# What's a Science Student to Do?

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**Abstract**

This study examined the influence of cognitive ability and student activities on high-school students' science achievement. Students (n=1651) from four high schools in three states were assessed in terms of their cognitive abilities (i.e., science knowledge, reading skill, and metacognitive reading strategies), course involvement, reading interest, and TV habits. Science achievement was measured in terms of students' course grade, comprehension of a science passage, and performance on a statewide standards of learning (SOL) test. Course involvement significantly predicted only course grade, whereas reading interest predicted SOL scores and science passage comprehension. Cognitive abilities and TV habits predicted all three of the student achievement measures. However, the effects of these cognitive variables interacted in interesting ways.

## Introduction

In recent years, scientists have become increasingly interested in uncovering factors that are important for predicting educational success (e.g., Buckner, Bassuk, & Weinreb, 2001; Herman & Tucker, 2000). For example, researchers have reliably predicted academic achievement with measures of student personality (Paunonen & Ashton, 2001; Stewart, Bond, Deeds, Westrick, & Wong, 1999), parental influence (Hoge, Smit, & Crist, 1997), social economic status (Jimerson, Egeland, & Teo, 1999), and school demographics (Sutton & Soderstrom, 1999). While this line of research has certainly shed light on how student personality and social factors can impact a child's education, the utility of this information is questionable if the goal of scientific inquiry is to improve scholastic prosperity. Most personality characteristics and social factors are relatively stable; very few introverts quickly turn into extroverts, and even fewer people increase their level of social economic status overnight. In contrast, the investigation of more mutable influences such as cognitive abilities may provide a promising direction for improving academic performance. The purpose of this work was to examine the impact of three cognitive factors on students' success in their science courses: reading skill, science knowledge, and knowledge of metacognitive reading strategies.

It is generally assumed that reading skill is a critical component of academic achievement. Skilled readers are more likely to monitor their comprehension and use active reading strategies such as previewing, predicting, making inferences, drawing from background knowledge, and summarizing (Long, Oppy, & Seely, 1994; McNamara, 2001; Oakhill, 1984; Oakhill & Yuill, 1996). In addition, skilled readers tend to have more knowledge about the world – most likely from reading more often.

Readers' domain knowledge can have a dramatic impact on how well new information is acquired (Bransford & Johnson, 1972). For instance, many school texts are incomplete because they fail to make relations amongst concepts in the text explicit (Beck, McKeown & Gromoll, 1989). Accordingly, domain knowledge can facilitate comprehension by providing the reader with the necessary resources to fill in conceptual gaps (McNamara, Kintsch, Songer, & Kintsch, 1996). In addition, readers with greater prior knowledge are more likely to use effective reading strategies (Lundeberg, 1987) and convey greater interest in the reading material than low-knowledge readers (Tobias, 1994; Zhang, & Zhang, 1996). Collectively, these findings suggest that learners' prior knowledge critically determines their ability to learn and understand new information.

Metacognition refers to the ability to think about, understand and manage one's learning (Schraw & Dennison, 1994). In essence, metacognition is the capacity to monitor comprehension, and the initiative to correct misunderstanding. Recent research has revealed the significance of metacognitive awareness in learning. For instance, learners who score high on measures of metacognition are more strategic (Garner & Alexander, 1989), more likely to use problem-solving heuristics (Artzt & Armour-Thomas, 1992), better at predicting their test scores (Vadhan & Stander, 1994), and generally outperform learners who score low on metacognitive measures (Pressley & Ghatala, 1990).

More importantly, research has demonstrated the value of metacognition in predicting academic achievement. For example, greater metacognitive ability has been linked to grade point average (Everson & Tobias, 1998), math achievement (Maqsud, 1997), and reading skill (van Kraayenoord & Schneider, 1999). Moreover, McNamara and Scott (1999) demonstrated that providing metacognitive reading strategy training improved comprehension and course scores in college-level science courses.

