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Supporting self-regulated learning in a secondary applied mathematics course
Soutenir un apprentissage autorégulé dans un cours de mathématiques appliquées au secondaire

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Résumé de l'article

Cette étude examine comment un enseignant a soutenu l'apprentissage autorégulé d'élèves peu performants dans le contexte d'un cours de mathématiques au secondaire. L'échafaudage de l'enseignant a fourni aux élèves de multiples occasions d'employer la rétroaction constructive et d'adapter les stratégies d'apprentissage et d'étude. Les données ont comparé les mesures (d'avant et d'après) des compétences métacognitives, des croyances motivationnelles et des comportements d'apprentissage et d'étude, et ont examiné les effets de la pratique dirigée sur le développement de l'apprentissage autorégulé des élèves ainsi que sur leurs résultats en mathématiques. Les résultats suggèrent le besoin de plus amples recherches sur les effets des soutiens individualisés et ciblés, spécifiquement afin d'aider les élèves à utiliser la rétroaction métacognitive pour adapter leurs stratégies d'apprentissage.

SUPPORTING SELF-REGULATED LEARNING IN A SECONDARY APPLIED MATHEMATICS COURSE

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ABSTRACT. This study examines how one teacher supported low-achieving students' self-regulated learning (SRL) in the context of a secondary mathematics class. The teacher's scaffolding provided students with multiple opportunities to use feedback and adapt learning and study strategies. Data compared pre- and post-measures of metacognitive skills, motivational beliefs, and learning and study behaviours, and examined the effects of directed practice on students' developing SRL as well as their mathematics achievement. Results suggest the need for more research into the effects of individualized, targeted supports, particularly in assisting students in using metacognitive feedback to adapt learning strategies.

SOUTENIR UN APPRENTISSAGE AUTORÉGULÉ DANS UN COURS DE MATHÉMATIQUES APPLIQUÉES AU SECONDAIRE

RÉSUMÉ. Cette étude examine comment un enseignant a soutenu l'apprentissage autorégulé d'élèves peu performants dans le contexte d'un cours de mathématiques au secondaire. L'échafaudage de l'enseignant a fourni aux élèves de multiples occasions d'employer la rétroaction constructive et d'adapter les stratégies d'apprentissage et d'étude. Les données ont comparé les mesures (d'avant et d'après) des compétences métacognitives, des croyances motivationnelles et des comportements d'apprentissage et d'étude, et ont examiné les effets de la pratique dirigée sur le développement de l'apprentissage autorégulé des élèves ainsi que sur leurs résultats en mathématiques. Les résultats suggèrent le besoin de plus amples recherches sur les effets des soutiens individualisés et ciblés, en particulier afin d'aider les élèves à utiliser la rétroaction métacognitive pour adapter leurs stratégies d'apprentissage.

Research on self-regulation in academic settings has become more prevalent in the past three decades, perhaps because self-regulatory behaviours are stronger predictors of academic success than IQ scores or prior subject knowledge (Blair & Razza, 2007; Rimm-Kaufman et al., 2009; Veenman & Spaans, 2005). In most conceptualizations of self-regulated learning (SRL), cognition, metacognition, motivation, and strategic action work in iterative and interactive ways before, during, and after learning activities (Butler et al, 2017). The effectiveness with which learners self-regulate is thought to depend on internal characteristics (e.g., motivation, metacognitive skills, prior subject knowledge, emotional and volitional control skills) as well as external influences (e.g., task complexity, classroom supports) (Butler et al, 2017; Shanker, 2012; Tobias & Everson, 2009; Zimmerman, 2008). Teachers can play a key role in fostering self-regulation through regular classroom instruction, so that students not only acquire content knowledge but also become lifelong learners.

This article details a case study examining how one secondary mathematics teacher supported low-achieving students' development of SRL. Our overall research question was: can low-achieving grade 9 mathematics students' metacognitive skills, motivational beliefs, strategic learning behaviors, and mathematics achievement be enhanced through teacher-designed SRL supports? The teacher provided students with scaffolding that afforded multiple opportunities to use feedback and adapt learning behaviours throughout a semester-long course. We compared pre-and post-course scores on SRL-related variables, including metacognitive skills, motivational beliefs, and learning behaviours. We also observed the effects of repeated practice on students' developing SRL skills as well as their mathematics achievement.

MOTIVATION AND METACOGNITION IN LEARNING AND SELF-REGULATION

Research has shown important relationships between student SRL and motivational beliefs such as self-efficacy, task interest, and perceived instrumentality (Bandura, 1989; Cleary, 2006; Zimmerman, 2011). For example, self-efficacy predicts the effort students invest in learning, and their use of learning strategies (e.g., self-testing, redoing challenging homework problems) (Bandura, 1989; Butler et al, 2017; Zimmerman, 2008). However, research also demonstrates declines in such motivational beliefs as well as in achievement during early adolescence (Buzza, 2013). Ahmed and colleagues (2012) note that research shows age-related declines in students' mastery goals, success expectancies, and task-values, particularly in mathematics (Linnenbrink-Garcia & Fredricks, 2008; Wigfield et al., 2006). Mastery goals focus on one's own achievement standards as opposed to comparison with others (Elliott & Dweck, 2005). Success expectancies are judgments about the likelihood of success at a task and task-values are perceptions of how personally meaningful or important success is (Schunk & Pajares, 2005).

