the problem] out." "This is so messy." "I'm not done." "I made a mistake!"
Control	CON	Changing strategy when monitoring or evaluation results in a determination that goal has not been met.	[learner runs out of workspace] "I'll have to do it really really small." "This doesn't seem very right so I'm going to erase it [after judging the garden was not correctly drawn] "I have to restart the puzzle piecing, at least I'll know all the areas."
Task Difficulty	TD	Statements reflecting the difficulty or easiness of a task.	"That was easy enough." "Ok, this is not fun, this is hard!"

CHAPTER 4

Results

Preliminary Analyses

First, skewness and kurtosis values for ER, micro-level SRL processes, and mathematics achievement were examined using Tabachnick and Fidell's (2013) criteria of <|3| for skewness and <|8| for kurtosis. See Table 3. Three micro-level SRL strategies, coordinating informational sources, highlighting/labelling/coloring and goal directed search, were removed from subsequent summation of respective macro-level SRL processes due to high skewness and kurtosis values. See Table 4 for skewness and kurtosis of macro-level variables.

Table 3.

Skewness and kurtosis for micro-level SRL strategies.

Learning Strategy	Skew	Kurtosis
Prior knowledge activation	.580	-1.021
Identifying important information	.975	.036
Reading	2.730	7.368
Planning / restating plans	.519	-.632
Goals / restating goals	-.695	-1.452
Hypothesizing	-.605	-1.627
Summarizing	-1.365	-.121
Help seeking - information	.284	-1.826
Help seeking - evaluation	-1.489	.247
Coordinating informational sources	-4.816	21.674
Highlighting/labelling/coloring/drawing/writing	-5.669	32.889

Calculating	.473	.186
Re-reading	.403	-1.741
Making inferences	.096	-1.953
Goal directed search	-4.302	16.774
Self-questioning	.574	-1.331
Monitoring	.884	-.124
Judgement of learning	.956	-.816
Self-correcting	1.230	-.225
Evaluation	.534	-.296
Control	-.002	-1.993
Task difficulty	-.274	-1.907

Table 4.

Skewness and kurtosis for macro-level SRL processes.

SRL process	Skew	Kurtosis
Task definition	1.066	.547
Planning and goal setting	-.303	-.541
Enactment	-.207	-1.03
Monitoring and evaluation	.393	-.706

Second, given the nested nature of students within grades and teachers/classrooms, intraclass correlation coefficients (ICCs) were computed for each variable to assess whether nested analyses were necessary. All ICCs were less than .05 and, as such, nested analyses were not necessary. Accordingly, all students were grouped into one sample. See Table 5 for variable means and standard deviations, and see Table 6 for correlations between variables.

Table 5.

Mean and standard deviation for study variables.

	Mean	*SD*
1. Grade	4.54	1.05
2. Emotion reappraisal	3.37	.92
3. Task definition	6.28	4.01
4. Planning/goal setting	11.57	8.10
5. Enactment of learning strategies	15.29	8.69
6. Monitoring/ evaluation	9.06	5.27
7. Math problem solving achievement	70.32	19.22
8. Current math achievement	4.89	1.45

Note. Math problem solving achievement is reflected as a percentage. Current math achievement is scored using a 5-point Likert scale.

Table 6.

Pearson product-moment correlations for study variables.

	2	3	4	5	6	7	8	9	10	11
1. Sex	.05	-.07	-.02	-.13	-.09	-.12	-.21*	-.22	.07	.12
2. Teacher		.43*	-.22*	-.21*	.07	.16	.12	.08	.19*	.01
3. Grade			-.29**	-.33**	.05	.30**	.42**	.38**	.11	.16
4. IEP status				.10	-.14	.11	-.18*	-.08	-.23**	-.51**
5. Emotion reappraisal					-.07	-.18	-.26*	-.18*	.06	.12
6. Task definition						.30**	.42**	.30**	.14	.05
7. Planning/goal setting							.59**	.51**	.23**	-.01
8. Enactment of learning strategies								.79**	.24**	.03
9. Monitoring/evaluation									.24**	.03
10. Math problem solving achievement										.32**
11. Current math achievement										

Note. Significant correlations are noted as **p < .01, *p < .0

Path Analyses

To test the proposed mediation model, M*plus* 8.0 (Muthen & Muthen, 2018) was used. Given the relatively small sample size (*N*=134) for the number of parameters being estimated (Tabachnick & Fidell, 2013), and that traditional path analytic approaches with small sample sizes suffer from low power (MacKinnon, Lockwood, Hoffman, West, & Sheets, 2002), confidence intervals were set to 90% and a bootstrap sampling technique was used (10,000; Hayes & Preacher, 2013). Given that the bootstrap sampling method has no underlying distributional assumptions, it was the most appropriate analytic approach to use with slightly skewed data (see Hayes, 2013).

To assess the first research question, to explore the relationship between emotion reappraisal and the four phases of self-regulation, results revealed a good fit to the hypothesized model (final model is shown in Figure 2), χ^2 (df = 7) = 55.42, $p < .001$, CFI = .94, RMSEA = .06. Specifically, consistent with our hypotheses, ER positively predicted task definition [$\beta = .36$, $p < .0001$], planning and goal setting [$\beta = .25$, $p < .004$], enactment [$\beta = .41$, $p < .0001$], and monitoring and evaluation [$\beta = .39$, $p < .0001$]. Moreover, task definition positively predicted enactment [$\beta = .40$, $p < .0001$], and monitoring and evaluation [$\beta = .35$, $p < .0001$]. Planning and goal setting also positively predicted monitoring and evaluation [$\beta = .23$, $p < .0006$]. Contrary to our hypothesis, planning and goal setting did not predict enactment [$\beta = .10$, $p = .22$]. Finally, as hypothesized, enactment positively predicted mathematics problem solving achievement [$\beta = .15$, $p = .02$].

For the second research question, mediation analyses revealed that enactment mediated the relationship between emotion reappraisal and mathematics problem solving achievement, with an indirect effect = .90 and a bias-corrected bootstrap (90%) CI from .17 to 2.16.

