Thinking About Thinking: Students' Perceived Usefulness of Metacognitive Strategies and Effects on Academic Literacy

Steven Svoboda

University of Nebraska - Lincoln

Abstract

This multilevel, multivariate study examined the effects of the perceived usefulness of summarizing, and understanding and remembering to predict plausible values of reading, mathematics, and science competencies of 5,233 fifteen-year-old students within 165 schools in the United States. Data were taken from PISA (2009) and analyzed using PROC MIXED within SAS 9.3. As hypothesized, the perceived usefulness of metacognitive strategies and their interaction were significant, positive predictors of students' plausible values in reading, mathematics, and science, holding everything else constant. The effects of the perceived usefulness of metacognitive strategies are not domain specific.

Keywords: metacognition, reading, mathematics, science, plausible values, PISA

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In the broadest sense, metacognitive ability is the degree to which a person is able to think about his or her own thinking (Jacobs & Paris, 1987). Flavell (1979) provides a useful definition of metacognition and defines it as "knowledge and cognition about cognitive phenomena" (pg. 906). Arslan and Akin (2014) provide a more nuanced definition of metacognition and describe it as the "knowledge, awareness, and deeper understanding of one's own cognitive processes and products," and it may be "expanded through reflection on learning experiences" (pg. 33). The definition of metacognition is complex and under debate, but at its core, metacognition is thinking about thinking.

It is important to note that the computational power of the human brain is not unlimited. Attention or "the mental energy used to perceive, think, and understand" is limited (Bruning et al. 2011, pg. 15); however, as Bruning et al. (2011) points out, this limit may be stretched by increasing metacognitive ability and using "capacity saving" strategies. For example, "chunking" is a way of summarizing and organizing information to facilitate knowledge transfer and recall as well as conserving mental resources (Miller, 1994). That being said, the metacognitive abilities of students within an educational system cannot be ignored given the fact that "metacognition plays an important role in oral communication of information, oral persuasion, oral comprehension, reading comprehension, writing, language acquisition, attention, memory, problem solving, social cognition, and, various types of self-control and self-instruction" (Flavell, 1979, pg. 906). Because attention is limited, it is important to understand metacognition and strategies to efficiently use one's own working memory. The purpose the current study is to highlight the importance of metacognition in education, or more specifically, to describe its impact on students' competencies in reading, mathematics and science. "In many studies, measures of metacognition, self-regulation, and self-regulated learning are not linked with measures of students' learning or achievement," (Schunk, 2008, pg. 466) and when they are, the results are mixed (Schraw, 2000; Sperling et al., 2002; Sperling et al., 2004; Sperling et al., 2012; Vo et al., 2014; Zion et al., 2005). The proposed study aims to make that link and accurately describe the effects of metacognition on students' plausible values in reading, mathematics and science by answering the following research questions:

1. Do metacognitive strategies account for a significant proportion of variability in students' plausible values reading, math and science competencies in the United States?

2. Is one component of metacognitive ability (UNDREM or METASUM) a better predictor of students' plausible values reading, math and science competency than the other?

3. Does the perceived usefulness of metacognitive strategies differ across the following domains: reading, mathematics, and science?

In order to describe the effects of metacognition in education, the perceived usefulness of metacognitive strategies of students within schools in the United states was assessed and its impact on students' plausible values in reading, mathematics and science competencies using data taken from the 2009 Programme for International Student Assessment (PISA).

Metacognition in Education

Self-regulated learning encompasses metacognition and is the degree to with students "are metacognitively, motivationally, and behaviorally active participants in their own learning processes" (Zimmerman, 2014, pg. 137). Students who set goals, monitor their learning, and effectively use strategies attain "mastery more quickly" and are more motivated to learn (Zimmerman, 2014). Metacognitive monitoring or the ability to reflect on what and how one learns is a desirable quality in every student (Hoogeveen & van Gelderen, 2013). Rather than being passive, consumers of information, students with high levels of metacognitive ability are active seekers and processors of information. In addition, students with high levels of metacognitive ability have the skills needed to regulate, rehearse and organize new information that needs to be learned as well as the ability to monitor their understanding during the process of encoding that new information (Schunk, 2008). High achievers tend to be more efficient in their use of metacognitive strategies and are better able to distinguish between answerable and unanswerable questions on an exam (Krebs & Roebers, 2012). On the other hand, students with low levels of metacognitive ability overestimate their knowledge and therefore study and learn less than those with higher levels of metacognitive ability (Vo, Li, Kornell, Pouget, & Cantlon, 2014). Positive correlations exist between metacognition, strategy use and motivations, (Sperling, Howard, Staley, & DuBois, 2004) and students are likely to benefit from an increased metacognitive ability in all subjects including reading, mathematics and science.