Many of the SRL supports provided by the teacher in the present study were designed to help students increase their metacognitive knowledge and control skills. Metacognitive knowledge (learners' understanding of what they do and do not know) and metacognitive control (learners' ability to modify or develop learning strategies to improve learning) are essential to learning and self-regulation (Tobias & Everson, 2009). Students' metacognitive judgments about their understanding, knowledge, and / or readiness to take tests are referred to as "knowledge monitoring" (see Pintrich et al., 2000; see also Winne, 2011). Tobias and Everson's (2009) framework for studying the role of metacognition in learning situates knowledge monitoring as foundational. They reported 26 studies involving the use of a Knowledge Monitoring Accuracy (KMA) assessment, which measures one's knowledge or understanding in a specific domain, such as mathematics or biology (Schraw, 1995; Tobias et al, 1999). Tobias and colleagues (1999) used "Hamann Coefficients" to measure KMA. The Hamann coefficient is a correlation that expresses 'feeling of knowing' accuracy; it is calculated from students' judgments of whether they answered test questions correctly versus their actual performance (Tobias et al, 1999) by taking the difference between the proportions of correct versus incorrect responses (Schraw, 1995). "Hamann coefficients range from −1 to 1, where 0 corresponds to no association or chance level of accuracy" (Schmitter-Edgecombe & Anderson, 2007, p. 7), with stronger positive coefficients representing higher KMA, and stronger negative coefficients representing lower KMA. Negative coefficients reflect either over-confidence or under-confidence (Tobias et al, 1999). Some studies (e.g., Everson & Tobias 1998; Tobias & Everson, 2009) indicate a strong and robust relationship between KMA and achievement, but there are some conflicting results (e.g. Thiede et al, 2003).

Training learners to make more accurate judgments of their learning has shown inconsistent increases in achievement scores. For example, high-achieving students showed improvement in KMA with training, while low-achieving students did not (e.g., Hacker et al, 2008; Hacker et al, 2000; Keleman et al, 2007). Hacker et al. (2000) also observed that despite marked improvements in high-performing students' KMA after training, these improvements did not correlate with better exam performance. Similarly, Nietfeld et al (2005) concluded that feedback on the accuracy of students' predictions on individual test questions and on their overall exam performance did not improve metacognitive calibration.

In a study that spanned four exams, Miller and Geraci (2011) sought to improve students' KMA in predicting exam performance by providing concrete feedback and extra marks if the students changed their behaviour in accordance with feedback. Concrete feedback was provided in the form of three specific pieces of information: students' exam scores, their predicted exam scores (to remind them of their predictions), and their final exam scores after adding extra credit if their predictions were accurate. Students were also given feedback in class, explaining that most of them had been overconfident in their predictions. They were encouraged to either lower their predictions or try to increase their actual exam performance. Lower-achieving students improved their KMA from the first exam to the second. However, their monitoring accuracy did not improve after the second exam nor did their final grades . Predictions of high achieving students did not improve, but their monitoring accuracy was extremely high to begin with (92-96%). In a post-course questionnaire about use of feedback, many low-achieving students indicated that they studied more or lowered their predicted exam scores (strategies which were suggested in class).

Finally, one study showed increased mathematics achievement after students self-reflected on their performance and work habits and used performance feedback to change their learning strategies (Zimmerman et al, 2011). In this study college students were assigned randomly to one of nine intervention (SRL) classes or one of nine control classes. In the SRL classes students assessed their own ineffectual problem-solving strategies in a first test, and then went on to establish new strategies for a second test. After the first test, the intervention group outperformed the control group on all mathematics tests and the final exam. Notably, students who received the intervention were significantly less likely to be overconfident in self-efficacy and self-evaluation ratings before taking the second test, illustrating the importance of SRL support in helping students become more accurate in their metacognitive knowledge.

In summary, in some studies, KMA predicted achievement. However, after creating higher- and lower-achieving groups using a median split based on final course grades, Miller and Garaci (2011) found that training increased KMA scores for lower-achieving but not higher-achieving students. Exam performance was not always related to KMA increases. Thus, although metacognitive knowledge appears to be related to achievement, increasing KMA alone may be insufficient to boost performance. It is possible that the absence of associations between metacognitive training and KMA, and KMA and performance, is due to a lack of concrete feedback and personalized guidance. Although KMA training allows students to practice making metacognitive judgements and gives them information about accuracy of their judgements, specific coaching on how to adapt their learning behaviours effectively in response to performance feedback may be needed (Kirschner et al, 2006).