The purpose of this investigation was to examine the influence of science knowledge, reading skill, and metacognitive reading strategies on high school students' achievement in science. While the individual effects of these factors on learning have been examined in separate studies, to the best of our knowledge, no single study has simultaneously measured the influence of all three variables

on students' comprehension and achievement in a classroom setting. Furthermore, we were interested in determining how course involvement, reading interest, and TV habits would influence science performance, and how well these variables would predict student success in comparison to the cognitive factors. Finally, we investigated whether reading skill or metacognitive reading strategies could compensate for knowledge deficits. In this study, science achievement was assessed by the student's science course grade, comprehension of a science passage, and a statewide measure of students' science achievement (Virginia's Standards of Learning, SOL). It was hypothesized that both the cognitive and student activity measures would reliably predict science achievement; but overall, it was hypothesized that the cognitive measures would better predict performance than measures of student activity.

In line with other work (Perfetti, 1989), it was hypothesized that either reading skill or metacognitive reading strategies would compensate for science knowledge. While some researchers have argued that reading skill and domain knowledge can compensate for each other (Perfetti, 1989), there is little consensus as to whether metacognitive reading strategies could make up for meager science knowledge. On the one hand, one might infer that high metacognitive reading strategies could help a learner offset a low level of science knowledge because research has shown that metacognition can compensate various cognitive abilities (Swanson, 1990). On the other hand, others have argued that metacognition has strong knowledge requirements; that is metacognition is not knowledge free (Schwartz & Bransford, 1998) and consequently, one might not expect metacognitive reading ability to compensate for low science knowledge. In any event, the issue is unclear and further investigation is required.

## Method

### Participants

The sample consisted of 1651 high school students from four schools. Four hundred and ninety-eight students were from an inner city high school in Norfolk, Virginia; 372 were from a rural high school in Americus, Georgia; 364 were from a rural Appalachian high school in Prestonsburg, Kentucky; and the remaining 417 were from a suburban high school in Williamsburg, Virginia. Students' grade level ranged from 9 to 12, and the average age of the students was 16.25 years.

### Materials

Metacognitive reading strategy use was measured by a modified version of the Metacognitive Strategies Index (MSI) adapted for use with high-school students (Forget, 1999). The MSI is a 25-item multiple-choice questionnaire which is designed to measure six factors associated with metacognitive reading strategy use: predicting and verifying; previewing; purpose setting; self-questioning; drawing from background knowledge; and summarizing. The Cronbach's Alpha for the MSI was $\alpha$=.68. Science knowledge was measured with an 18-item multiple choice test on general science information. The test consisted of questions concerning experimental methods, mathematics, and meteorology. Cronbach's Alpha for the science knowledge was $\alpha$=.63. Reading skill was measured by a modified version of the Gates-MacGinitie reading skill test for grades 10-12. The test consisted of 40 multiple choice questions designed to assess student comprehension on several short text passages. The reliability of the gates-MacGinitie is typically between $\alpha$=.85-.92 (Phillips, Norris, Osmond, & Maynard, 2002).

Students were given a questionnaire concerning their course involvement, reading interest and TV habits. The participants were required to rate the following statements related to their course involvement on a one to five-point scale: "How much do you enjoy learning science, or scientific concepts?"; "How much time per week do you generally spend reading and studying for this science course?" and "How much effort have you devoted to this science course?". For reading interest, the following questions were asked "How much do you enjoy reading?"; and "How many books do you read each year that are not required by your teachers?". TV habits were assessed by two questions: "How many hours of television do you watch during a school day?"; and "How many hours of television do you watch on the weekend?". The scales were designed such that higher numbers indicated larger amount of the entity in question.

Finally, participants were given an 844-word passage on meteorology (Flesch-Kincaid grade level of 6.7). The passage covered the types and origins of air masses as well as their impact on weather patterns. An accompanying set of 8 multiple choice and 12 open-ended comprehension questions were created for the passage. Cronbach's Alpha for the open ended questions was $\alpha$=.72, while alpha level for the multiple choice questions was $\alpha$=.57.

### Design and Procedure

The students were tested during regular classroom hours in a 90-minute class period, or two 50-minute class periods, and all testing was conducted near the end of the academic year. The complete set of materials were presented in a single booklet with "stop'' pages inserted between each measure. If a student finished a particular test early, they could recheck their answers, but could not go on to the next section. The participants completed the measures in the following order and time frame: Science passage and questions (20 minutes), Gates reading test (20 minutes), prior knowledge test (10 minutes) MSI (10 minutes), and the student activity questionnaire (5 minutes). At the end of the academic year, the students' science course grade and their Standards of Learning science scores were collected.

