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Reading Proficiency and Mathematics Problem Solving by High School English Language Learners

Carole R. Beal,[1] Niall M. Adams,[2] and Paul R. Cohen[1]

Abstract

The study focused on the relationship of English proficiency and math performance in a sample of high school students, including 47% English language learners (ELLs). Data sources included state math test scores, study-specific pre- and posttest scores, problem solving in an online math tutorial, and responses to a self-report assessment of mathematics self-concept. English conversational and reading proficiency data were available for the ELLs. Results indicated that math performance for the ELLs increased with English-reading proficiency in a nonlinear manner. ELLs' English-reading proficiency predicted math test scores, progress in the online math tutorial, and math self-concept.

Keywords

English learners, mathematics, computer-assisted instruction

As the population of the United States becomes more diverse, the challenges of educating students whose primary language is not English are becoming increasingly apparent. For example, in California, one in four students is an English language learner (ELL). Other states facing similar challenges

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include Texas, North Carolina, New York, Florida, Illinois, Arizona, New Mexico, Colorado, and Massachusetts (National Clearinghouse for English Language Acquisition, 2007).

Recent changes in state policies have resulted in many ELLs being placed in English-speaking classrooms with relatively few sources of instructional support (Guerrero, 2004). Not surprisingly, educational outcomes for students who are not proficient in English lag behind those of students for whom English is a primary language (NCELA, 2007). This is especially apparent for adolescents: ELLs score lower on end-of-year achievement tests and are more likely to drop out of high school than English-proficient students (California Department of Education, 2007). In California, only 25% of the ELLs who graduate from high school have completed all the courses required for admission to the state university system (California Department of Education, 2007; Wang & Goldschmidt, 1999).

Poor English is usually treated as a literacy problem, and much research has focused on intervention programs to help ELLs develop reading skills (Franzak, 2006; National Center for Education Evaluation, 2007; What Works Clearinghouse, 2007). By comparison, the low level of mathematics achievement by ELLs has attracted relatively little attention from researchers, practitioners, policy makers, and parents (Robertson & Summerlin, 2005; Secada, 1996). However, there is growing evidence that limited English proficiency also has implications for high school students' success in math. For example, in California less than 40% of ELLs passed the math portion of the high school exit exam, which requires only Grade 6 math proficiency for a passing score (California Department of Education, 2007). More than half of the ELLs enrolled in Algebra 1 courses in Los Angeles schools fail the class at least once, and failing Algebra appears to be a strong predictor of dropping out of high school (Helfand, 2006).

To date, there has been relatively little investigation into how limited English proficiency influences students' mathematics learning. One relevant concept is the notion of the student's "opportunity to learn," meaning that there is more to learning than the student's physical presence in the classroom (Wang & Goldschmidt, 1999). More specifically, if the student cannot easily understand the teacher's explanations or the textbook materials, he or she will not benefit from the instruction to the same extent as an English-proficient student (Guerrero, 2004; Secada, 1996). The challenges faced by ELLs in math classes are exacerbated by the fact that only about 15% of high school math teachers have specific training in working with students who are not proficient in English (Coates, 2006; Combs, Evans, Fletcher, Parra, & Jimenez, 2005).

The notion that ELLs' lower math achievement reflects differential opportunity to learn in the classroom is consistent with research on cognitive processes in mathematics problem solving. These studies indicate that 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 (Royer, Tronsky, Chan, Jackson, & Merchant, 1999; Swanson & Jerman, 2006; Walczyk & Griffith-Ross, 2006). By implication, students who must devote substantial cognitive resources to English comprehension will have less capacity available to devote to math problem-solving operations.

Support for this view is found in studies of the impact of accommodations to reduce the demands of English text comprehension on math problem solving. For example, Helwig, Rozek-Tedesco, Tindal, Heath, and Almond (1999) found that poor readers performed better when math word problems were presented by video than text, suggesting that reading difficulties can undermine math problem solving. However, the study did not specifically focus on ELLs. Morales (1998) found that with limited English proficiency, elementary students' ability to solve word problems correctly varied with their comprehension of the problem text.