Reading. "Awareness and monitoring of one's comprehension processes are critically important aspects of skilled reading" and awareness and monitoring are commonly referred to as components of metacognition which may be considered to be "readers' cognition about reading and the self-control mechanisms" when discussing competency in reading (Mokhtari & Reichard, 2002, pg. 249). Skilled readers tend to have high metacognitive abilities suggesting that they know what they are reading, have strategies for handling any potential problems they may encounter, and monitor their comprehension of textual information. In addition, good readers know more about reading strategies, detect more errors when reading and have a more accurate memories of what they read compared to poor readers (Jacobs & Paris, 1987). Jacobs and Paris (1987) conclude by stating "metacognitive instruction can improve children's awareness and understanding of reading strategies" (pg. 274). It appears that a positive correlation exists between metacognition and reading ability. Because of this, it is hypothesized that the perceived usefulness of metacognitive strategies will be a positive and significant predictor of students' plausible values in reading.

Mathematics. Similar to reading, students with strong metacognitive abilities also tend to have increased mathematics knowledge. Vo et al. (2014) demonstrated how metacognition is correlated with a mathematics test score in children as young as five years of age. More importantly, Vo et al. (2014) conclude that metacognitive monitoring is not a global ability nor does it develop uniformly across domains suggesting that the relation between metacognition mathematics differs from the same person's relation between metacognitive ability and reading. Pilten and Yener (2010) conducted a qualitative study that corroborates the findings of Vo et al. Findings from Pilten and Yener (2010) suggest that metacognitive knowledge evolves over time and that it is related success in solving non-routine mathematical problems in fifth-grade students. Kramarski and Mizrachi (2004) explained the benefits of increasing seventh-grade students' metacognitive ability in solving real-life mathematical tasks through a forum discussion with metacognitive guidance. Students exposed to metacognitive guidance used significantly more logical arguments and mathematical expressions, and outperformed students who were not exposed to the guidance on mathematical literacy. Because of this, it is hypothesized that the perceived usefulness of metacognitive strategies will be a positive and significant predictor of students' plausible values in mathematics.

Science. Zion, Michalsky, and Mevarech (2005) investigated the effects of metacognitive training on students' achievement in science. They conclude that the use of metacognitive training enhances students' achievements in science and provide suggestions for improvement. Social collaboration, reflection on stages, evaluation of peer work and online support offer avenues to provide metacognitive guidance. Student performance suffered in the absence of metacognitive guidance. White and Frederiksen (1998) suggest that metacognitive knowledge and skills may develop via scaffolding, generalization and reflection. Reflection is key and “provides an explicit classroom activity that brings metacognition into the social processes of the classroom, which enhances the acquisition of metacognitive knowledge and skills” (White, & Frederiksen, 1998, pg. 79). Incorporating a reflection process into the curriculum increased the quality of students’ research projects and test performance. Because of this, it is hypothesized that the perceived usefulness of metacognitive strategies will be a positive and significant predictor of students’ plausible values in mathematics.

It is important to note some discrepancy between the domain specific and general metacognitive ability. Whereas Vo et al. (2014) conclude that metacognitive monitoring does not form uniformly across domains in five-year-old children, Zion, Michalsky, and Mevarech (2005) demonstrate how domain specific knowledge and general ability increase simultaneously, albeit not to the same degree, in older students with a mean age of 16.3. Given the findings from Pilten and Yener (2010) that suggest metacognitive knowledge evolves over time and the discrepancies between age groups, perhaps older students are better equipped to transfer metacognitive abilities across domains.