Additionally, task definition mediated relations between emotion reappraisal, enactment and mathematics achievement, with an indirect effect = .38, and a bias corrected bootstrap (90%) CI from .15 to 1.20. Planning and goal setting also mediated the relationship between emotion reappraisals, enactment and mathematics achievement, with an indirect effect = .15, and bias corrected bootstrap (90%) CI from .39 to 2.67.

For the third research question, we examined the fit indices for both the parallel and sequenced models of the four phases of SRL during mathematics problem solving. Results from the parallel model revealed a poor fit to the data, χ^2 ($df = 7$) = 75.83, $p < .001$, CFI = .86, RMSEA = .12. Given the nested nature of the models, we compared model fit across the two models. The difference between models resulted in a difference of χ^2 ($df = 7$) = 20.41, $p < .005$. Given the better fit of the serial model compared to the parallel model, these results support our hypothesis that modeling the phases of SRL in a serial fashion may be more representative of what younger students do when solving complex mathematics problems.

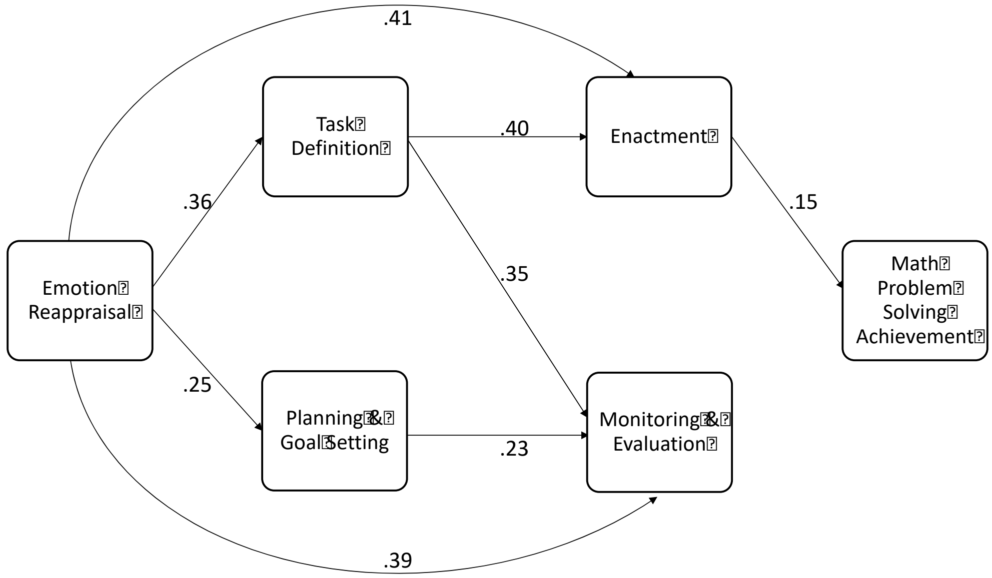

Figure 2. *Final model.*

Supplemental Analyses for the Sequential Nature of SRL

To provide a rich description of the sequential nature of the four phases of SRL, we analyzed participants' transcriptions. For comparative purposes, we chose students with the highest and lowest mathematics problem solving achievement, balanced across grades. In total, we examined 25 transcripts from students who completed problems from the regular curriculum (approximately 20%); 13 students were chosen based on their high achievement on the mathematics problem (three scored 96% and 10 scored 100%), and 12 students were chosen as they received the lowest scores (two of these students scored between 20-25%, four students between 30-39%, and six students between 40-45%). The author then read each student's transcription and recorded the approaches they used to solve the grade-appropriate mathematics problem. Student names and their achievement level were blinded to avoid bias while identifying trends. The author's findings were then sorted into respective high/low achievement groups where they were compiled and comparisons were drawn both between and within the high/low achieving groups. Criteria for identifying trends was set so that 75% or more of the students within the high- (10 students) and low-achieving (9 students) groups had to engage in a similar approach to SRL strategy employment during their math problem solving.

Analysis revealed that high achieving students demonstrated two trends for employing SRL. First, these students were more likely to employ task definition and planning and goal setting before moving into enactment followed by monitoring and evaluation. For example, one student read the problem statement and said, "So, what I'm going to do is I'm going to take a highlighter and just highlight everything that's going to help me solve this problem." The student then identified important information from the problem statement, "the first school is going to have had two fifths of the money raised, school two had three eighths of the money raised, school three had the rest of the money raised.", before stopping to identify what the task required the student to do, "Sorry, I'm just going to reread the question. So, given the way in which the organizing committee decided to distribute the money, will each school be able to order the sports items it has requested? So, this is a yes or no answer." At this point, the student moved from the task definition and planning/goal setting phases of SRL to the enactment phase by implementing strategies and monitoring and evaluating their outcomes. This trend is in line with findings from path analyses which suggest a sequenced nature to employing SRL such that students define the task, set goals and make plans prior to enacting their strategies and monitoring/evaluating their outcomes during complex mathematics problem solving.

The second trend identified was that high achieving students would interrupt their engagement in SRL when they did not understand the requirements of the task. That is, these students would interrupt their employment of enactment (e.g., calculating, hypothesizing, making inferences) and/or monitoring and evaluation to re-define tasks, identify important information and adjust their goals and plans. For example, a student read the problem out loud and said, “So, what I gotta do now is figure out what is my answer. If I look at the chart […] the father and the mother both are going to cost 16, 16 or 20, 27, and 8 dollars. So, it would be 27 plus 8. Which would be…let’s get back to that later.” At that time, the student re-read the problem and said “Okay, what I know is…one second…I know is that... for the adults going, the nature package, adults... are... 27 dollars for the nature package. And... ugh. So... yes. It will be much easier if I had done this before!” While engaging in enactment, this student’s monitoring and evaluations indicated that his understanding of the task and/or the plans and goals he had set for the task were insufficient or inappropriate. This trend supports theoretical models that suggest that SRL is cyclical wherein information from one phase may feed back into other phases to help redefine those phases when information from evaluation becomes available.