SRL SUPPORT IN A CLASSROOM CONTEXT

The complex interactions between learner characteristics and context have received significant academic study (Butler et al, 2005; Buzza, 2013; Perry et al, 2004; Perry & VandeKamp, 2000). Students' adaptive, regulatory behaviour appears to mediate the relationship between student performance, contextual factors, and individual characteristics (Moos & Ringdal, 2012; Winne & Hadwin, 2012). Accordingly, although all learners are likely self-regulating in some ways during learning, enacting self-regulatory strategies and approaches to academic work varies. For instance, research shows that low-achieving students typically demonstrate lower levels of self-efficacy as well as reactive, rather than proactive, self-regulatory learning behaviours (Zimmerman, 2012; see also Buzza & Dol, 2015). One reason why reactive learners regulate their learning less effectively than proactive learners is that they set vague or general goals (if goals are set at all) and rely on outcomes and self-reflection to guide future behavior (Zimmerman, 2008). Effective self-regulation involves task analysis, goal setting, and strategic planning before learning tasks, allowing for effective monitoring and adaptation during performance (Zimmerman, 2012). In mathematics, for instance, ineffective learning strategies can result from a failure to analyze tasks effectively or to set appropriate task criteria or standards (Butler, 1994; Butler & Winne, 1995). However, much like any acquirable skills and dispositions, SRL can develop over time with appropriate support. For instance, asking students to practice making metacognitive judgements and to identify their studying techniques supports development of metacognitive knowledge, motivation, and strategic learning behaviours (Paris & Paris, 2001).

Based on consistent evidence that SRL predicts positive academic outcomes for students, including those of lower-achieving students (Butler et al, 2013; Cleary et al, 2008; Zimmerman et al., 2011), many teachers are encouraged to support the development of students' SRL skills (Ontario Ministry of Education, 2010). This is especially important in mathematics, where Canadian students' performance has declined steadily in recent years (OECD 2019).

Generally, research demonstrates that SRL support can help learners identify and adapt strategic learning behaviours for specific tasks and contexts, but we lack a clear understanding of how classroom practices influence self-regulation. Establishing effective practice guidelines is challenging given variations in students' prior subject knowledge, motivational beliefs, learning behaviours, and metacognitive skills. Further, instructional time that teachers can afford for individual students is limited.

In research by Butler et al (2013) and Cleary et al (2008), teachers coached SRL strategies directly. Butler et al's (2013) study incorporated SRL support throughout a school year, allowing multiple opportunities to address students' individual needs. In that study, support practices did not directly predict achievement, but rather appeared to influence students' SRL development by affecting how students approached their learning. Cleary et al's (2008) study involved coaching for small intervention groups over eleven weeks. Post-intervention grades showed significant improvement when compared to pre-intervention grades; however, the degree of individualization that coaches provided is unclear. Neither study used class-wide interventions, which may be a more realistic approach to SRL support within today's classrooms.

Research on teachers' SRL support is important in classrooms with lower-achieving students, given that SRL can improve learning and performance regardless of ability. Lower-achieving students who have not been formally identified with learning disabilities typically receive no 'special' or individualized education and have received very little SRL research attention. This article assesses the effectiveness of classroom support strategies for lower-achieving students' SRL development (i.e. metacognitive skills, motivational beliefs, strategic learning behaviours) in Grade 9 mathematics.

METHOD

Participants

Participants were enrolled in a one-semester Grade 9 Applied Mathematics class in a mid-sized Canadian city. In this district, students typically choose to take Applied Mathematics when their previous mathematics grades are too low for post-secondary preparatory courses and / or they lack interest in post-secondary mathematics. Generally, these students lack confidence in their capability to perform well in mathematics. Seventeen of the 22 students in the course provided informed consent to participate. The five students who did not were removed from the study. Two students were removed because they consistently misunderstood instructions on one of the measures. The final sample included 15 participants.

Classroom Practices to Support SRL

Students' SRL development was supported in three ways: a) creation and use of study sheets for practice tests and graded unit tests; b) making metacognitive judgments about response accuracy on each test question; and c) completing a Self-Assessment Questionnaire (SAQ; See Appendix) before and after each unit test. The teacher developed these supports after participating in a three-year professional development program on SRL, then used them to address her students' apparent low motivation and confidence in mathematics.

Students were encouraged to create study sheets for practice tests that they completed one week before each of the eight unit tests. They could include any information that would fit on a single 8" x 11" sheet. During class, the teacher coached students in creating these study sheets. Practice tests were reviewed and discussed immediately after completion and students were encouraged to revise their study sheets to increase their usefulness for the upcoming unit test. After unit tests were graded and returned with teacher feedback, students were encouraged to revise their study sheets once again, and to use the revised version in the creation of a comprehensive study sheet for the culminating final exam. Creating study sheets supported student motivation and engagement through identifying important content covered in class; opportunities to revise study sheets following review of practice tests encouraged self-reflection on their study strategies (Paris & Paris, 2001).