2009 Programme for International Student Assessment (PISA)

The 2009 Programme for International Student Assessment (PISA) consists of a series of surveys administered to fifteen-year-old students in sixty-five countries. The major focus of PISA is to measure students’ overall competencies in reading, mathematics and science. The PISA assessment also includes contextual indicators related to school characteristics as well as student characteristics, family background and students’ perspectives.

Previous Findings from 2009 PISA. Bilican and Yildirim (2014) used data taken from the 2009 Programme for International Student Assessment to investigate the effect of metacognition on student's reading performance in Turkey. They found that understanding and remembering (UNDREM) and summarizing (METASUM) were significant predictors of reading performance. Students who used understanding, remembering, and summarizing strategies outperformed those who used memorization strategies.

The work by Kaur and Areepattamannil (2012) describe additional benefits of metacognition and explored its influence on the mathematical literacy of adolescents in Australia and Singapore using data taken from PISA. They conclude that metacognitive strategies have a positive influence on mathematical literacy of Australian and Singaporean adolescents. Similar to the findings of Bilican and Yildirim (2014) of memorization and reading performance, the use of memorization strategies was negatively associated with mathematical literacy. The current study hopes to add to the work of Bilican and Yildirim (2014) and Kaur and Areepattamannil (2012) by describing the effects of metacognition on plausible values in reading, mathematics and science of students within the United States.

Method

Participants

Data taken from the 2009 Programme for International Student Assessment (PISA) was analyzed to assess the effect of the perceived usefulness of metacognitive strategies of 5,233 fifteen-year-old students nested within 165 schools (SCHOOLID) in the United States. The number of students within each school ranges from 1 to 41. PISA uses student questionnaires to collect information on aspects of their home, family and school background. Of all the students surveyed in the United States, a total of 345 students attended 11 private schools. The majority of students attended public schools.

Materials

Recent versions of the PISA assessment include the following items designed to measure the perceived usefulness of metacognitive strategies: Understanding and remembering (UNDREM) and Summarizing (METASUM). Both of the metacognition indices included in PISA are standardized to have a mean of 0 and a standard deviation of 1. 250 students had missing data in UNDREM and 271 in METASUM.

PISA estimates academic literacy in reading, mathematics and science in terms of plausible values (PVREAD, PVMATH, and PVSCIE respectively). It is important to note that plausible values are not test scores; rather, they are random numbers drawn from a distribution of scores that could be reasonably assigned to each student. Plausible values contain random error variance components and are better suited to describing the performance of the population, rather than individual performance. PVREAD, PVMATH and PVSCIE are scaled such that the mean of each is 500 with a standard deviation of 100. Please refer to the OECD, PISA 2009 Technical Report for more information about measures used.

Procedure

Data taken from the 2009 Programme for International Student Assessment was analyzed using PROC MIXED within SAS version 9.3 to assess the effect of the perceived usefulness of metacognitive strategies of 15-year-old students in the United States and their effects on students' plausible values in reading, mathematics and science. Three linear mixed models were developed to describe the usefulness of metacognitive strategies and their interaction, and their effect on students' overall reading, math, and science proficiency scores. Satterthwaite was the method used for computing the denominator degrees of freedom. Please refer to Figures 1, 2 and 3 for visual depictions of the mixed models. The mixed equations are as follow:

$$y_{ij} = \beta_{0j} + \beta_{1j}METASUM_{ij} + \beta_{2j}UNDREM_{ij} + \beta_{3j}METASUM_{ij}*UNDREM_{ij} + r_{ij}$$
$$\beta_{0j} = \gamma_{00} + u_{0j}$$
$$\beta_{1j} = \gamma_{10} + u_{1j}$$
$$\beta_{2j} = \gamma_{20} + u_{2j}$$
$$\beta_{3j} = \gamma_{30}$$

Additional multivariate analyses were conducted to determine if the effect of the perceived usefulness of metacognitive strategies differs across three criteria: PVREAD, PVMATH, and PVSCIE.