Other research has investigated the effects of simplified English text on ELLs' performance on high-stakes tests. Although the evidence is somewhat mixed, the general conclusion is that students are more likely to solve math problems correctly when the demands of understanding the problem are reduced by accommodations such as simplified English and definitions for unfamiliar vocabulary (Abedi & Lord, 2001; Abella, Urrutia, & Shneyderman, 2005). That is, when ELLs do not have to devote cognitive resources to English comprehension, their performance in math appears to improve (Lara-Alecio, Cmajdalka, Parker, & Cuellar, 1996).

One limitation of this research is that within-group variation in English proficiency has not yet been addressed in relationship to math performance. More specifically, the population of ELLs may include students who are conversationally proficient in English but are not able to read English at grade level as well as students who do not speak or read English at all. One possibility is that students' math performance may improve more or less linearly as their overall English proficiency increases. However, there is some reason to expect that English-reading skill may be especially important. Basurto (1999) pointed to the central role of reading comprehension in math problem solving and argued that teachers should help build ELLs' reading skills so that students could interpret word problems correctly. This view was supported by case studies of three teachers who focused on children's reading skills as a way to improve math word problem solving. One goal of the present study was therefore to examine math performance for students varying in English proficiency, with a specific focus on the role of reading proficiency. Multiple measures of math problem solving were obtained, including performance on state achievement tests and study-specific tests and process measures of how students solved computer-presented math word problems while using an online tutorial.

A second goal of the study was to examine the impact of English proficiency on ELLs' mathematics motivation. Considerable research has shown that students' mathematics motivation influences the use of good study strategies, effective help-seeking, and learning outcomes. In particular, students' beliefs about their ability to succeed in math contribute to math achievement (Leder, Pehkonen, & Torner, 2002). Prior work suggests that the link between math achievement and math self-concept may be stronger for Hispanic students than White students (Stevens, Olivarez, Lan, & Tallent-Runnels, 2004). However, the Hispanic sample in the Stevens et al. (2004) study was not specifically limited to ELLs. Tapia and Marsh (2001) investigated math motivation in a sample of bilingual middle and high school students and found that the math self-concept component of motivation was strongly related to math achievement. However, the participants were primarily high-achieving students from affluent American and European families on assignment in Mexico, attending private college preparatory schools. Thus, the findings may not generalize to ELL samples in the United States. Here, we examined the relationships of English-reading skill, math performance, and mathematics motivation for a sample of adolescent ELLs.

Method

Participants

The study included Grade-9 students enrolled in Algebra 1 classes in four high schools (N = 442). The schools were located in the downtown area of Los Angeles, California, and served primarily African American and Hispanic students. The initial sample included 233 students who spoke English as their primary language and 209 ELLs. As not all students completed all tasks, the analyses described below were conducted on the data available for each task.

Materials: Math Tutorial Software

Students worked with AnimalWatch, a Web-based tutorial for prealgebra mathematics (basic computation, fractions, and postfractions topics such as decimals, unit conversion, proportions, and percentages). Teachers wanted the students to review this prealgebra material in hopes of helping them make better progress with algebra topics.

The software selected word problems that were estimated to be challenging but within the student's ability to solve, based on performance on preceding problems. Problem difficulty increased as the student demonstrated that she or he could solve problems involving a particular skill. Thus, a student who correctly solved a series of computation problems would be allowed by the software to move into fractions problems, and then into prealgebra problems. Another student who made errors on computation problems would continue to receive similar problems until he or she demonstrated problem-solving success on computation material.

The word problems presented in the AnimalWatch software involve authentic science content about endangered species, such as the Giant Panda, The North Atlantic Right Whale, and the California Condor, among others. AnimalWatch word problems include 50 words, on average. An example of a challenging multiplication problem is, "Pandas are called 'cloud bears' because they live high in the mountains. Bamboo grows there. One panda lived on a mountain 3,800 meters above sea level. One meter is 3.28 feet. What was the height of the mountain in feet?" Each problem was illustrated with a picture of the animal or its habitat. Students could click on a "Help" icon to view a menu of multimedia resources for solving similar problems, including worked examples and short video lessons.