During unit tests, students made metacognitive judgments after completing each question (called 'postdictions') by circling "Y" or "N" to indicate whether they thought their answer was correct. Reflecting on postdiction accuracy during test review in class was intended to offer students insight into their ability to make metacognitive judgments. Previous literature demonstrates this strategy is an effective means of developing metacognitive knowledge and awareness (e.g., Cleary et al, 2008; Zimmerman et al., 2011).

Just before each unit test, students completed the pre-test section of the SAQ (Hughes, 2012). They reported whether they studied and for how long. They then identified their learning and study strategies from a list of 19 options and reflected on their usefulness, thereby supporting metacognition. Students noted specific concerns about the upcoming test, gauged their readiness, and predicted their test grade (in percentages). Instructional time constraints prevented the teacher from having students complete the post-test section of the SAQ. For the same reason, pre-test SAQs were completed for only six of the eight unit tests.

MEASURES

Achievement

Achievement was measured using a percentage score attributed to each student, calculated by combining the weighted average of each student's scores on the eight unit tests and the final exam.

Metacognition

Hamann coefficients (Tobias et al, 1999) were calculated from students' judgments about the correctness of their test performance and used as a measure of KMA.

Indicators of motivation

Self-efficacy.

Self-efficacy in mathematics was evaluated pre- and post-course using a six-item self-efficacy scale (Urdan & Midgley, 2003). This scale has a reported internal consistency of .84 for a seventh-grade sample (Urdan & Midgley, 2003).

Task interest.

Interest in mathematics was assessed pre- and post-course using a five-item Task Interest Inventory (TII). The TII was adapted for use in assessing students' level of interest and enjoyment in learning mathematics, as opposed to learning in science or biology (Cleary et al, 2008). Cleary et al (2008) reported a strong internal consistency estimate (α = .96).

Perceived instrumentality.

Students' perceived value of mathematics was evaluated pre- and post-course using a Perceived Instrumentality Inventory (PII, Cleary, 2006). This inventory was designed to assess students' perceptions of the value or importance of studying and performing well in a particular subject (in this case, mathematics) (Cleary, 2006, p. 311). As recommended by Cleary, a five-item version of the PII was used instead of the original four-item version (personal communication, 2010). An internal consistency estimate for the PII was reported on the original four-item scale (α = .60, Cleary, 2006), but was not available for the current five-item scale.

Strategic Learning Behaviours

Attendance.

Student attendance scores were assigned based on presence during the 84 days of classes. Attending class in this case study was essential for students to benefit from SRL support, thus attendance scores were treated as indicators of strategic learning behaviour.

Time spent studying.

Pretest SAQs asked students to indicate the amount of time spent studying for each test. Although previous literature demonstrates inconsistent relationships between time spent studying and student achievement (Allen et al., 1972; Kember et al., 1995; Plant et al., 2005), we categorized time spent studying as a strategic learning behaviour, since the teacher repeatedly told students that studying will help them improve their grades.

Learning and study strategies.

The pretest SAQ measured strategic learning behaviour by asking students to select their study strategies from a list of 19 options.

Student-created study sheets.

Although strongly encouraged by the teacher, students' creation of study sheets was optional. Therefore, the use versus non-use of a study sheet for each unit test was recorded as an indicator of a strategic learning behaviour.

RESULTS

The impact of one teacher's class-wide support for SRL in a grade 9 Applied Mathematics classroom was examined using behavioural and self-report measures. We assessed students' metacognitive skills, motivational beliefs, strategic learning behaviours, and achievement in a naturalistic classroom setting at the beginning and end of the course.

Metacognitive Skills

Knowledge Monitoring Accuracy (KMA) was measured using a Hamann coefficient for each student for each unit test as well as the final exam (Schraw, 1995; Tobias et al, 1999). Table 1 shows average test grades and the corresponding Hamann coefficients for each test.

TABLE 1. *Test Grades and Hamann Coeficients throughout Course.*

Assessment	Grade		Hamann Coefficient	
	N	*M* (*SD*)	N	*M* (*SD*)
Unit 1	13	71.22 (19.90)	13	0.33 (0.34)
Unit 3	15	76.67 (16.08)	15	0.37 (0.29)
Unit 4	14	74.84 (14.65)	14	0.49 (0.24)
Unit 5	14	70.52 (14.51)	14	0.30 (0.41)
Unit 6	13	74.11 (14.47)	13	0.22 (0.46)
Unit 8	15	69.31 (24.80)	N /A	N /A
Final Exam	15	68.67 (9.19)	15	0.40 (0.26)

NOTE 1. Unit 2 was not tested, Unit 7 test was open-book, and for Unit 8, Hamann coefficient data were not collected.

NOTE 2. See p. 10 for an explanation of how Hamann coefficients are calculated and interpreted

To determine relationships between students' metacognitive knowledge, motivation (pre- and post-), and use of strategic learning behaviours, correlation coefficients were computed (Table 2) along with Hamann coefficients (measuring metacognition), self-efficacy, task-interest, and perceived instrumentality (measuring motivation), attendance, grades, number of study sheets, and number of study strategies used (measuring strategic learning behaviours).