Results

Descriptive statistics and bivariate correlations are presented in Table 1. The inctraclass correlations of the unconditional models for students' plausible values in reading, mathematics and science controlling for school (SCHOOLID) were ρ = .24, .29, and .27 respectively, indicating that additional variance in plausible values in reading, mathematics and science may be accounted for by controlling for the effects of school at level 2. Fixed effects of the perceived usefulness of summarizing (METASUM), understanding and remembering (UNDREM), and their interaction (METASUM*UNDREM) were added to the unconditional models at the student level. A random intercept, random effect of the perceived usefulness of summarizing, and the random effect of perceived usefulness of understanding and remembering were entered into the models at the school level. Ultimately, three linear mixed models were analyzed to assess the proportion of variability in students' plausible values in reading, math and science literacies accounted for by perceived usefulness of metacognitive strategies of students within school. All three final models fit the data well relative to their unconditional counterparts. Please refer to Table 2 for model fit indices and regression equations.

Holding everything else constant the effects of METASUM, UNDREM and their interaction were all significant, positive predictors across all three criteria: students' plausible values in reading, mathematics, and science. Together, METASUM, UNDREM, and their interaction accounted for a small proportion of the variation in students' plausible values in reading, mathematics, and science in the models accounting for school (R^2 = .17, .11, and .13 respectively). METASUM seems to make the most contribution in all three models holding everything else constant.

Additional analyses were conducted to determine if the effects of the perceived usefulness of metacognitive strategies differ across three criteria: students' plausible values in reading, mathematics and science. A comparison of the structure of the models for the three criterion variables was conducted by applying the models derived from students' plausible values in reading to students' plausible values in mathematics, from students' plausible values in reading to students' plausible values in science, and from students' plausible values in mathematics to students' plausible values in science and comparing the resulting "crossed R^2" with the "direct R^2" originally obtained for each criterion. The direct R^2 and crossed R^2 were not significantly different between any of the three criteria indicating no structural differences between the perceived usefulness of metacognitive strategies and its effect on students' plausible values in reading, mathematics, and science.

Discussion

As hypothesized, the perceived usefulness of metacognitive strategies and their interaction were significant, positive predictors of students' plausible values in reading, mathematics, and science and corroborated some of the findings discussed in Jacobs and Paris (1987), Kramarski and Mizrachi (2004), and Zion, Michalsky, and Mevarech (2005). Holding everything else constant, the results suggest that the perceived usefulness of metacognitive strategies account for a significant proportion of variability in 15-year-old students' plausible values reading, math and science competencies in the United States.

The perceived usefulness of summarizing strategies (METASUM) seemed to make the largest contribution in all three models. According to Schunk (2008), students with high levels of metacognitive ability have the skills needed to regulate, rehearse and organize new information that needs to be learned as well as the ability to monitor their understanding during the process of encoding that new information. In notion with Schunk (2008), summarizing or the ability to rehearse and organize new information in an individual's own words may tap into more higher-order thinking than understanding and remembering (UNDREM). The results of the current study coincide with the findings of Kaur and Areepattamannil (2012) that suggest students benefit more from using metacognitive strategies than by simply trying memorize information.

The perceived usefulness of metacognitive strategies did not differ across criteria. This result contradicts that found by Vo et al. (2014) that suggests that children's metacognition is domain specific; however, it is important to note that Vo et al. used a sample of 5-year-old children and the current study's sample consisted of 15-year-olds. Pilten and Yener (2010) that suggest metacognitive knowledge evolves over time. Similarly, Krebs and Roebers (2012) showed that although 9 to 10-year-old children and 11 to 12-year-old children showed adequate metacognitive processes during a test, the older children outperformed the younger during retrieval processes. Perhaps 15-year-old students are better equipped to transfer metacognitive abilities across domains, as the current study suggests.

Given the differences in metacognitive abilities in different age groups, the results of the current study may not be generalizable to populations of different age or schools in countries other than the United States. Also, the effect of the perceive usefulness of metacognitive strategies is likely to differ from the effect of efficiency or frequency of use. It is possible that the effect of the perceived usefulness of metacognitive strategies would be underestimated compared to that of the efficient or frequent use of metacognitive strategies. That being said, it remains unclear how the perceived usefulness of metacognitive strategies as assessed by PISA compare to other measures of metacognition. Furthermore, this study relied on students' plausible values and not test scores, and the effect of the perceived usefulness of metacognitive strategies across different outcomes has yet to be explored.