Data Sources and Scoring: Mathematics Problem Solving

California Standards Test-Math (CST-Math). The CST is administered each year and includes a mathematics section mapped to the state curriculum standards. Students' scale scores and performance-level categories were available. The scale score range is from 150 to 600. Performance categories are based on the scale scores and include far below basic (41% of the sample), below basic (40%), basic (11%), proficient (6%) and advanced (0%) levels.

Study-specific pre- and posttests. The software included an integrated test module that provided study-specific assessments of math proficiency. Tests include 30 items covering computation, fractions, and postfractions topics mapped to the California standards for number sense, algebra and functions, and measurement and statistics. The module includes two forms: one is completed before students work with the software (pretest) and one at the end of the activity (posttest). Individual items on a test are presented in random order.

Log-odds correct scores were used in the analyses (log of the odds of a correct answer, meaning the number correct divided by the number incorrect). A regression analysis indicated that the ELLs' pretest scores were strongly predicted by their CST-Math scores, $F(1, 267) = 45.292$, $p < .0001$. Overall performance was low: Mean proportion correct for the whole sample was 30% correct on the pretest; the posttest mean was 34% correct.

Software word problem solving. One indicator of how effectively the student worked with the tutorial software is the number of word problems completed. However, we also want to consider whether the student appears to be attempting to solve the problems versus guessing or "gaming" the software (Baker et al., 2006). For example, a student might move through a large number of problems quickly by deliberately entering a wrong answer and moving on to the next problem. To address this, the following measure adjusts the number of problems presented by the number the student actually solved:

$$\text{Effort} = \frac{\text{unique} + \text{correct}}{\text{unique}} - 1 = \frac{\text{correct}}{\text{unique}}$$

where *unique* is the number of unique problems encountered by the student and *correct* is the number of these solved correctly. This number will approach zero if students simply click through the problems and it will approach one if students solve them correctly.

The software also tracked the number of problems presented to the student in relationship to the math curriculum topics. Computation items (addition, multiplication, subtraction, and division) were typically presented before fractions items and, in turn, postfractions topics. Each student received scores for the proportion of computation, fractions, and postfractions problems completed in relationship to the total number of problems seen by the student.

Teacher ratings. Math teachers provided ratings of individual students' achievement in math class: High (above-grade level), average (student would pass the class), or low (student was at risk of failing the class). Students rated by teachers as high in achievement had higher CST-Math scores than students rated as average or low in achievement, $F(2, 291) = 9.672$, $p < .001$.

Data Sources and Scoring: English Proficiency

The California English Language Development test (CELDT). Scale scores on the CELDT were available for the ELLs, including an overall score and subscores for listening, speaking, reading, and writing. The associated performance-level categories were also available. The sample included students at the CELDT-Beginning

(10% of the ELL sample), Early Intermediate (17%), Intermediate (37%), Proficient (31%), and Advanced (10%) levels. No measures of reading proficiency were available for the non-ELLs in the sample.

Data Sources and Scoring: Mathematics Motivation

Student self-report. Students' mathematics motivation was assessed with the "Math Profile," an online self-report instrument based on the paper-and-pencil survey developed and validated by Eccles, Wigfield, Harold, and Blumenfeld (1993). Prior work indicates that components of motivation, such as self-confidence in math, can be successfully assessed via online instruments (Beal, Qu, & Lee, 2008; Boekaerts, 2002; Galbraith, 2002; Pierce, Stacey, & Barkatsas, 2007). The Math Profile included two questions each for the following constructs: self-efficacy, perception of math difficulty, expected success in math, perceived relevance of math, and attraction to math. Students clicked on a 5-point Likert-type rating scale to respond to each item.

Students' responses on the Math Profile were subjected to factor analysis, with the first two factors accounting for 55% and 12% of the overall variance. Consistent with the design of the instrument, the first factor appeared to represent students' math self-concept (self-efficacy, expected success in math, and perception of math as easy or difficult). The second factor represented students' perception of math as having value in their lives (attraction to math, relevance of math). Thus, mean scores were computed for each student for self-concept (average of responses to the six self-efficacy, expected success and math difficulty items) and math value (average of responses to the four relevance and attraction items). Self-concept and math value scores were used in subsequent analyses.

