Influences of Metacognitive and Self-Regulated Learning Strategies for Reading on Mathematical Literacy of Adolescents in Australia and Singapore

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This study, drawing on data from the Programme for International Student Assessment (PISA) 2009, explored the influences of metacognitive and self-regulated learning strategies for reading on mathematical literacy of adolescents in Australia and Singapore. Ordinary least squares (OLS) regression analyses revealed the positive influences of metacognitive learning strategies and control strategies for reading on mathematical literacy of adolescents in Australia and Singapore. In contrast, the two components of self-regulated learning strategies for reading—memorization and elaboration—had negative influences on mathematical literacy of adolescents in Australia and Singapore.

Metacognition, self-regulation, and self-regulated learning are the three influential types of cognitive control processes (Schunk, 2008). Metacognition, originally conceptualized by Flavell (1971, 1976, 1979), refers to “any knowledge or cognitive activity that takes as its cognitive object, or that regulates, any aspect of any cognitive activity” (Flavell, Miller, & Miller, 1993, p. 150). In other words, metacognition is “one’s knowledge concerning one’s own cognitive processes” (Flavell, 1976, p. 232). Metacognition is a multifaceted phenomenon, and comprises of two fundamental elements—knowledge of cognition (metacognitive knowledge) and regulation of cognition (metacognitive control or regulation; Brown, 1987; Flavell, 1979). Metacognitive knowledge is multidimensional in nature, and “consists primarily of knowledge or beliefs about what factors or variables interact in what ways to affect the course and outcomes of cognitive enterprises” (Flavell, 1979, p. 907).

There are three distinct, but interrelated, facets of metacognitive knowledge: declarative knowledge, procedural knowledge, and conditional knowledge (Brown, 1987; Jacobs & Paris, 1987). Declarative metacognitive knowledge refers to “one’s knowledge about oneself as a learner, including knowledge about one’s own abilities (strengths and weaknesses)” (Harris, Graham, Brindle, & Sandmel, 2009, p. 133). Procedural metacognitive knowledge refers to “the knowledge needed to carry out procedures, including strategies, in order to apply declarative knowledge and reach goals” (p. 133). Finally, conditional metacognitive knowledge refers to “knowing when, where, and why to use declarative knowledge as well as particular procedures or strategies (procedural knowledge)” (p. 133).

Self-regulated learning, on the other hand, is defined as “the process by which learners personally activate and sustain cognitions, affects, and behaviours that are systematically oriented toward the attainment of learning goals” (Schunk & Zimmerman, 2007, p. 7). Self-regulated learners are “metacognitively, motivationally, and behaviourally active participants in their own learning process” (Zimmerman, 1986, p. 308). The process of self-regulated learning comprises of three distinct cyclical phases: forethought, performance or volitional control, and self-reflection (Zimmerman, 1998, 2000; Zimmerman & Kitsantas, 2005). Each phase includes several important subprocesses (Zimmerman, 1998). The forethought phase includes goal setting, strategic planning, self-efficacy, learning goal orientation, and intrinsic interest in the task. The performance phase includes focusing attention on the learning task, using self-instruction, imagery, and self-monitoring. The self-

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reflection phase includes self-evaluation, attributions, and self-reactions. Whereas proactive learners tend to have high quality forethought and performance phase processes, reactive learners tend to rely on post-performance self-reflections to learn (Zimmerman, 2008). Therefore, proactive learners self-regulate more effectively than reactive learners (Zimmerman, 2008).

Proactive learners—self-regulated learners—are strategic learners (Hadwin, 2008). Van Blerkom (2009) sums up the characteristics of self-regulated learners as follows:

> Self-regulated learners are actively involved in their own learning, they set goals, develop plans for achieving those goals, monitor their progress, and evaluate their results. They tend to be more motivated, have higher self-efficacy, and focus more on mastering the material than on grades. Self-regulated learners value the learning process itself and set mastery goals, which lead to the use of self-regulated learning strategies. They use more effective learning strategies and also tend to make adjustments when they are having difficulty mastering material. (pp. 4–5)

Therefore, teachers and policymakers alike agree that students need to be self-regulated learners to learn effectively (Boekaerts, 1997). Although a substantial body of research has examined the influences of metacognitive and self-regulated learning strategies for reading and mathematics on reading and mathematics achievement of adolescents (e.g., Özsoy, 2011; Schneider & Artelt, 2010; van der Stel, Veenman, Deelen, & Haenen, 2010), there is a dearth of research on the influences of metacognitive and self-regulated learning strategies for reading on mathematical literacy of adolescents. However, a growing body of research has demonstrated the crucial role that proficiency in the language of test plays in enhancing mathematics achievement among school children (e.g. Abedi & Herman, 2010; Abedi & Lord, 2001; Beal, Adams, & Cohen, 2010; Le, 2011).