Interestingly, our analysis revealed that of these high achieving students, only one student did not engage in any task definition or planning.

> “Okay, so the first thing I need to do is… a thousand dollars. Zero, zero, zero, zero. Two thousand four hundred dollars. The eight gets…that is school one. School two gets, it goes 16, 24, 17. Add that. 8, 16, 60! Sorry. 1, 2, 3, 4, 5, 6, 7, 8. Add that to that. Zero point. School three gets the rest, so I can add up […] And that’s how much money school three gets.”

However, this student demonstrated an inherent understanding of the task given his ability to identify the task structure and requirements, and provide the correct answer to the question.

> “[reading] Given the way in which the organizing committee has decided to distribute the money, will each school be able to order the sports items? No, they can’t, cause school two can’t. One and three can, but just one of them can. [reading] Explain using rigorous mathematical arguments. [completes problem].

That is, although this student did not externalize any instances of engaging in task definition and planning/goal setting, it is evident that the student understood the task structure and its requirements. In other words, this student displayed expert-like problem-solving SRL behaviors (Muis, 2008).

Analyses of students with the lowest mathematics problem solving achievement also demonstrated two trends of SRL employment. First, students engaged in SRL in a sequenced nature but often the products of their mathematics problem solving (i.e., counting, calculating, reading number pairs) were inaccurate. For example, one student began by reading the problem and identifying important information from the problem statement to figure out the parameters of the problem (i.e., define the task at hand). “There is 7 houses. There’s a monster party and he is going to 3 houses. 3. There is house 1,2,3,4,5,6, and 7. He is going to house 3,4, and 5. House 3 is selling a hundred [gooey] gummies. House 4 is selling ten hundred [gooey] gummies. And house 5 is selling 34.” Next, this student reread the problem statement and immediately began enacting strategies and monitoring/evaluating his progress “He’s going to house 3,4,5. He will get a, first house he’s gonna get a hundred. Second house, a thousand, and third house, 3 hundred and 40.” Unfortunately, this student’s sequenced employment of SRL did not support problem solving performance due to inaccurate monitoring of calculation mistakes made along the way.

Indeed, many of the students who performed poorly made calculation errors that they did not catch or could not correct when monitoring their progress. Some of these students identified their errors and attempted to adjust their task definitions, plans and goal, or use of strategies. For example, one student engaged in rigorous task definition and planning/goal setting:

> “so, we gotta remember the potatoes have a quarter percent, (sighs) okay. The cabbage has one fifth of the garden, highlight that, I’m just highlighting it with a big pink highlighter. […] Onions and herbs half of the area for the beets, hmm that’s interesting. So, you gotta figure out what the beets are first. The thing is here I don’t know how to find the area so I need to know a little bit more. I’m just flipping through all the pages to know every single information, so here I have my plan. Yup that’s what I need now.”

The student then enacted learning strategies and continued with math problem solving. When her monitoring and evaluation made it clear that she could not resolve her misunderstanding, she eventually sought help:

> "Miss? Okay, uh I don't know why I have a remainder here. I think I'm going to restart cause that can't, that can't be right. I don't know why I got a remainder here."
>
> Researcher: "You might want to check your answer."
>
> "So, twenty-three times eighteen. I'm gonna re-do that. If this doesn't work again cause I, I don't know. No, it would have been no difference! I think I got my multiplication wrong."

The student continued to struggle, "Okay I don't know what happened here, what I did wrong… I'm just unsure about this. I'm just really confused here with this one. Oh okay. The way I usually do it... Uh I don't know what I did wrong here cause everything that I did looks about right even though my answer looks terribly wrong. The thing I usually do is not working." Unfortunately, this student continued to enact the same learning strategies, which resulted in an incorrect answer to the problem.

The second trend that students with low mathematics problem solving achievement demonstrated was that their verbalizations were richer than the work they provided on the mathematics problem work sheet. Several students, regardless of the pattern of their SRL engagement, failed to complete the required components of the work sheet. For example, two sections of the problem required students to write down "What I know" and "What I need to find out" to solve the problem. These components were worth a significant portion of the problem. By not completing these sections, students could not be awarded points due to lack of information. For example, one learner immediately began enacting their learning strategies, and while the products of this were correct they failed to complete their worksheet.

> “So, school one, 2/5ths of 1000 dollars, which would make 400 dollars. Um 3/8ths of 1000 dollars, you divide 8 into 1000, and that will make…it goes into 10 one time, then you subtract and you get 2, uh, 8 goes into 20 2 times, you subtract, and then you get 4, and 8 goes into 40 5 times, so school 2 will get 125 dollars. And then the rest of the money goes to school three. So, uh 525 dollars, subtracted from 1000 dollars is 475, so school 3 got the most money, um.”

Like the high-achieving expert-like student described above, this student immediately enacted his math learning strategies. While the products of his enactment were correct, he failed to provide sufficient information to receive full points for the components of the problem. Although students were reminded to check for the completeness of their work prior to submission, this trend may suggest that the design of the mathematics tasks may not accurately reflect each students’ math problem solving skills.

Together, the examples of students with high or low mathematics problem solving achievement provided an in-depth characterization of the sequential nature of the four phases of SRL. While most students engaged in SRL sequentially, low achieving students demonstrated difficulty developing accurate understandings of the task structure and requirements and failed to set realistic goals and plans. They also failed to check or adjust their understanding, goals and plans or did not have the skills to correct their mistakes when they made them. Subsequently, this lead to their poor mathematics problem solving performance. Additionally, students’ grades suffered when students did not provide the required information on the mathematics work sheet, despite teachers and researchers reminding students to “show your work!”

CHAPTER 5

Discussion

To date, a great deal of literature has focused on individual relations between ER or SRL, and achievement in older students (Mega et a., 2014; Whitebread et al., 2007), with none taking into consideration the potential role of both during learning with a younger population. Our research is the first to address this gap in the literature. Specifically, we examined whether SRL mediated the relationship between elementary-aged students' employment of ER strategies and mathematics problem solving achievement. Additionally, we sought to determine if there was a sequential order to the employment of the phases of SRL, such that engagement in task definition and planning and goal setting occurred prior to the enactment of learning strategies and monitoring and evaluation.