Future experiments should utilize structural equation modeling to aggregate plausible values into overall proficiency scores based on the imputation theory of Rubin (1987) to assess the perceived usefulness of metacognitive strategies on latent, overall academic literacy. Metacognitive researchers would benefit from the creation of non-self reported measure of metacognition to ensure the validity of future experiments.

Conclusion

The perceived usefulness of metacognitive strategies was predictive of 15-yearold students' plausible values in reading, mathematics, and science within the United States, holding everything else constant. The perceived usefulness of summarizing seemed to make more of a contribution than the perceived usefulness of understanding and remembering. The effects of the perceived usefulness of metacognitive strategies are not domain specific and high school teachers within the United States can expect significant academic gains in multiple domains simply by honing their students' metacognitive strategies.

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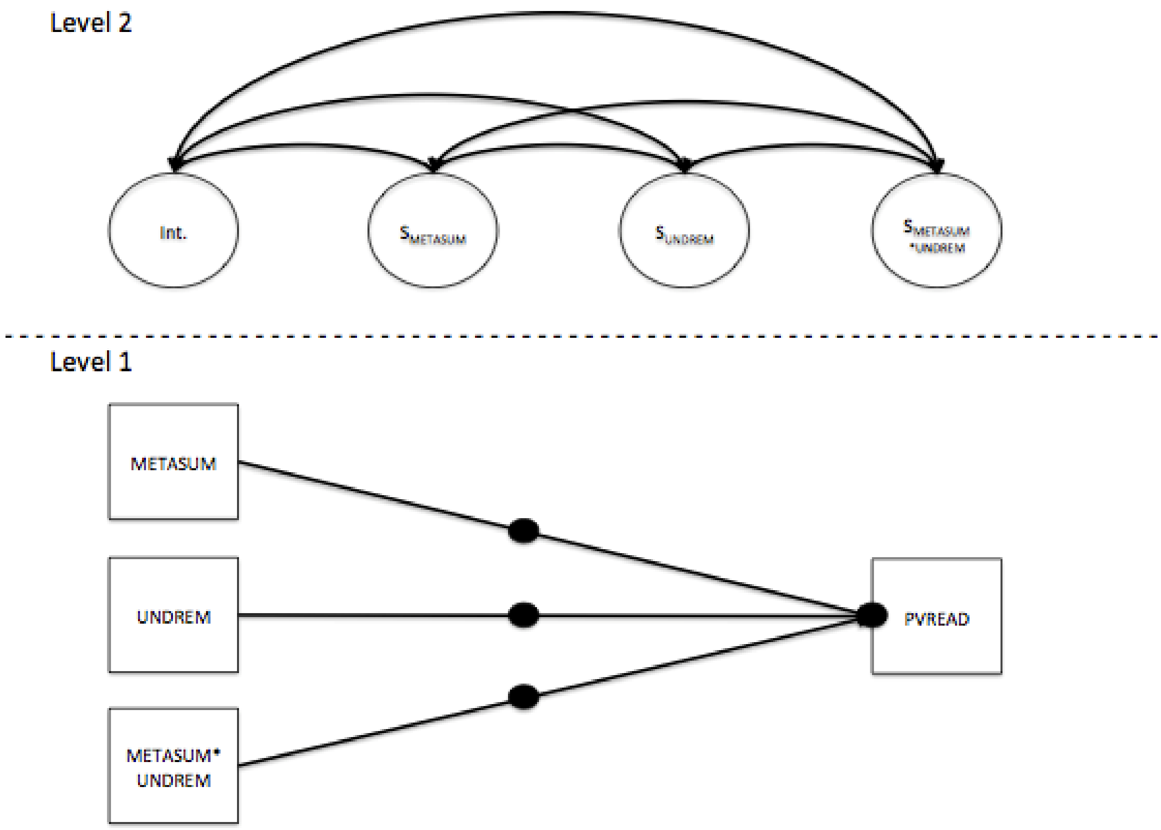