This analysis yielded two notable findings. Specifically, Hamman coefficient scores (measuring KMA) were strongly related to achievement (r = .62, p < .05), and to posttest self-efficacy (r = .69, p < .01). Students who monitored their knowledge more accurately tended to receive higher grades and possess higher self-efficacy at the end of the course.

TABLE 2. *Spearman's Correlations between Questionnaires, Attendance, Grades, Number of Study Sheets, and Hamann Coef icients*

	Att	Pre SE	Pre TII	Pre PII	Pt SE	Pt TII	Pt PII	Ach	#S.S.	Ham
Att	-									
Pre SE	.113	–								
Pre TII	.275	.428	–							
Pre PII	.363	.527*	.180	–						
Pt SE	-.005	.326	.463	.290	–					
Pt TII	-.047	.478	.545*	.474	.772**	–				
Pt PII	-.090	.441	.491	.372	.254	.244	–			
Ach	.490	-.055	-.146	.218	.607*	.524	-.040	–		
#S.S.	.594*	-.011	-.509	.034	-.048	-.281	-.354	.276	–	
Ham	.408	-.058	.163	.193	.687**	.469	.027	.621*	.376	–
#Strat	.593*	.276	-.181	.678*	.162	.021	.164	.227	.548	.400

NOTE. * $p < .05$ (2- tailed),** $p < .01$ (2-tailed). Att. = Attendance, calculated as number of days present out of 84; Pre = Pretest; Pt = Posttest; SE =Self-Efficacy scale from the Patterns of Adaptive Learning Scale (PALS, Urdan & Midgley, 2003); TII = Task Interest Inventory (Cleary, 2006); PII = Perceived Instrumentality Inventory (Cleary, 2006); % = Grades; # S.S. = Number of times had study sheet; Ham = Hamann coefficients; # Strat. = Number of strategies used when studying. Sample size for all correlations was n = 15 except: correlations with Grades (n = 13), correlations with Hamann coefficients (n = 13), and correlations with Number of strategies used when studying (n = 12). Students' motivational beliefs were measured using adapted versions of the Task Interest Inventory for Math (TII) and the Perceived Instrumentality Inventory (PII) (Cleary, 2006). Each of these measures consists of five-items and uses a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The TII was adapted for use in assessing students' level of interest and enjoyment in learning mathematics, as opposed to learning in science or biology (Cleary et al., 2008). Cleary et al. (2008) reported changes they made to the original version of the TII , including rephrasing two of the items from negative to positive and adding the fifth item, resulting in a strong internal consistency estimate (α = .96).

Motivational Beliefs

Indicators of students' motivational beliefs were self-reports of self-efficacy (SE), task interest (TII), and perceived instrumentality (PII). The internal consistency of these measures was evaluated using pre-and post-course questionnaire responses. Table 3 shows means, standard deviations, and Cronbach's alpha internal consistency coefficients for each measure. The internal consistency on these measures was generally high, with PII (perceived usefulness of mathematics) at pretest showing the lowest coefficient (α = .68). Means for all measures were above the mid-point at pre- and post-course. All mean scores were higher at the end of the course than at the beginning, although the average scores on PII were highest of the three measures.

TABLE 3. *Means, Standard Deviations, and Cronbach's Alpha Internal Consistency Coef icients for Measures and Subscales.*

Measure	M	SD	α
Pre SE	3.93	0.71	.857
Post SE	4.04	0.80	.897
Pre TII	3.09	1.04	.909
Post TII	3.49	1.17	.975
Pre PII	4.40	0.64	.676
Post PII	4.71	0.51	.934

NOTE. SE = Self-Efficacy scale from the Patterns of Adaptive Learning Scale (PALS, Urdan & Midg-ley, 2003); TII = Task Interest Inventory (Cleary, 2006); PII = Perceived Instrumentality Inventory (Cleary, 2006). All values of n are 15, except for Post TII, which had n = 14 for Cronbach's alpha but n = 15 for mean and standard deviation.

Wilcoxon signed-rank tests were used to compare pre-and post-semester SE, TII, and PII measures. PII showed a statistically significant difference from pretest ($n = 15$, $Mdn = 4.6$) to posttest ($n = 15$, $Mdn = 5.0$), $Z = -2.02$, $p < .05$, while pre- and post-course differences in TII and SE did not reach significance. Thus, while students' perceptions of the usefulness of mathematics increased significantly throughout the course, their interest in, and self-efficacy for mathematics remained relatively static.

Analyses between motivation measures showed three statistically significant correlations: one between pretest self-efficacy and perceived instrumentality ($r = .53$, $p < .05$), another between posttest self-efficacy and task-interest ($r = .77$, $p < .01$), and a third between pre-and posttest task-interest ($r = .55$, $p < .05$).

Strategic Learning Behaviours

Strategic learning behaviours associated with SRL in this study were: attendance, number of minutes spent studying, number of study strategies used, and creation of study sheets. Descriptive statistics on these measures appear in Table 4.