Our first research question assessed the relationship between ER and the four phases of SRL. Analysis revealed that young students' employment of emotion reappraisals as a form of ER positively predicted the cognitive and metacognitive processes they used across the four phases of SRL during complex mathematics problem solving. These findings are supported by previous literature which suggest that the use of emotion reappraisal is less cognitively taxing (Richards & Gross, 2000), and that the experience of positive emotions allows students to effectively employ SRL strategies (Villavicencio & Bernardo, 2013), which ultimately improves their mathematics problem solving achievement.

These findings also extend previous research as they highlight the importance of considering ER as a conceptually distinct but theoretically important antecedent to successful SRL (Hutchinson, 2013; Perry et al., 2018). Unless students possess the necessary skills to employ ER (i.e., metacognition, motivation, strategic action) and effectively deal with detrimental emotions (i.e., reappraise emotions), educators' efforts to develop students' SRL processes and promote academic success will be impeded. As such, our findings demonstrate a need for educators to develop young learners' ER and SRL skills in tandem. Although social-emotional learning is now part of the curriculum across schools in North America, future research should assess what kinds of classroom climates support the simultaneous development of ER and SRL (Hamre & Pianta, 2005). Specifically, little research has explored how features of classroom instruction can promote or curtail young students' development of both ER and SRL (Hutchinson, 2013; Perry, 1998, 2003; Perry et al., 2017). As such, our study calls for future research to examine how features of instruction promote the development of ER and SRL, and their dynamic interactions during learning and complex problem solving.

Our second research question examined whether the four phases of SRL mediated relations between ER and mathematics problem solving achievement. Findings from the current study support our hypothesis that the four phases of SRL mediate the relationship between young learners' ER and their mathematics problem solving achievement. Specifically, findings demonstrated that enactment of learning strategies positively mediated the relationship between ER and complex mathematics problem solving achievement. These findings are supported by previous research that has shown ER is an important predictor of young children's academic success in mathematics (Graziano, et al., 2007). Additionally, previous research highlights how emotions and ER predict individuals' learning strategies, as well as their learning outcomes (Di Leo et al., 2017; Gross & Thompsons, 2007; Hutchinson, 2013), and that SRL predicts mathematics problem solving achievement (Muis et al., 2015a; Muis et al., 2016). Results from our study provide further evidence of this relationship and extend previous work by revealing that relations between ER and learning outcomes are likely due to the mediating role of SRL processes during learning.

Furthermore, our findings demonstrated that ER fosters mathematics problem solving achievement by promoting the use of more effective learning strategies. That is, students are better able to maintain focus on the task at hand and use learning strategies when they can effectively regulate their emotions. In contrast, when students are consumed by their negative emotions, this draws functional resources (e.g., inhibitory control, attention focusing) away from the task, which can undermine learning processes (Meinhardt & Pekrun, 2003). These findings have implications for learners' academic outcomes and highlight the need for researchers and educators to develop instructional practices that facilitate young students' engagement in adaptive and effective forms of ER and SRL. Moreover, our results have important theoretical implications. Specifically, models of ER and SRL have been developed through separate lines of work, rarely cross-referencing each other. Given the same underlying processes critical to both ER and SRL, one coherent model that integrates ER and SRL together would result in a more inclusive understanding of complex learning.

Our third research question addressed whether there was a sequenced nature to the phases of SRL during complex mathematics problem solving. We found that task definition serially mediated the relationship between ER, enactment of learning strategies, and complex mathematics problem solving achievement. Similarly, planning and goal setting serially mediated the relationship between ER, enactment of learning strategies, and complex mathematics problem solving achievement. These finding support our hypothesis that the first two phases of SRL (task definition, planning/goal setting) occur prior to the employment of the last two phases (enactment of learning strategies, monitoring/evaluation). Additionally, we found that the serial model of SRL was a better fit to the data compared to the parallel model.

Trend analyses of students' transcriptions provided further evidence that most of the students we sampled moved sequentially through the phases of SRL, and that information from later phases fed back into earlier phases, reflecting its cyclical nature (Muis, 2007). Trend analyses further revealed that what separated low- from high-performing students included students' skills in adjusting strategies to overcome obstacles during problem solving and providing their complete work. These results support our hypothesis that modeling the phases of SRL in a serial fashion may be more representative of what younger students do when solving complex mathematics problems. Future research should assess whether modeling SRL phases in serial fashion is more reflective of what happens during complex learning with older students and across different contexts. Moreover, given the low-performing students' tendency to provide incomplete work researchers and educators should continue to work together to examine how scaffolding can be implemented and adapted to support students learning and achievement during mathematic problem solving.

Our findings extend current theoretical models by demonstrating that while SRL is traditionally considered to be weakly sequenced (Winne & Hadwin,1998), certain learning contexts (Pintrich, 2000) such as mathematics problem solving, likely require understanding of task requirements and structure prior to enacting learning strategies or monitoring and evaluation for the problem-solving activity. These findings reinforce the importance of modeling SRL phases in more than one way, and highlight that context should be taken into consideration when exploring the role of SRL in learning. Given that our study was conducted in an authentic learning context, it may also be the case that results are more reflective of what naturally occurs during learning with this particular population.

Finally, results from this study deepen understanding of the relationship between young students' ER and SRL and reinforce the notion that individuals differ in their development of and engagement in ER and SRL (Hutchinson, 2013, Perry, 2013; Zimmerman, 2008). That is, variations in students' ER and SRL are associated with learning and achievement differences (Eisenberg, Spinrad, Fabes, Reiser, Cumberland, Shepard et al., 2004; Muis et al, 2015; Muis et al., 2016; Pekrun & Stephens, 2012). These insights provide a platform for designing instructional interventions, which should be implemented in schools at a global level to help students learn how to regulate their emotions to improve SRL and learning outcomes. As such, we call for continued collaboration between researchers and educators to design effective instructional practices and interventions to bridge the gaps between learning and developmental theories and application (Perry et al., 2018).