Teacher ratings. Math teachers were asked to rate each student's motivation, using a three-level checklist attached to the class roster (Ryan, Patrick, & Shim, 2005). The levels were (a) high: student regularly attends class with the textbook in hand, completes all assignments, appears attentive and asks questions about the material, and expresses the goal of doing well in the class; (b) average: student completes most assignments, usually has the textbook and materials, attends class fairly regularly, and seems moderately interested in passing the class; and (c) low: student frequently fails to turn in homework, does not take notes or ask questions in class, misses classes without excuses, and expresses a lack of interest in math and in his or her grade. Teachers rated 27% of the sample as high in motivation, 46% as average, and 27% as low in motivation.

Validity of students' responses on the Math Profile instrument was suggested by comparison with the teachers' ratings of students' classroom motivation. A one-way analysis of variance with teacher ratings (high, average, and low motivation) as the grouping factor and students' mean math self-concept scores showed a significant effect of motivation, $F(2, 259) = 24.795$, $p < .0001$. Students rated as high in motivation by their teachers had higher math self-concept than students rated as lower in motivation. A similar effect of teacher ratings were observed for students' math value scores, $F(2, 275) = 15.752$, $p < .001$. Students rated by teachers as highly motivated had higher ratings for the value of math.

Procedure

Data were collected as students worked with the AnimalWatch tutoring software as part of their math class instruction, using laptops connected to the Internet via the school's wireless network. In the first session, students were provided with user names and passwords and directed to the AnimalWatch site, where they logged in and completed the integrated pretest. In the next session, they completed the Math Profile self-report assessment of mathematics self-concept and math value and then began solving math problems in the software, continuing for three class periods. In the final session, students completed the integrated posttest.

Results

The results indicated that many of the participants were struggling with basic math, even though they were enrolled in Algebra 1 classes. The average score on the CST-Math for the overall sample was 269.24, putting the majority of the students in the "far below basic" or "below basic" performance categories. Students also correctly solved only 30% of the items on the math pretest integrated into the online tutorial, which focused on Grade-6 math topics such as computation and fractions. Teachers also rated 40% of their students as failing or at risk of failing Algebra 1.

To learn how math performance varied with English proficiency, a one-way analysis of variance was conducted with English proficiency (CELDT-Beginning, Early Intermediate, Intermediate, Proficient, Advanced, and non-ELL) as the grouping factor and CST-Math scores as the dependent measure. The results indicated a main effect of English proficiency, $F(5, 296) = 7.0215$, $p < .001$. Tukey's HSD ($\alpha = .05$) post hoc comparisons showed that the non-ELL, CELDT-Advanced and CELDT-Proficient students all had

Table 1. Mean Math Performance for ELL and Non-ELL Students

	CST-Math (scale score)	Online tutorial pretest (proportion correct)	Tutorial word problem solving (proportion correct)	Tutorial posttest (proportion correct)
CELDT-Beginning	249.61 (30.93)	0.19 (0.19)	0.39 (0.25)	0.24 (0.18)
CELDT-Early Intermediate	250.46 (25.54)	0.19 (0.13)	0.35 (0.21)	0.25 (0.18)
CELDT-Intermediate	263.32 (30.50)	0.24 (0.16)	0.42 (0.22)	0.28 (0.17)
CELDT-Proficient	291.33 (40.04)	0.35 (0.18)	0.55 (0.18)	0.37 (0.25)
CELDT-Advanced	294.70 (61.84)	0.48 (0.18)	0.56 (0.23)	0.48 (0.20)
Non-ELL	276.55 (42.84)	0.34 (0.22)	0.52 (0.22)	0.38 (0.23)

Note: Mean math performance include CST-Math scale score, online tutorial pretest proportion correct, proportion of tutorial word problems solved correctly, and posttest proportion correct. Standard deviations are given in parentheses.

similar math scores, which were significantly higher than the scores for CELDT-Intermediate, CELDT-Early Intermediate, and CELDT-Beginning students. Mean scores are shown in Table 1.