Figure 1. Linear mixed model of the effect of metacognitive strategies on PVREAD

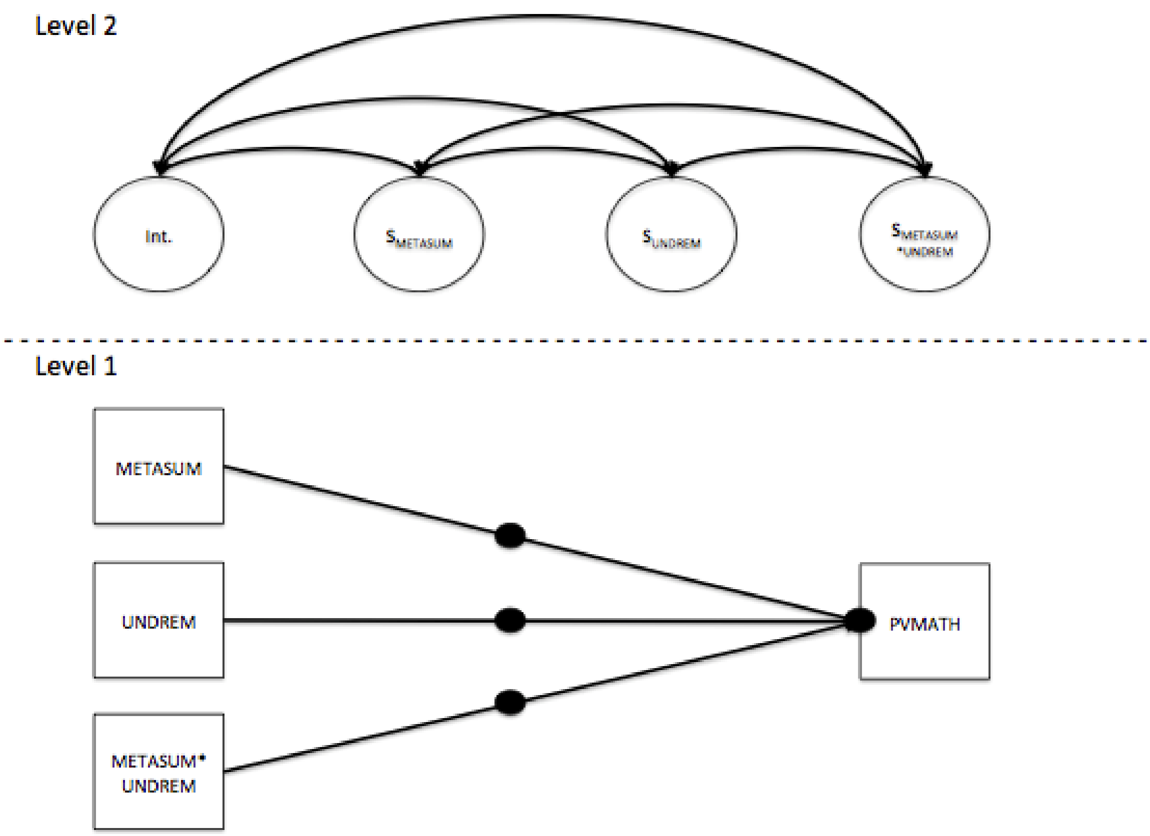

Figure 2. Linear mixed model of the effect of metacognitive strategies on PVMATH

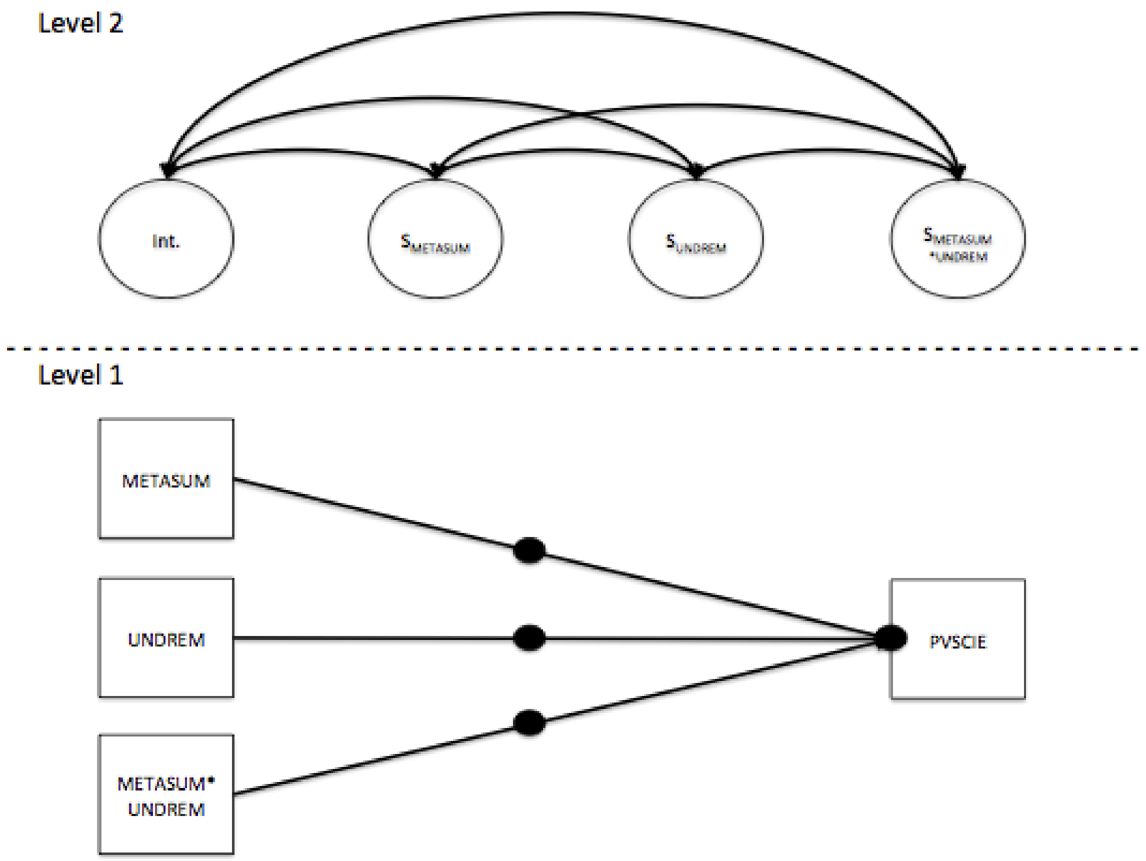

Figure 3. Linear mixed model of the effect of metacognitive strategies on PVSCIE

Table 1

Descriptive statistics and correlations

	M	*SD*	*r*			
Variable			1.	2.	3.	4.
1. PVREAD	497.59	95.60				
2. PVMATH	485.64	89.36	.858			
3. PVSCIE	499.63	96.54	.912	.902		
4. METASUM	-.20	1.02	.386	.308	.332	
5. UNDREM	-.22	1.01	.334	.278	.291	.456

Note. All correlations were significant at the .001 level.

Table 2

Model fit indices and unstandardized regression coefficients

Model			Deviance	AIC	BIC	*b*	*SE*
PVREAD							
	Unconditional		61635.4	61639.4	61645.6		
	SCHOOLID		56339.3	56347.3	56359.7		
		Intercept				507.20	3.25
		METSUM				26.16	1.38
		UNDREM				15.95	1.35
		METASUM*UNDREM				3.91	1.10
PVMATH							
	Unconditional		60628.5	60632.5	60638.7		
	SCHOOLID		55744.2	55752.2	55764.7		
		Intercept				492.23	3.56
		METSUM				17.75	1.25
		UNDREM				12.40	1.26
		METASUM*UNDREM				3.13	1.03
PVSCIE							
	Unconditional		61546.3	61550.3	61556.5		
	SCHOOLID		56485.8	56493.8	56506.3		
		Intercept				507.82	3.66
		METSUM				21.78	1.34
		UNDREM				13.77	1.34
		METASUM*UNDREM				3.70	1.11

Note. All unstandardized regression coefficients were significant .001 level.