Limitations

There are two limitations of the current study. First, we focused on the role of an effective ER strategy, emotional reappraisal (Gross & Thompson, 2007). As such, we did not consider how emotion suppression, an ineffective form of ER, predicts students' engagement in SRL and their mathematics problem solving achievement. Given the host of negative consequences associated with emotion suppression (e.g., increase negative emotions, poor executive functioning; Richards & Gross, 2003), continued research is needed to investigate how ineffective forms of ER support or impede students' engagement in effective SRL and ultimately their learning outcomes. Additionally, our findings demonstrated that students' grade was positively associated with their use of SRL (i.e., planning/goal setting and monitoring/evaluation), which suggests an improvement in the development of SRL over time. Unfortunately, small sample sizes within grades prevented us from analyzing the data as a function of developmental level. Future research with larger sample sizes should investigate whether students' age moderates the relationships between ER, SRL and academic achievement.

Conclusions

These findings illustrate the importance of supporting young learners' ongoing ER and SRL development for their learning and academic success. The results of this study successfully demonstrate that future theoretical and empirical research can and should contextualize ER as distinct from, yet theoretically united with SRL. Furthermore, researchers should continue to develop understanding of the sequenced nature of the various phases SRL in other learning contexts (e.g., literacy, science). By better understanding how ER and SRL work in concert, better calibrated interventions and pedagogical approaches to supporting ER and SRL can be developed for the benefit of all students.

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APPENDIX A: PARENT CONSENT/CHILD ASSENT FORM AND DEMOGRAPHICS

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INFORMED CONSENT

Dear Parent/Legal Tutor,

I am a professor in the Department of Educational and Counselling Psychology at McGill University. My areas of expertise include learning and motivation across the lifespan. I am conducting a multi-year research study in collaboration with Mrs. Harwood (Grade 3), Mrs. Laframboise (Grade 4), Mrs. Szollozy (Grade 5) and Mrs. Kavanagh (Grades 5/6) at Dorset, and we would like to ask your permission to have your child participate. All children from Grades 3 through 6 are invited to participate. This study began in May 2017 and will continue until June 2019. Children in Grade 3 who sign up this September 2017 may participate until the end of Grade 4. Children in Grade 4 may participate until the end of Grade 5. Those in Grade 5 may participate until the end of Grade 6, and those in Grade 6 may participate this year. The purpose of this research is to examine how student characteristics (achievement, motivation, emotion and behavior) and features of classroom contexts (tasks, instructional practices, interpersonal interactions) relate to self-regulated learning through the elementary grades. "Self-regulated" describes individuals who control their thoughts and actions to achieve goals and respond productively in their environment. Specifically, we are interested in understanding: (a) how children's self-regulated learning responds to variations in classroom experiences across time and contexts; and, (b) how teachers' instructional practices support self-regulated learning.

The specific purpose of this research is to understand how children's classroom experiences help them develop strategies for learning and problem solving in mathematics. The outcomes of this study will be highly valuable for teachers and students. For teachers, the information that we gather from this study may help to inform mathematics instruction designed to better meet the needs of all students. For students, they may learn how to better regulate their learning and emotions, which may lead to better learning outcomes in mathematics.

What would your child have to do?

For the 2017-2018 and 2018-2019 academic years, your child will be asked to participate in two sessions – one in October, and one in May. Before the session begins, your child will respond to items used to measure his or her value for learning mathematics, and confidence in learning and problem solving in mathematics. Then, he or she will be given a mathematics problem (one used in the regular curriculum). Your child will work on the mathematics problem during regular class time and his/her thought processes will be audio-recorded. After completing the mathematics problem, your child will then complete a questionnaire that will measure his or her emotions experienced during problem solving. Performance on the mathematics problem will also be measured. These sessions will occur during regularly scheduled class activities and will take no more than 1 hour.

Moreover, for each year of the study, we will collect:

1. Teachers' ratings of children developing self-regulation: Your child's teacher will respond to questions about how your child approaches learning.
2. Teachers' descriptions of their classroom contexts: Your child's teacher will describe her classroom context by responding to questions about how she provides opportunities for children to develop self-regulated learning in her classrooms.
3. Classroom observations: My research assistants and I will observe your child's classroom two times each year (October and May). These observations help us understand how different teachers implement activities that support self-regulation, and how students take up these opportunities on a day-to-day basis. These observations do not require your child or his/her teacher to do anything they would not normally be doing.

Other Important Information

First, in all cases, your child's responses will be kept confidential. Confidentiality is protected by assigning a random identification number to each child. This number will be stored in a file separate from the information used to analyze the results. The audio-recording of your child's though processes while completing each problem will be heard only by the research team. All information and audio files will be kept in a locked room that is accessible only to the research team.

Participation in this study is completely voluntary on the part of your child. We expect that students who participate in this study will benefit given that they will have the opportunity to further develop their numeracy skills through practice. Moreover, to compensate your child for his or her time, your child will receive an iTunes gift card for $10 for each year that he or she participates.

Your child may withdraw from the study at any time for any reason. Moreover, participating (or not participating) in this study will not in any way affect his or her regular classroom activities and will not negatively influence his or her grades. Given that this study will be conducted during regularly scheduled activities, the students who do not consent will be doing the same thing as those who do consent. We will simply not use their information for the study. Risks to your child are minimal and should be no greater than those associated with everyday classroom activities. The students will be informed of all aspects of the study before they participate, as described here in the consent form. We will gladly answer any questions and address any concerns they may have. We plan to publish the results of the study in journals designed for teachers and researchers. No reference will be made to the school or to your child in written or oral materials that could link them to this study. All information will be stored in a locked facility at McGill University for at least five years after the completion of the study. After this time, all information gathered will be destroyed.

In the event that you have any questions or concerns about this research, you may contact Dr. Krista Muis at (514) 398-3445. If you have any concerns regarding ethics, please contact the Ethics Officer, Lynda McNeil at (514) 398-6831.