A similar one-way analysis of variance was conducted with English proficiency as the grouping factor and log-odds correct performance on the software pretest as the dependent measure. The results again indicated a main effect of English proficiency, $F(5, 387) = 12.928$, $p < .001$. Mean scores for the proportion of problems correctly solved are included in Table 1.

A one-way analysis of variance with English proficiency as the grouping factor (CELDT-Beginning through non-ELL) was conducted with the proportion of AnimalWatch software word problems correctly solved without errors as the dependent measure. Again, the results showed a significant effect of English proficiency, $F(5, 420) = 7.552$, $p < .001$, indicating better problem solving by students who were more proficient in English. Mean scores are shown in Table 1.

To evaluate the relative contributions of conversational and reading skills to math performance for the ELLs, we fit a regression model using CELDT scale scores for listening, speaking, reading and writing as predictors of CST-Math scores. The overall model was significant, $F(4, 143) = 4.669$, $p < .01$. None of the individual predictors was significant, perhaps due to the high intercorrelations between the scale scores. However, the effect of reading was suggestive, $F(1, 143) = 3.399$, $p = .067$.

The CELDT subscores were also used to predict the ELLs' performance on the software pretest (log-odds correct). The overall model was significant, $F(4, 182) = 11.489$, $p < .001$. Only the reading scale score was a significant predictor, $F(1, 182) = 15.262$, $p < .001$.

CELDT subscores were used to predict ELLs' problem solving while working with the tutoring software, using the proportion of word problems solved correctly without any errors as the dependent measure. The overall model was significant, $F(4, 195) = 6.536$, $p < .001$. English listening comprehension was a significant predictor, $F(1, 195) = 6.678$, $p < .05$. Reading was also a significant predictor, $F(1, 195) = 5.505$, $p < .05$.

Although ELLs' reading proficiency was related to multiple measures of math problem solving, the relationship appeared to be nonlinear. Figure 1 plots the log-odds of pretest performance (number of problems correctly solved over the number attempted) against CELDT reading score, along with a fitted regression line. This line is the result of a piecewise linear regression model, in which math performance is modeled as a sharp transition from one linear regression to another, and the position of the break-point is determined from the data (Toms & Lesperance, 2003). This break-point indicates the reading proficiency score that is associated with the transition from one regression to the other, a value very close to 550 in Figure 1. This model results in significantly smaller residual error than a simple regression model. Thus, there is evidence to suggest a qualitatively different relationship between math performance and reading below a CELDT reading performance level of 550. Moreover, given estimated parameters of this piecewise model, this suggests a minimum level of reading proficiency is required before improvements in math performance will be observed.

We used the break-point of 550 on the CELDT reading scale to divide the ELL sample into low and high proficiency groups and then looked at the raw number of word problems completed in the online tutorial. Low-reading ELLs completed an average of 26 word problems, compared to 32 for the ELLs with higher reading scores and 30 problems for the non-ELLs. These numbers were not significantly different. However, reading proficiency did influence how ELLs worked with the AnimalWatch tutoring software, using the effort score defined earlier (number of problems completed correctly over the number attempted). For the ELLs, a regression model indicated that CELDT reading scores predicted their work with the software, $F(1, 198) = 9.015$, $p < .01$. Students who were better English readers tended to have higher software effort scores than those who did not read English well.