Average attendance was 73.87 days out of a possible 84 instructional days (*SD* = 8.14), with a range of 56 to 83 days. Since study sheets were optional, creation of study sheets was treated as evidence of strategic efforts toward learning and test performance. The average number of study sheets created was 3.33 (*SD* = 2.16), out of a possible seven (including six unit tests and the final exam). Minimum and maximum values showed that some students did not use study sheets at all, while others used them for every test.

Another measure of learning and study behaviour was the number of learning strategies selected from the list of 19 on the SAQ for (each of six) unit tests and the final exam. The total number of strategies averaged 31.58 (*SD* = 19.51), although the high standard deviation indicated significant variability in the number of strategies used. Strategies reported most frequently were "stayed up to date on each day's homework", "completed the unit study sheet", and "used my Multiple Subject Instructional Period to complete homework / assignments / review." Strategies least often selected were "re-did challenging homework questions" and "tested myself on the material." Thus, while most students reported reviewing, practicing, summarizing, and getting help in understanding information during each mathematics unit, less emphasis was placed on identifying areas of importance or studying strategically for tests.

TABLE 4. *Means, Standard Deviations, and Minimum and Maximum Values for Behavioural Indicators of Motivation and SRL*

Measure	M	Median	SD	Min	Max	N
Attendance	73.87	75.00	8.14	56.00	83.00	15
Min Studying	202.19	116.25	235.40	.00	735.00	8
# of Strategies	31.58	31.00	19.51	1.00	68.00	12
Study Sheets	3.33	4.00	2.16	.00	7.00	15

NOTE. Attendance = days present out of 84; Min Studying = Total # of minutes spent studying on Units 1, 3, 4, 5, 6, and 8; Study Sheets = Number of times students had a study sheet out of 7 possible tests and the final exam; # of Strategies = Number of reported study strategies (out of possible 19 per unit) used during Units 1, 3, 4, 5, 6, and 8.

Attendance was significantly related to the number of different learning strategies used ($r = .59$, $p < .05$) and the number of participants' study sheets ($r = .59$, $p < .05$). In other words, students who missed fewer days of class tended to use study sheets as well as other learning and study strategies more frequently than students who were often absent. Pretest scores on the perceived usefulness of mathematics (PII) also predicted the number of learning strategies students used ($r = .68$, $p < .05$), indicating that students who valued mathematics were more likely to use more learning and study strategies.

An average of 202.19 minutes were spent studying (*SD* = 235.40) across six unit tests and the final exam. The large standard deviation on this measure shows significant variation in how much time students spent studying. The range shows that some students did not study at all, while some studied for as long as 735 minutes during the course. In this case, time spent studying is best described by the median of 116.25 minutes.

DISCUSSION

This article describes a case study on the effects of a teacher's SRL supports for lower achieving students in a grade 9 Applied Mathematics classroom. Research suggests that SRL supports may increase student achievement and improve metacognitive and motivational self-regulation capacities if students adapt their learning behaviours in response to such supports (Butler et al, 2013; Cleary et al, 2008; Paris & Paris, 2001; Zimmerman et al., 2011). Since few studies have examined SRL development in an authentic classroom setting, unique insights are offered on the potential impact of SRL supports. Data collected over a semester allowed investigation into how metacognitive skills, motivational beliefs, and strategic learning behaviours were related to student achievement. Pre-and- post-course scores on motivation variables (self-efficacy, perceived value of mathematics (TII), and interest in mathematics (PII) provided an indicator of possible changes in motivation as classroom support for SRL development was implemented throughout the course.

By asking students to practice making metacognitive judgements, creating, and revising study sheets, and identifying studying techniques, the teacher supported metacognition, motivation, and strategic learning behaviours. Despite the small sample size, some statistically significant relationships were found among SRL-related indicators and achievement. The absence of statistical significance in some cases may contribute to our understanding of potential shortcomings of the use of class-wide strategies.

Supporting Metacognitive Knowledge Development

In this study, asking students to practice assessing their mathematics knowledge by judging the accuracy of their test question responses (KMA, measured by Hamann coefficients) measured metacognitive knowledge, and supported metacognitive skill development (Paris & Paris, 2001).

Pre-test mathematics self-efficacy was unrelated to KMA and post-test self-efficacy. However, students with higher KMA to start with exited the course with higher self-efficacy than those with lower KMA. Thus, successfully assessing test question accuracy may have had a positive impact on students' self-efficacy. It is not clear though, whether students' increased self-efficacy was fostered by making metacognitive judgements or by achieving high test grades, or both (see Nietfeld et al, 2006).

The KMA measure was positively correlated with test grades and post-test self-efficacy; however, test grades did not increase during the course. Thus, there is no evidence of an impact on achievement due to practicing these metacognitive judgments. Despite this outcome, students who could accurately assess the veracity of their answers generally performed better on tests. This relationship is consistent with previous studies showing a positive relationship between metacognitive knowledge and performance (Nietfeld et al., 2006; Tobias & Everson, 2009), and demonstrates this relationship in the naturalistic setting of a high school classroom.