To ensure the study is being conducted properly, authorized individuals such as a member of the Research Ethics board, may have access to your child's information. By signing this consent form, you are allowing such access. Please sign below if you have read the above information and consent to participate in this study. Agreeing to participate in this study does not waive any of your rights or release the researchers from their responsibilities. A copy of this consent form will be given to you and the researcher will keep a copy.

Thank you for your co-operation,

Krista R. Muis, PhD

Associate Professor and Canada Research Chair
Faculty of Education
McGill University

Yes. I, ________________________________ (Parent/ Legal Tutor), give permission for my

child _______________________ (name of child) to participate in all research aspects as

described above.

I give permission to audio-record my child while completing the tasks. ☐ yes ☐ no

Signature of Parent/Legal Tutor: ___________________________

Date: _____/_________/_________
Day Month Year

Birth date of child: _____/_________/_________
Day Month Year

No. I, ________________________________ (Parent/ Legal Tutor), do NOT give my child

_______________________ (name of child) permission to participate in this research.

INFORMED ASSENT

Dear Student,

I am a professor at McGill University and am doing a project with your teacher. We would like to learn more about how you solve math problems, the feelings you have about math, and how those change over the school year. We will continue this project at Dorset from October 2017 until June 2019. During the time you are at Dorset, you may participate each year until the end of the study (or until you leave Dorset).

What will you do?

For each school year, you will work on two math problems – one in October and another one in May. We will ask you to talk out loud to tell us what you are thinking as you solve the problem. The problem will take about 20 minutes to solve, and we will record your voice as you try to solve the math problem. We will also ask you about your feelings about math after solving these problems. Your teacher will also fill out questionnaires about classroom activities, and the kinds of things you do when you learn. We will also visit your classroom a few times to see what kinds of activities happen in your class.

Other Important Information

Your information and audio-recording will be private. We will not tell your teacher or your parent/legal tutor what you say and write.

You can quit this study any time you want. You can say yes or no if you want to take part in the study. This will not affect your school grades. If you do not want to be part of this study, you will be doing the same work as the other students in your class.

If you take part, you will receive an iTunes gift card for $10 for each year that you participate. If you have questions you can call Dr. Krista Muis at (514) 398-3445. Thank you for reading this letter and for your help,

Krista R. Muis, PhD

Associate Professor and Canada Research Chair
Faculty of Education
McGill University

Yes. I ________________________ (name of child) agree to take part in this study.

I give my permission to audio-record me while I complete the tasks. ☐ yes ☐ no

I am taking part of this project because I want to. I have been told that I can stop at any time.

____

(child's signature)

No. I ________________________ (name of child) DO NOT agree to take part in this study.

____

(child's signature)

APPENDIX B: EMOTION REGULATION QUESTIONNAIRE (GROSS & JOHN, 2003)

Emotions at School

We would like to ask you some questions about how you control your emotions while at school. There are no right or wrong answers.

For each item, please answer using the following scale:

Strongly Disagree	Disagree	Do not disagree nor agree	Agree	Strongly Agree
1	2	3	4	5

1. When I want to feel happy, I think about something that makes me happy.

1 2 3 4 5

2. When I am feeling angry, I try to think about something that will make me less angry.

1 2 3 4 5

3. When I'm scared about something, I try to think of ways to stay calm.

1 2 3 4 5

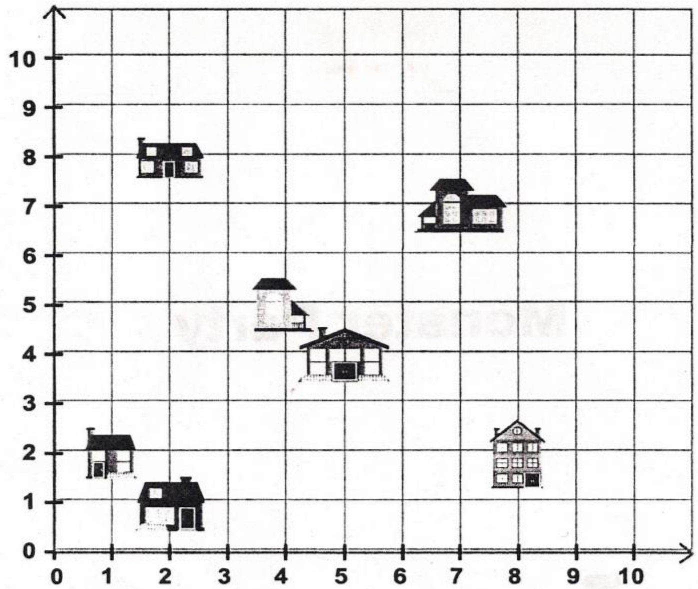
APPENDIX C: GRADE 3 COMPLEX MATHEMATICS PROBLEM

Name: ______________________ **Date:** ____________

I Solve a Problem

Monster Party

Here is a map of the monsters' town.



The monsters are having a party today. To celebrate, the monsters hand out gooey gummies to each child who comes to their door.

Here is the number of gooey gummies that each monster gives to each child.

①	②	③	④	⑤	⑥	⑦
153	12 tens	1 hundred	10 hundreds	34 tens	234	789

Leo visits the houses located at these number pairs:
(1, 2), (8, 2) and (5, 4).

How many gooey gummies does Leo get?