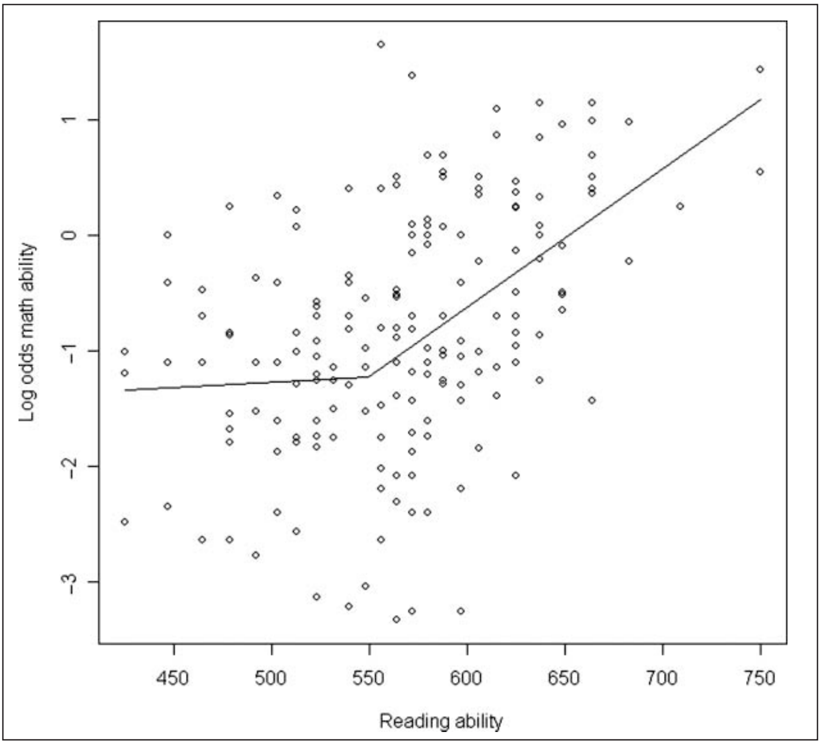

Figure 1. Log-odds correct pretest scores plotted against CELDT reading scale score, with estimated piecewise regression model

A similar finding was observed for students' progress through the Animal-Watch tutorial curriculum topics. Students were assigned into one of three groups: ELL with reading score below 550, ELL with reading score above 550, or non-ELL student. A one-way analysis of variance was conducted with the proportion of computation problems completed as the dependent measure. The results indicated that ELL students with reading scores below 550 spent more of their instructional time (66%) on problems involving simple computation, relative to other students (59% for high-reading ELLs and 55% for non-ELL students), $F(2, 423) = 7.229$, $p < .001$. In turn, the ELL students with reading scores below 550 completed fewer fractions problems (17%) than other students (22% high-reading ELLs and 25% non-ELL students), $F(2, 423) = 6{,}288$, $p < .01$. There were no differences by group for postfractions problems; however, students saw relatively few (18%) of these items.

Table 2. Mean Ratings for Math Self-Concept and Perceived Value of Math for ELL and Non-ELL Students

	Math self-concept	Math value
CELDT-Beginning	2.36 (0.70)	3.22 (1.04)
CELDT-Early Intermediate	2.74 (0.80)	3.37 (0.68)
CELDT-Intermediate	2.60 (0.78)	3.30 (0.88)
CELDT-Proficient	3.07 (1.05)	3.60 (1.00)
CELDT-Advanced	3.46 (0.92)	3.38 (0.76)
Non-ELL	3.05 (0.88)	3.43 (0.87)

Note: Standard deviations are given in parentheses.

To assess the impact of the AnimalWatch online tutorial, a one-way analysis of variance was conducted with three groups: ELLs with reading scores below 550, ELLs with reading scores above 550, and non-ELLs. The dependent measure was the difference between log-odds pretest and posttest scores. The results indicated that the groups were not significantly different, $F(2, 274) = 2.599$, $p = .076$. However, as may be viewed in Table 2, the low-reading ELL students showed slightly more improvement than the high-reading ELLs and non-ELL students. We therefore ran a regression analysis with CELDT reading scale scores as the predictor and the difference scores for pre- and posttest log-odds correct as the outcome measure, with only the ELLs in the analysis. The model fit was significant, $F(1, 143) = 5{,}879$, $p < .05$, indicating that ELLs with lower reading skills showed more improvement from pre- to posttest than their peers with better English reading skills.

To investigate the relationship of English proficiency and math self-concept, a one-way analysis of variance was conducted with English proficiency level (CELDT-Beginning through non-ELL) as the grouping factor and mean math self-concept scores as the dependent measure. The results indicated a main effect of English proficiency, $F(5, 264) = 4.666$, $p < .001$. Tukey's HSD post hoc comparisons ($\alpha = .05$) showed higher math self-concept scores for students who were more proficient in English. However, a similar analysis showed that there was no effect of English proficiency on scores for the value of math. Mean scores are shown in Table 2.