In one of such studies, Beal and her colleagues (2010) investigated the relationship between proficiency in the language of test and mathematics performance of 442 Grade 9 students enrolled in Algebra 1 classes in four high schools in the United States. The authors found that students who had to devote cognitive resources to understand a problem presented in English text performed less well in mathematics than their peers who were able to read English well. Prior research on cognitive processes in mathematics problem solving has also documented similar findings—students who must devote substantial cognitive resources to English comprehension will have less capacity available to devote to math problem-solving operations (e.g., Swanson & Jerman, 2006; Walczyk & Griffith-Ross, 2006). In other words, "if working memory must be devoted to low-level operations, there are fewer cognitive resources available to allocate to higher-order problem-solving activities, such as forming an appropriate problem representation, identifying needed information, and checking progress toward the solution" (Beal et al., 2010, p. 60).

Recently, Le (2011), using the PISA 2003 data sought to detect differential item functioning (DIF) in mathematics items related to reading ability among 275,000 adolescents in 41 countries. He found that lower reading ability students were most disadvantaged on open constructed-response items and advantaged on complex multiple-choice, closed-constructed, and multiple-choice items. Further, lower reading ability students were also disadvantaged on items that required understanding, applying or establishing a formula, and items that required selecting relevant information.

Indeed, learning to perform complex tasks in mathematics may rely heavily on academic language proficiency (Kieffer, Lesaux, Rivera, & Francis, 2009). Because facility with the academic language used to characterize, express, and apply mathematical concepts are indispensable for the development of mathematical skills and mastery of mathematics concepts, students who have not had the opportunity to develop the specialized academic language skills may struggle to understand much of the language that is used in mathematics classrooms and in the mathematics curricular materials (Kieffer et al., 2009). Hence, such linguistically challenged students may perform poorly on assessments of mathematics (Kieffer et al., 2009). Given the pivotal role of academic language proficiency in mediating the learning of mathematics, it is imperative to explore the influences of metacognitive and self-regulated learning strategies for reading on mathematical literacy.

As Swanson, Jerman, and Zheng (2009) opine, "it is hard not to overemphasize the importance of mathematical ability in a society that requires technical competence among its citizens, a competence that in turn draws on high levels of mathematical literacy" (p. 175). While deficiencies in mathematical competence may seriously limit individuals' educational opportunities (Hanich, Jordan, Kaplan, & Dick, 2001), individuals proficient in mathematics may earn approximately 38% more than their peers who are not proficient in mathematics (Clarke & Shinn, 2004). Hence, the purpose of the present study was to examine the influences of metacognitive and self-regulated learning strategies for reading on mathematical literacy of adolescents in Australia and Singapore. Specifically, the study addressed the following research question: How well do metacognitive and self-regulated learning strategies for reading predict mathematical literacy among adolescents in Australia and Singapore? Australia was one of the top performing Western countries, which took part in the Programme for International Student Assessment (PISA) 2009, and Singapore was one of the top performing East Asian countries. However, there were statistically significant differences between Australian and Singaporean adolescents in terms of their achievement in reading and mathematics (OECD, 2010). Hence, these two countries were chosen for comparison in the present study.

Method

Data

Data for the study were drawn from the 2009 Programme for International Student Assessment (PISA). PISA is a collaborative initiative of member countries of the Organization for Economic Cooperation and Development (OECD) that is aimed at assessing the knowledge and life skills of 15-year-old students as they approach the end of their compulsory period of schooling. It is a policy-oriented assessment program, designed and guided by an international steering committee to provide regular data that pertain to the most pressing policy issues confronting educational administrators and policy makers around the world. The PISA 2009 data include measures of student proficiency in reading, mathematics, and science; however, reading was the major domain in PISA 2009, assessed with a large and comprehensive set of test items, whereas mathematics and science were minor domains. The Australian sample comprised of 14251 students from 353 schools and the Singaporean sample comprised of 5283 students from 171 schools.

Measures

Mathematical literacy was the outcome measure in the study. This variable was based on 35 test items and was reported on a continuous scale as a set of five plausible values for each student. The plausible values were random elements from the set of scores that could be attributed to each student and their variation helped capture the measurement error at the individual student level (OECD, 2011). The International Database (IDB) Analyser, a plug-in for SPSS, was used to combine the five plausible values.