Name: ______________________ **Date:** ____________

What I Know	What I'm Looking For
analysis = x/15	analysis = x/15
• The monsters are having a party and handing out Gooey Gummies	• How many Gooey Gummies did Leo get in total
• Leo visits the houses at these number pairs: (1,2) (8,2) (5,4)	• Which houses are at the numbered pairs
• How many Gooey Gummies each house has	Total analysis = x/30

My Solution

House 1: (1,2) application = x/5 Justification = x/5
house 1 hands out 153 Gooey Gummies

House 2: (8,2) application = x/5 Justification = x/2.5
house 2 hands out 12 tens Gooey Gummies
12 x 10 = 120 = 120 Gooey Gummies
application = x/5 Justification = x/5

House 3: (5,4)
house 6 hands out 234 Gooey Gummies
application = x/5
Justification = x/5

153
+120
+234
507

application = x/5
Justification = x/2.5

Leo visited houses 1, 2 and 6 where he got 507 Gooey Gummies
application = x/5
Justification = x/5

Total application = x/30 = (*5)/3 = x/50
Total Justification = x/25 = (*4)/5 = x/20

APPENDIX D: GRADE 4 COMPLEX MATHEMATICS PROBLEM

AR6-006

Name: ____________________ Date: ______________

VALIDATION SITUATION ***AR6 Arithmetic*** ***(6)***						
		***Observable manifestations of a level...***				
		5	*4*	*3*	*2*	*1*
Evaluation Criteria	Analyze Choice					
	Application					
	Justification					

Summer Vacation

During their summer vacation, a family is planning to spend a weekend in Montreal. They want to visit the Insectarium, the Biodome and the Planetarium.

This family has 5 members:

- the grandfather, 67 years old
- Leanne, 10 years old
- the father, 44 years old
- Billy, 9 years old
- the mother, 44 years old

Using the table below, Leanne and Billy calculated the total amount the family must pay to visit the Insectarium, the Biodome and the Planetarium.

	Regular Rates			
	Insectarium	**Biodome**	**Nature Package (Insectarium and Biodome)**	**Planetarium**
Adults	$16.00	$16.00	$27.00	$8.00
Age 65 and over	$12.00	$12.00	$20.25	$6.00
Age 5 to 17	$8.00	$8.00	$13.50	$4.00
Age 2 to 4	$2.50	$2.50	$4.25	free

Leanne says the family must pay a total of $131.25.

Billy says the family must pay a total of $150.00.

The grandfather says that Leanne and Billy are both right. Why? Answer in the space provided on the next page.

I Analyze the Situation

What I know...

- The family wants to visit the insectarium, the biodome and the planetarium
- The age of all 5 family members and the cost of each attraction

Leanna thinks the total cost will be 131.25 $ and Billy thinks it will be 150.00 $

analysis = x/10

What I am looking for...

- If Billy and Leanna are both right about the total price for the family to visit all 3 attractions

analysis = x/10

It is essential to think about:

Adding — analysis = x/10
place values
equivalents — Total analysis = x/30

My answer...

Show all your work.

	① Insectarium	② biodome	③ nature package	④ Planetarium	⑤ Billy
mom	16.00	16.00	27.00	8.00	insectarium
dad	+ 16.00 = 32.00	+ 16.00 = 32.00	+ 27.00 = 54.00	+ 8.00 = 16.00	+ biodome
grandpa	+ 12.00 = 44.00	+ 12.00 = 44.00	+ 20.25 = 74.25	+ 6.00 = 22.00	+ planetarium
Billy	+ 8.00 = 52.00	+ 8.00 = 52.00	+ 13.50 = 87.75	+ 4.00 = 26.00	60.00 + 60.00 + 30.00 = 150.00 $
Leanna	+ 8.00 = 60.00 $	+ 8.00 = 60.00 $	+ 13.50 = 101.25 $	+ 4.00 = 30.00 $	

Leanna ⑥
nature pack + planetarium
101.25 + 30.00 = 131.25 $

1–6: application = x/4 Justification = x/5

Total application: = x/30 = (x5)/3) = x/50
Total Justification: = x/40 = (/2) = x/20

Leanne and Billy are both right because Leanna calculated the family cost using the nature package and Billy did not.

application = x/6 justification = x/10

Show all your work in a clear and organized manner to justify your answer.

APPENDIX E: GRADE 5 COMPLEX MATHEMATICS PROBLEM

OP4-002

Name: ____________________ Date: ________________

Uses math reasoning Action Situation OP4 (8)					
Evaluation criteria	Observable indicators corresponding to level				
	A	B	C	D	E
Analysis	30	24	18	12	6
Application	50	40	30	20	10
Justification	20	16	12	8	4

Garden Plot

Sarah is planning her kitchen garden. She is planting many root vegetables to last her through the winter.

This is a list of the vegetables and the amount of space Sarah has decided to give each one:

- potatoes: $\frac{1}{4}$ of the garden.
- cabbage: $\frac{1}{5}$ of the garden.
- beets: 10% of the garden.
- carrots: 0.20 of the garden.
- onions and herbs: $\frac{1}{2}$ of the area for beets.
- turnips: the same area as the cabbage.

Help Sarah plan her garden.

The grid on the next page shows the square area of land she will use for the garden.

OP4-002

I Analyze the Situation

What I know...

- Sarah is planting a garden
- The space needed for each vegetable
- Fractions, decimals and percentages are used

analysis = x/10

What I am looking for...

- The area used for each vegetable in the garden

analysis = x/10

It is essential to think about:

area analysis = x/10
conversion
equivalency Total analysis = x/30

My answer...

Show how you found the area for each section. 1–7: application = x/5 justification = x/5

1. Potatoes $\frac{1}{4}\frac{\times 25}{\times 25} \rightarrow \frac{25}{100}$
2. Cabbage $\frac{1}{5}\frac{\times 20}{\times 20} \rightarrow \frac{20}{100}$
3. Beets 10% $\rightarrow \frac{10}{100}$
4. Carrots 0.20 $\rightarrow \frac{20}{100}$
5. Onions & Herbs 5% (half area of Beets) $\rightarrow \frac{5}{100}$
6. Turnips $\frac{1}{5}$ (same as cabbage) $\rightarrow \frac{20}{100}$
7. Area = 10×10 = 100 (25+20+10+20+5+20=100)

Ca	Ca	B	C	C	T	T	P	P	P
Ca	Ca	B	C	C	T	T	P	P	P
Ca	Ca	B	C	C	T	T	P	P	P
Ca	Ca	B	C	C	T	T	P	P	P
Ca	Ca	B	C	C	T	T	P	P	P
Ca	Ca	B	C	C	T	T	P	P	OH
Ca	Ca	B	C	C	T	T	P	P	OH
Ca	Ca	B	C	C	T	T	P	P	OH
Ca	Ca	B	C	C	T	T	P	P	OH
Ca	Ca	B	C	C	T	T	P	P	OH

Grid: application = x/15 justification = x/15

Legend: Potatoes (P), Cabbage (Ca), Beets (B), Carrots (C), Onions/Herbs (OH), Turnips (T)

Total: application = x/50 Justification = x/50 = (*2)/5 = x/20

Show all your work in a clear and organized manner to justify your answer.