We investigated the relative contributions of math skill (CST-Math scores) and reading proficiency (CELDT reading) as predictors of math self-concept for the ELLs. The overall model was significant, $F(2, 79) = 5.153$, $p < .01$. Reading proficiency was a significant predictor of ELLs' math self-concept, $F(1, 79) = 9.760$, $p < .01$ but math skill was not.

Discussion

The goal of the study was to investigate the relationship of English proficiency to math problem solving and math motivation in adolescent ELLs. The sample of high school students included ELLs as well as students whose primary language was English. Multiple measures of math problem solving were available, including state achievement test scores, software pre- and posttest scores, and correct solutions to math word problems recorded as students worked with an online tutorial software for prealgebra review. Students completed a survey of their mathematics self-concept and the perceived value of math in their lives.

The results indicated that many of these Grade-9 students were struggling with basic math. The majority (81%) had scores on the state achievement test in the "far below basic" or "below basic" performance categories. Teachers rated almost half of their students as failing or at risk of failing their algebra class. Students correctly solved fewer than half of the problems on the software pre- and posttests, even though the problems involved basic computations, fractions, and prealgebra skills mapped to the state curriculum frameworks for Grade 6.

Although overall math performance was poor, there were significant variations related to English proficiency, with the ELLs scoring less well than the students who spoke English as their primary language. This finding is consistent with other research indicating an achievement gap in math between ELL and non-ELL students. In the present study with adolescent learners, English-reading skill was significantly related to math performance, whereas measures of English conversational proficiency (speaking and listening) were not. English-reading skill predicted performance on the state math achievement test, scores on the software pretest, the proportion of word problems correctly solved in the software, and progress through the software curriculum. Reading proficiency also predicted ELLs' math self-concept. Thus, the ability to read English seems critical for success in math for adolescent ELLs.

The results also suggested that the relationship of English-reading skill and math performance may be nonlinear and that there may be a minimum reading level associated with improvement in math performance. Specifically, the regression analysis indicated that math performance was essentially flat for students with reading scale scores below 550 on the CELDT, whereas there was linear improvement in math as reading scores increased above 550. This finding suggests that measures of English-reading proficiency could inform decisions about individual students' need for additional assistance with English in the context of math activities.

English-reading skill was also related to improvement after working with the AnimalWatch online tutorial. More specifically, ELLs with low English-reading skill showed slightly more improvement from pre- to posttest than other students. The likely reason is that the pre- and posttests were originally designed for Grade-6 students and included proportionally more computation items (30%) than other topics. The less-skilled ELL readers spent more of their instruction time with the tutorial working on computation problems and, as a result, showed relatively more improvement on the posttest. However, although the software activity was beneficial, these students did not have the opportunity to progress into the more challenging material. The AnimalWatch tutorial adapts to each student's problem solving, and so students who were proficient with basic computation were allowed to move ahead into fractions and prealgebra problems, whereas those students who made errors on the computation items were estimated by the software to need additional practice on these items.

Several limitations to the study must be acknowledged. First, no measure of reading skill was available for the non-ELL participants. Poor reading skills may also contribute to low math performance by some English-primary students. In fact, this seems likely given that so many of the non-ELL students were also struggling with math. Second, the ELLs in the study were adolescents, which raises questions about why they had not yet become proficient in English. Some may have been recent immigrants; others were not. More detail about home language situation, prior school history, and immigration status would be necessary to understand the complex barriers to full English acquisition for these students. Third, the measures of English proficiency were specific to one state (California), and the results may not necessarily generalize to other assessments.

The results are consistent with studies indicating that students who must devote cognitive resources to understanding a problem presented in English text perform less well in math than students who are able to read English well. Given the evidence regarding the role of reading proficiency in math performance, testing, and instructional accommodations may be especially appropriate for adolescent students with low English-reading scores. More specifically, California students in Grade 9 Algebra 1 courses with a reading scale score on the CELDT lower than 550 might benefit from additional assistance to ensure that they have a fair opportunity to learn math.

Authors' Note

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