Metacognitive learning strategies for reading were measured using the PISA 2009 indices: (a) metacognitive strategies-understanding and remembering, and (b) metacognitive strategies-summarizing. In the PISA 2009 assessment, students were asked to report the usefulness of a number of metacognitive strategies for understanding, remembering, and summarizing the text (11 items). Students' ordering of the metacognitive strategies in reading was compared with the reading experts' agreed order of the metacognitive strategies in reading. A score was assigned to each student based on the reading experts' agreed order of the items (see OECD 2010, 2011). Higher scores on both indices indicate a preference for metacognitive strategies in reading.

Self-regulated learning strategies for reading were measured using the PISA 2009 indices: (a) use of memorization strategies (4 items); (b) use of elaboration strategies (4 items); and (c) use of control strategies (5 items). These items were rated on a 4-point Likert scale ranging from 1 (*almost never*) to 4 (*almost always*). Cronbach's alpha was used to measure the internal consistency of the three indices: use of memorization strategies (α = .76, .74 in Australia and Singapore, respectively), use of elaboration strategies (α = .79, .77, respectively), and use of control strategies (α = .84, .76, respectively).

In addition to these measures, student demographic variables, gender (0 = male, 1 = female) and socio-economic status (SES), were included in the study. The PISA 2009 index of economic, social, and cultural status (ESCS), an index of SES derived from parental occupations, parental education, and home possessions (see OECD, 2011), was used as an SES measure in the current study.

Results

The descriptive statistics and the correlation between outcome variable and predictor variables are presented in Tables 1 and 2. Metacognitive learning strategies for reading—understanding and remembering and summarizing—were positively correlated with the mathematical literacy of adolescents in Australia and Singapore. Similarly, two of the self-regulated learning strategies for reading—use of elaboration and control strategies—were also positively correlated with the mathematical literacy of adolescents in Australia and Singapore. The use of memorization strategies was positively correlated with mathematical literacy in Australia, whereas it was negatively correlated with mathematical literacy in Singapore.

Two separate ordinary least squares (OLS) regression analyses were conducted to address the purpose of the study (see Table 3). Mathematical literacy was the dependent variable. Metacognitive learning strategies for reading—understanding and remembering and summarizing—and self-regulated learning strategies for reading—use of memorization, elaboration, and control strategies—were the independent variables. Student demographic variables, such as gender and SES, were also included in the regression model. The overall regression models predicting mathematical literacy from metacognitive learning strategies for reading, self-regulated learning strategies for reading, and student demographic variables were statistically significant in Australia, Adjusted R^2 = .32, $F(7, 13264) = 819.16$, $p < .001$, 95% CI [.30, .33], f^2 = .47; and Singapore, Adjusted R^2 = .31, $F(7, 5203) = 333.43$, $p < .001$, 95% CI [.29, .33], f^2 = .45.

Table 1
Descriptive Statistics

	Australia		Singapore	
	M	*SD*	*M*	*SD*
Mathematical literacy	519.49	90.77	563.38	103.42
Gender	.52	.50	.49	.50
Economic, social, and cultural status (ESCS)	.35	.75	-.43	.80
Metacognition—summarizing	-.08	1.03	.17	1.01
Metacognition—remembering and understanding	.03	1.01	.05	.95
Memorization strategies	-.05	1.00	.06	.91
Elaboration strategies	-.13	1.01	.24	.92
Control strategies	.08	1.10	.30	.93

Table 2
Bivariate Correlations

	Australia	Singapore
	Mathematical Literacy	*Mathematical Literacy*
Gender	-.07	-.03
Economic, social, and cultural status (ESCS)	.37	.38
Metacognition—summarizing	.38	.40
Metacognition—remembering and understanding	.33	.29
Memorization strategies	.06	-.15
Elaboration strategies	.13	.04
Control strategies	.32	.23

Note. All coefficients are statistically significant, $p < 0.05$.

Table 3
Ordinary Least Squares (OLS) Regression Analyses Predicting Mathematical Literacy

	Australia		Singapore	
	B	*SE*	*B*	*SE*
Constant	521.80	2.33	578.94	2.19
Gender	-28.57	1.95	-17.09	2.58
Economic, social, and cultural status (ESCS)	30.58	1.29	37.53	2.08
Metacognition—summarizing	21.37	1.17	27.38	1.53
Metacognition—remembering and understanding	10.62	1.07	11.07	1.41
Memorization strategies	-13.59	1.29	-18.33	1.42
Elaboration strategies	-3.40	1.09	-6.74	1.78
Control strategies	24.04	1.25	21.06	2.15

Note. All coefficients are statistically significant, $p < 0.05$.