## Results

The following results were significant at the $p < .001$ level unless noted otherwise. It was verified for all analyses reported here that students' age differences did not alter the pattern of results.

### What's More Important?

A factor analysis was conducted to determine whether the predictors used in this study could be grouped into smaller subset of factors (e.g., Cognitive ability, reading interest, etc.). All 10 measures of student ability and activity were entered into the analysis using the principal components method of extraction. Predictors with Eigenvalues over 1 were retained in the analysis, and the Varimax procedure was used as the method of rotation. The analysis revealed four distinct factors that accounted for 68% of the overall variance. Science knowledge, reading skill and metacognitive reading ability loaded on factor 1, *Cognitive Ability* (loadings=.800, .760, .692; Eigenvalue=2.67), and accounted for 27% of the variance. The number of books read and reading enjoyment loaded on factor 2, *Reading Interest* (loadings=.891, .849; Eigenvalue=1.90), and accounted for 19% of the variance. The amount of TV watched on a school day and the amount watched on a weekend loaded on factor 3, *TV Habits*, (loadings=.890, .890; Eigenvalue=1.20) and explained 12% of the variance. Finally course effort, time spent reading and studying the textbook, and enjoyment of learning science loaded on factor 4, *Course Involvement* (loadings=.807, .684, .638; Eigenvalue=1.07), and explained 11% of the variance. Thus, the factor analysis provided support for our initial categorical distinction of the predictors.

The four factors were regressed onto each of the measures of science achievement. For the students' **course grade**, the overall model accounted for 13% of the variance, $F(4,1295)=49.57$. Reading interest did not predict course grade, whereas cognitive ability, $t(1295)=10.15$, $\beta=.263$, and course involvement $t(1295)=9.43$, $\beta=.244$ were strong predictors. TV habits significantly predicted course grade but the relationship was small $t(1295)=-2.43$, $\beta= -.063$, $p= .015$.

For students' **SOL score**, the overall model accounted for 38% of the variance, $F(4,618)=94.09$. Course involvement did not predict SOL scores, whereas cognitive ability, $t(618)=16.24$, $\beta=.516$, TV Habits, $t(618)= -9.23$, $\beta=-.294$, and reading interest $t(618)=5.06$, $\beta=.160$, were significant predictors.

Table 1 Correlations between science achievement and student activities.

| Factor | Individual Measure | Course Grade | SOL | Open Ended Comp. | Multiple Choice Comp. |
|---|---|---|---|---|---|
| Cognitive Ability | Reading Skill | .24 | .58 | .64 | .53 |
| | Science Knowledge | .25 | .59 | .55 | .51 |
| | Metacognitive Reading Strat. | .20 | .15 | .26 | .24 |
| Course Involvement | Enjoy Learn Science | .18 | .16 | .13 | .14 |
| | Time Reading & Studying | .12 | N.S. | N.S. | N.S. |
| | Effort Given to Course | .30 | N.S. | N.S. | N.S. |
| Reading Interest | Number of Books Read | N.S. | N.S. | N.S. | .11 |
| | Enjoyment of Reading | .12 | .16 | .14 | .16 |
| TV Habits | Hrs. TV School day | -.13 | -.34 | -.25 | -.23 |
| | Hrs. TV Weekend | N.S. | -.27 | -.23 | -.23 |

In terms of **science passage comprehension scores**, the model accounted for 42% of the variance for open-ended questions, $F(4,1213)=219.79$, and 33% for multiple-choice questions, $F(4,1292)=158.81$. For both comprehension measures, cognitive ability ($t(1213)=27.44$, $\beta=.600$; $t(1292)=22.56$, $\beta=.514$); reading interest ($t(1213)=5.01$, $\beta=.110$; $t(1292)=5.46$, $\beta=.124$); and TV habits ($t(1213) =-9.83$, $\beta=-.215$; $t(1292)=-9.58$, $\beta=-.218$) were significant predictors, whereas course involvement was not significant.

In summary, cognitive ability and TV habits were significant predictors for all of the student achievement measures. Course involvement reliably predicted only course grade, whereas reading interest reliably predicted SOL scores and science passage comprehension.