Relationships between Motivational Beliefs, SRL and Achievement

It was expected that motivational beliefs (i.e. self-efficacy, task interest and perceived instrumentality) measured at the beginning of the course would be related to indicators of effort in the course (i.e., strategic learning behaviours) as ascertained by attendance, number of minutes spent studying, and use of various learning strategies. However, pre-test mathematics interest was related only to post-test mathematics interest, suggesting that students' interest remained relatively consistent through the semester and was not influenced by other variables. In contrast, pre-test perceived instrumentality (i.e. perceived value of mathematics) was related to the total number of different learning and study strategies students used. The temporal nature of this outcome suggests the relationship could be causal. If so, it may be that students will use a broader range of learning and study strategies if teachers help them to see real-life, personally relevant uses for mathematics.

Interestingly, post-test self-efficacy and task interest correlated with each other and with test grades, which was not the case in pre-test findings. This is consistent with previous research (e.g. Bandura, 1989), supporting the idea that performance influenced students' motivational beliefs, rather than the reverse.

Notably, significant differences were not found in self-efficacy and task interest from pre- to post-test. Further, these pre-test measures did not predict measures of strategic learning behavior or test grades. This suggests that pre-course indicators of mathematics-related self-efficacy and task interest provide little to no indication of who will employ strategic learning behaviours, who will achieve high course grades, or who will report strong motivation at the end of the course. Should these findings be replicated with larger samples, educators working with students entering high school as low mathematics achievers should avoid making assumptions about their students' abilities or predicting their future efforts based on initial levels of interest or confidence.

Effects of SRL Support

Several of the SRL support practices employed in this study align with those suggested by Paris and Paris (2001), such as equipping students with a broad array of learning strategies and encouraging them to reflect on which strategies they find most useful. On the pretest SAQ, students identified strategies they used when preparing for the test, and then reflected on their usefulness. The teacher also tried to encourage students to create study sheets in preparation for practice tests. Study sheets gave students the opportunity to reflect on performance feedback and adapt their learning and study behaviours for each unit test.

During class, the teacher frequently promoted the use of multiple learning strategies and study sheets. It was not surprising, then, that students with higher attendance used a greater number of strategies (r = .59) and used study sheets more often (r = .59). However, neither of these practices predicted scores on outcome variables (i.e., KMA, grades, or post-semester measures of self-efficacy, task interest, or perceived instrumentality).

That students' use of multiple study strategies and study sheets was unrelated to achievement is notable. In contrast, Zimmerman et al. (2011) found that achievement outcomes were more positive for students who were given SRL training than for those without training. Although achievement was related to a number of variables in the present study, it did not follow from higher initial levels of motivation, nor did it correlate with strategic learning behaviours (attendance, creating study sheets, and adopting multiple learning strategies). One explanation could be that the wide variability in students' responses to these SRL supports negated any changes that might have occurred for some students within this small sample. However, given the importance of specific and conditional feedback (e.g., Nietfeld et al, 2006; Zimmerman et al., 2011), it is also possible that insufficient teacher guidance was given for making effective use of feedback and reflection to improve strategies and performance. A key feature of the SRL support in Zimmerman et al.'s (2011) study was individualized coaching to assist students in examining their errors and deciding on specific strategies for subsequent learning and studying. Paris and Paris (2001) also note that students "need to be given enough information about various strategies to know how, when, and why to apply them; and the teacher also needs to guide students to recognize the effects of using specific strategies" (p. 93). In this study, the absence of individualized guidance may explain why these students were unable to adapt their learning behaviours effectively. Given the high need for academic support in Applied Mathematics classes, this may have been one area where more intensive, individualized support was needed.

LIMITATIONS AND IMPLICATIONS OF THE STUDY FOR RESEARCH AND PRACTICE

Although the examination of SRL in a naturalistic setting is a strength of this study, there are a number of disadvantages associated with this methodological approach. First, although 15 students is a reasonable number for a case study, generalization of the results is limited. Second, it was not possible to randomly select the participating teacher, class, or students, further limiting generalizability of these findings. Third, inconsistent attendance meant that some measures were not completed by all students. Fourth, classroom time constraints meant that students did not complete the SAQ prior to all tests or use the post-test section of the SAQ. Finally, although mathematics education research (e.g. Boaler, 2015) suggests that different approaches to mathematics pedagogy can impact students' motivation, metacognitive skills, learning strategies, and subsequently achievement, this study did not allow for systematic tracking of the instructor's pedagogical approach. Moreover, while the importance of both conceptual and procedural understanding is recognized, these aspects of mathematical learning and assessment were beyond the scope of this study; therefore, this information was not collected.

Despite these limitations, examination of relationships among learning and instructional variables as they play out in real-world contexts is important (Barab, 2006). As such, the insights offered by this study far outweigh the limitations. Focusing on this classroom allowed for the evaluation of authentic supports for students' SRL development, increasing external validity. Using both behavioural and self-report measures of motivation and SRL provided triangulation of data, helping to strengthen the conclusions that can be drawn in an authentic setting where control over variables is limited (Barab, 2006).