APPENDIX F: GRADE 6 COMPLEX MATHEMATICS PROBLEM

Let's Get Moving!

A fundraising activity brought in $1 000 that will be spent on sports items for three schools in your area. The organizing committee has decided to divide the money raised as follows.

Distribution of the money raised	
School 1	$\frac{2}{5}$ of the money raised
School 2	$\frac{3}{8}$ of the money raised
School 3	the rest of the money raised

Each school has asked for the following sports items.

School 1	School 2	School 3
10 hopper balls 	2 folding nets  and at least 50 pinnies 	At least 65 cones 

The following is the list of prices for the sports items.

List of prices for the sports items	
Item	**Price** (Taxes included)
Hopper ball	$28.50 for 1 ball
Folding net	$100.50 for 1 net
Package of pinnies	$27 for a package of 8 pinnies
Package of cones	$20 for a package of 6 cones

An extra charge of $\frac{1}{10}$ of the amount of the bill must be added to have the items delivered to each school.

Given the way in which the organizing committee decided to distribute the money, will each school be able to order the sports items that it has requested?

Let's Get Moving!

Show all your work.

School 1: 2/5 of 1000 = $400

Hopper balls = 28.50

28.50 × 10 = 285

285 × 1/10 = 28.50

285 + 28.50 = $313.50 < $400

School 2: 3/8 of 1000 = $375

Folding nets + pinnies

100.50 × 2 = 201

50/8 = 6.25... round to 7 packs

27 × 7 = 189

201 + 189 = 390

390 × 1/10 = 39

390 + 39 = $429 > $355

School 3: Cones

remainder of budget

1000 − (400 + 375) = $225

65/6 = 10.83... round to 11 packs

220 × 11 = 220

220 × 1/10 = 22

220 + 22 = $242 > $225

Inferred analysis: x/30

- there are 3 schools with different budgets
- Packages cannot be split, must round
- 1/10th of total added for delivery

Schools 1, 2, + 3:

application = x/5

justification = x/5

Total application:

= x/20

= (*5)/2

= x/50

Total justification:

= x/20

Given the way in which the organizing committee decided to distribute the money, will each school be able to order the sports items that it has requested?

☐ Yes ☑ No

application = x/1

justification = x/1

Use rigorous mathematical arguments to explain why.

No they will not be able to order the sports items because School 2 is short $54 (429 − 375) and School 3 is short $17 (242 − 225)

application = x/4

justification = x/4

APPENDIX G: RUBRIC FOR THE COMPETENCY TO REASON USING MATHEMATICAL CONCEPTS AND PROCESSES

		OBSERVABLE INDICATORS				
		Level A	**Level B**	**Level C**	**Level D**	**Level E**
EVALUATION CRITERIA	**Appropriate analysis of a situation**	• Identifies all the elements and actions that allow him/her to meet the requirements of the situation • Chooses the mathematical concepts and processes that allow him/her to meet the requirements of the situation efficiently	• Identifies most of the elements and all actions that allow him/her to meet the requirements of the situation • Chooses the mathematical concepts and processes that allow him/her to meet the requirements of the situation appropriately	• Identifies the elements and actions that allow him/her to meet the requirements of the situation • Chooses the mathematical concepts and processes that allow him/her to meet the main requirements of the situation	• Identifies elements and actions that allow him/her to partially meet the requirements of the situation • Chooses the mathematical concepts and processes that allow him/her to partially meet some of requirements of the situation	• Identifies all the elements and actions that have little or no connection to requirements of the situation • Chooses the mathematical concepts and processes that have little or no connection to requirements of the situation

	Appropriate application of the required processes	• Applies the required concepts and processes appropriately in order to meet the requirements of the task and makes no mistakes	• Applies the required concepts and processes appropriately in order to meet the requirements of the task, but makes minor mistakes	• Applies some of the required concepts and processes, but makes one conceptual or procedural error*, or makes several minor mistakes	• Applies some of the required concepts and processes, but makes two conceptual or procedural errors*, or one conceptual or procedural error regarding a key concept associated with the task	• Applies concepts and processes, but makes several conceptual or procedural errors*, or applies inappropriate concepts and processes
	Correct justification of actions or statements by referring to mathematical concepts and processes	• Presents a clear and complete line of reasoning • Uses rigorous mathematical arguments when required to support his/her actions, conclusions or results	• Presents a clear line of reasoning even though some of its elements are implicit • Uses appropriate mathematical arguments when required to support his/her actions, conclusions or results	• Presents a line of reasoning consisting of incomplete or unclear elements • Uses insufficiently detailed mathematical arguments when required to support his/her actions, conclusions or results	• Presents a line of reasoning consisting of isolated and confusing elements • Uses largely inappropriate mathematical arguments when required to support his/her actions, conclusions or results	• Presents a line of reasoning that has little or no connection to the situation, or does not show any work • Uses mathematical arguments that are erroneous or unrelated to the requirements of the situation

*Students who omit a concept or process are considered to have made a conceptual or procedural error.

APPENDIX H: CURRENT MATHEMATICS ACHIEVEMENT

Achievement Ratings

Please circle your rating to each question below using the sliding scale from 1 to 7 where:

1 = Not yet meeting expectations
3 = Approaching expectations
5 = Meeting expectations
7 = Exceeding expectations

Statement	Rating						
1. What is this child's achievement level in terms of provincial expectations for Mathematics – Solves a situational problem?	**1**	**2**	**3**	**4**	**5**	**6**	**7**
2. What is this child's achievement level in terms of provincial expectations for Mathematics – Uses mathematical reasoning?	**1**	**2**	**3**	**4**	**5**	**6**	**7**

IEP Status (if applicable): ________________________