Table 1 presents the Pearson correlations between the students' science achievement performance (i.e., course grade, SOL, open-ended and multiple choice comprehension questions) and the 10 predictors used in this study. Correlations are significant at the $p< .001$ level unless specified otherwise. Several trends emerge from the analysis. First, the correlations between science achievement and the individual measures of cognitive ability are moderate to high. In contrast, the correlations between achievement and the individual measures of student activity were generally low. However, there were two exceptions, the amount of effort given to the course was moderately correlated with course grade ($r(1472)=.298$). In fact, of the measures used in this study, effort had the highest simple correlation with course grade. Second, the amount of TV watched on a school day and the weekend (with the exception of course grade) was moderately, but negatively correlated with science achievement. The magnitude of the correlations ranged from small for course grade ($r(1493)=-.125$ to moderate for SOL ($r(693)=-.337$).

## Can You Compensate for Low Knowledge?

Our second question was whether either reading skill or metacognitive strategies would compensate for science knowledge. Hence, we conducted ANOVAs for each measure including science knowledge and reading skill in the first set, and science knowledge and metacognitive reading strategies in the second set. (The three variables could not be included in one analysis because there were cells with too few participants.) Students scoring in the top and bottom thirds for each cognitive ability measure were included in the analyses. The dependent variables included course grade, SOL score, open-ended questions, and multiple-choice performance.

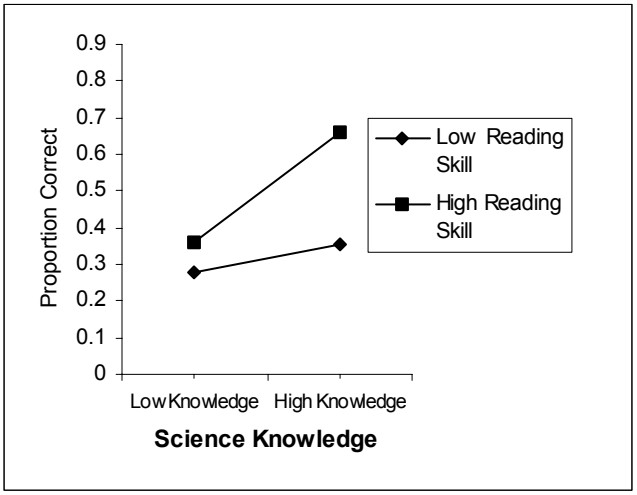


Figure 1. Proportion of multiple-choice comprehension questions correct as a function of science knowledge and reading skill.

The first set of analyses, including science knowledge and reading skill, yielded significant effects for all of the dependent measures. The results were significant at $p<.001$ unless otherwise specified. There was a significant interaction of science knowledge and reading skill only for students' performance on the multiple-choice comprehension questions, $F(4,1368)=7.85$ (see Figure 1). This interaction indicates that neither science knowledge nor reading skill had a major impact on comprehension unless the student possessed both.

The second set of analyses, including science knowledge and metacognitive reading strategies, yielded significant effects of science knowledge for all of the depended measures. Metacognitive strategies was significant for all of the measures except SOL. However, in this case, there was significant interaction of science knowledge and strategy use, $F(4,659)=2.52$, $p=.04$. As shown in Figure 2, greater metacognitive ability helped compensate for a student's low level of science knowledge. [No other interactions were significant.]

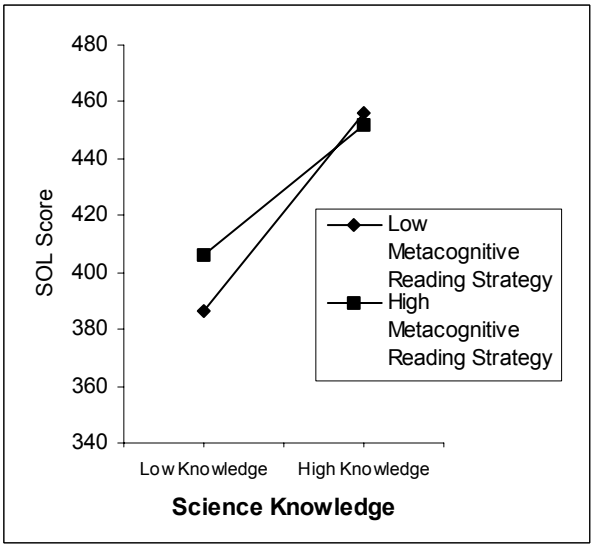


Figure 2. SOL score as a function of science knowledge and metacognitive reading strategy.