Metacognitive learning strategies for reading, understanding and remembering (B = 21.37, $p < .05$; B = 27.38, $p < .05$, Australia and Singapore, respectively) and summarizing (B = 10.62, $p < .05$; B = 11.07, $p < .05$, respectively) were statistically significant positive predictors of mathematical literacy in Australia and Singapore. Adolescents in Australia and

Singapore who had higher scores for metacognition in reading scored statistically significantly higher in mathematics than their peers in who had lower scores for metacognition in reading. Similarly, one of the self-regulated learning strategies for reading, use of control strategies, was a statistically significant positive predictor of mathematical literacy in both Australia (B = 24.04, p < .05) and Singapore (B = 21.06, p < .05). Adolescents in Australia and Singapore who frequency used control strategies in reading scored statistically significantly higher in mathematics than their peers who infrequently used control strategies in reading. In contrast, the other two self-regulated learning strategies for reading, use of memorization strategies (B = -13.59, p < .05; B = -18.33, p < .05, Australia and Singapore, respectively) and use of elaboration strategies (B = -3.40, p < .05; B = -6.74, p < .05, Australia and Singapore, respectively), were statistically significant negative predictors of mathematical literacy in both Australia and Singapore. Adolescents in Australia and Singapore who frequently used memorization and elaboration strategies in reading scored statistically significantly lower in mathematics than their peers who infrequently used memorization and elaboration strategies in reading.

Finally, student demographic variables, gender and SES, were also predictive of mathematical literacy in Australia and Singapore. The Australian and Singaporean female students scored statistically significantly lower than their male counterparts in mathematics. The ESCS, a measure of SES, was a positive predictor of mathematical literacy in Australia and Singapore. Put another way, Australia and Singapore are leaving some adolescents behind in mathematics, and they tend to be the less privileged.

Discussion

The purpose of the study was to examine the influences of metacognitive and self-regulated learning strategies for reading on mathematical literacy of adolescents in Australia and Singapore. The results of the study suggested the positive influences of metacognitive learning strategies for reading—understanding and remembering and summarizing—on mathematical literacy of both Australian and Singaporean adolescents. These findings suggest the key the role that metacognitive skills in reading may play in enhancing the mathematics achievement of adolescents in Australia and Singapore.

Because metacognitive instruction may help to enhance metacognition and learning in a broad range of students (see Veenman, Elshout, & Busato, 1994), classroom teachers in Australia and Singapore may need to tailor their classroom teaching accordingly. A successful metacognitive instructional programme, however, may need to abide with three fundamental principles (Veenman, Hout-Wolters, & Afflerbach, 2006): embedding metacognitive instruction in the content matter to ensure connectivity; informing learners about the usefulness of metacognitive activities to make them exert the initial extra effort; and prolonged training to guarantee the smooth and maintained application of metacognitive activity.

The results of the study also revealed that two of the self-regulated learning strategies for reading—use of memorization and elaboration strategies—were negatively associated with mathematical literacy of adolescents in Australia and Singapore. Students who use elaboration strategies tend to think deeply about concepts, and tend to integrate what they learn with other material. Furthermore, they are able to transfer concepts to different situations. However, use of elaboration strategies in reading did not help adolescents in Australia and Singapore to enhance their achievement in mathematics. This finding suggests that elaboration strategies in reading may not be similar to the elaboration strategies used in mathematics because the use of elaboration strategies in mathematics has been found to be positively associated with mathematics achievement. Hence, there is an inverse relationship between elaboration strategies in reading and mathematical literacy among adolescents in Australia and Singapore. Similarly, the use of memorization strategies in reading as well did not help adolescents in Australia and Singapore to enhance their achievement in mathematics. Students who use memorization learning strategies tend to resort to memorization and rote learning (Aharony, 2006). Although memorization strategy is useful for learning basic and new material, it might not be conducive to a deep understanding of concepts.

In contrast, the use of control strategies was positively associated with mathematical literacy among adolescents in Australia and Singapore. Prior studies have demonstrated that the use of control strategies is associated with positive educational outcomes (e.g., Marsh, Hau, Artelt, Baumert, & Pescha, 2006) and mathematics self-concept (Marsh et al., 2006). However, such studies explored the influence of control strategies in mathematics on mathematics achievement. The findings of the present study pinpoint the critical role that control strategies in reading may play in promoting mathematical literacy among adolescents in Australia and Singapore. "Students who can control their own learning in an effective manner are assumed to set realistic goals, to select learning strategies and techniques appropriate to the demands of particular tasks, to shield themselves from competing intentions, and to maintain motivation when learning" (Marsh et al., 2006, p. 345).

In conclusion, the findings of the study provide empirical support that metacognitive strategies in reading may help enhance adolescents' achievement in mathematics. Similarly, the findings of the study suggest the critical role that control strategies in reading may play in improving the mathematical literacy of adolescents. However, the negative influence of the use of elaboration strategies in reading on mathematical literacy of adolescents in Australia and Singapore warrant further investigation.

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