The support strategies here included varied opportunities for self-assessment, performance feedback, and encouragement to use multiple learning strategies. Such opportunities are thought to contribute to students' development of metacognitive knowledge, subject motivation, and SRL strategies (Buzza, 2013). While there were limited outcomes within this sample, previous evidence of positive effects on achievement from student use of such metacognitive skills supports their value in academic contexts (e.g., Winne & Perry, 2000). Additionally, the creation of study sheets could be a useful strategy for students in diverse academic learning situations (such as in other courses), given the reflection opportunities that this practice provides.

As noted by Winne and Perry (2000), metacognitive skills are key features of SRL; accurately evaluating one's learning strengths and weaknesses and subsequently selecting appropriate learning and study strategies are important examples of these skills. Using KMA as an indicator of knowledge monitoring is advantageous as it avoids problems associated with self-report measures of metacognitive processes such as social desirability responding and potentially inaccurate memories or judgments of cognitive processes during learning (Tobias & Everson, 2009; Winne & Perry, 2000).

However, the lack of individualized guidance on making productive use of the feedback given during this study may have limited the effectiveness of SRL supports for students. Previous studies involving SRL support (e.g., Cleary et al, 2008; Zimmerman et al., 2011) included individualized feedback and guidance to assist students in adapting their learning strategies based on performance data. The extent to which this occurred in Butler et al's (2013) study is unknown and may have varied across classrooms, but more positive achievement outcomes were shown with support being tailored to specific learning tasks, contexts, and content. Research also indicates that opportunities to engage in self-assessment are unlikely to enhance performance if the learner is unable to change strategies and behaviour effectively. Low-achieving students typically demonstrate lower levels of self-efficacy as well as reactive rather than proactive self-regulatory behaviours (Buzza & Dol, 2015; Zimmerman, 2008; 2012); they may be especially in need of individualized support to effectively alter study strategies and behavior.

This raises significant challenges for practical application, especially given the limited time and opportunities that many teachers have for individualizing support. Intensive one-on-one interventions might not be feasible in most classroom situations. However, it is yet unknown how much scaffolding is optimal, and how much variability exists in the level of scaffolding needed by different students. Answers to these important questions may suggest how to balance class-wide support with individualized coaching. Future studies may also address teaching practices that help groups of students consider the meaning of feedback on learning tasks; students might then work collaboratively to strategize on ways to improve their learning. Next steps in SRL research may include classroom-based interventions that test how well learners can improve their metacognitive skills with both feedback and strategic input from one another, contributing to a clearer understanding of how, when and why individualized support is required.

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APPENDIX:

SELF-ASSESSMENT QUESTIONNAIRE (HUGHES, 2012)

PRE-TEST

Unit#___ Topic:___________________________ Name:_____________
____

<table>
<tr><td>In the space below write about any concerns you have about the upcoming test.</td><td colspan="2">Preparing for this test what strategies and techniques did you use? Please check any that apply.</td></tr>
<tr><td rowspan="3">__________________________
____
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____
____
____
____
____
___________</td><td rowspan="3">□ Reread each lesson with a coloured pen / highlighter.

□ Wrote additional process notes to myself while the lesson was still fresh.

□ Redid the examples from the lesson.

□ Stayed up-to-date on each day's homework.

□ Got help with any challenging homework problems.

□ Got caught up on missed lessons right away.

□ Explained the material to someone else.

□ Redid challenging homework questions.

□ Completed the assigned review questions.

□ Completed the unit study sheet.</td><td rowspan="3">□ Corrected any quizzes or assignments.

□ Used my MSIP period to complete homework / assignments / review.

□ Worked with someone else during class time.

□ Worked independently during class time.

□ Tested myself on the material.

□ Studied with someone else for the test.

□ Studied independently for the test.

□ Got help in MathSIP

□ Other:
________________</td></tr>
<tr></tr>
<tr></tr>
<tr><td>Did you study for this test?
Yes __ No __</td><td colspan="2"></td></tr>
<tr><td>How much time did you spend studying for this test? _______</td><td colspan="2"></td></tr>
<tr><td colspan="3">Please make a prediction about your test score: 100-80 79-70 69-60 59-60 50-</td></tr>
</table>

POST-TEST

1. What kinds of questions did you do well on?	2. What kinds of questions did you NOT do well on?
3. On the study sheet you created, what information was <u>helpful</u> to you in writing the test? ___ Formulas ___ Definitions ___ Sample problems ___ Tips/notes to myself ___ Diagrams ___ Rules ___ Other: ______________________	4. What information was <u>missing</u> from the study sheet that *would have* helped? ___ Formulas ___ Definitions ___ Sample problems ___ Tips / notes to myself ___ Diagrams ___ Rules ___ Other: ______________________
5. Using a DIFFERENT COLOURED pencil, pen, or marker, add the items you thought would have been helpful to your study sheet □	
Correct your test questions and resubmit the corrected test and revised study sheet to your teacher! □	

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