## Discussion

One goal of the current investigation was to uncover some of the factors that are important in promoting high-school students' science achievement. A factor analysis of our ten measures of abilities and activities revealed that there were four distinct categories of variables: cognitive ability, TV Habits, reading interest, and course involvement. The results indicated that all four factors were important in predicting science achievement; however, some factors differentially predicted the measures of science achievement. Cognitive ability, and TV habits reliably predicted all measures of science achievement, while course involvement reliably predicted only course grade. In turn, reading interest predicted both SOL scores and passage comprehension.

A more detailed examination of the correlations between the individual components of the factors and science achievement revealed that all measures of cognitive ability and TV habits were relatively strong predictors of science achievement, while the individual measures of reading interest and course involvement were generally weak predictors. The major exception was the correlation between course effort and course grade, which proved to be the best single correlation with the students' grade.

The second goal of the study was to determine whether reading skill or metacognitive reading strategies could compensate for science knowledge (see also, Cottrell & McNamara, 2002). With multiple choice questions, science knowledge and reading skill interacted. In this case, neither science knowledge nor reading skill had a major impact on passage comprehension unless the learner had high levels of both cognitive abilities. This interaction is counter to the belief that reading skill and prior knowledge compensate for each other (e.g., Perfetti, 1989). If science knowledge and reading skill were compensatory, one would expect that a high level reading skill would make up for a low level

prior knowledge. Nevertheless, it is notable that the multiple-choice measure was the only dependent measure of science achievement for which an interaction occurred. In the other three cases (Sol score, open ended questions, and course grade), both reading skill and knowledge aided the students, and did not interact. So, in those cases, either reading skill or prior knowledge were beneficial – and thus could compensate for one another. Having both, of course, is the best scenario. Similarly, for the most part, either prior knowledge or metacognitive reading strategies were beneficial to students. In contrast, for SOL scores, metacognitive reading strategies and science knowledge interacted. High-knowledge students did not benefit from reading strategies. Yet, students with low science knowledge were presumably able to compensate for this knowledge deficit with reading strategies. The results support the notion that metacognitive reading strategies can compensate for a low level of domain knowledge.

So, what's a science student to do? The results of this study suggest several things. First, students should simply read more. Research has shown that an increase in exposure to print is associated with an increase in reading skill (see, McNamara, 2001). Accordingly, the current findings support the notion that reading skill is important for science achievement. In fact, reading skill was one of the best single correlates of student performance. Second, students should make informed decisions on the courses they take. For, example if a student is interested in taking biology courses, they should plan to take as many courses related to biology and chemistry in high school as possible. Prior knowledge is important in determining how well new information is learned. Thus the more elementary courses one has in a domain, the easier it will be to learn more advanced courses in the same domain.

However, as we well know, students will often find themselves in courses for which they are ill prepared. In that case, knowing and using metacognitive reading strategies can help the learner to partially overcome knowledge deficits. Hence, the results of this study suggest that students should increase their metacognitive awareness. Unfortunately, students do not automatically engage in such processing (Garner, 1990). Consequently, the solution is to discover and implement techniques that promote metacognitive strategy use (e.g., McNamara & Scott, 1999).

Finally, our findings suggest that parents and students should find a healthy balance between the amount of TV watched and the amount of effort the student puts into the course. Of the measures of student activity, TV habits seemed to be one of the best predictors of science performance: TV viewing was reliably related to all four of our measures of science achievement. However, the relationship between TV viewing and science achievement was negative. This result is congruent with research on TV viewing, which suggests that TV viewing can have a negative impact on reading comprehension (e.g., Koolstra, van der Voort, & van der Kamp, 1997). Conversely, our results underscore the importance of student effort on course performance; students' effort was the best single correlate of course performance. While readers often prefer the path of least resistance (McNamara et al., 1996) it is important to encourage students to expend effort into their academic endeavors.

It is important to note that these results were based on correlation, and therefore should be interpreted with caution. Despite this limitation, the conclusion we draw from this work is that both cognitive ability and student activities are important for science achievement. Moreover, it is important to develop ways to promote reading, and interest in reading, as well as ways to increase course involvement. These findings also recommend that parents should play an active role in educating children to balance their TV viewing and academic endeavors. Finally, the results suggest the need for the development and implementation of strategies to promote metacognitive awareness.

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