

# What Grade 7 Foundational Knowledge and Skills Are Associated with Missouri Students' Algebra I Achievement in Grade 8?

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# What Grade 7 Foundational Knowledge and Skills Are Associated with Missouri Students' Algebra I Achievement in Grade 8?

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To increase opportunities for students to take more advanced math courses in high school, many school districts enroll grade 8 students in Algebra I, a gateway course for advanced math. But students who take Algebra I in grade 8 and skip other math courses, such as grade 8 general math, might miss opportunities to develop the foundational knowledge and skills required for success in advanced math courses. This leaves educators to determine which students are ready for Algebra I in grade 8 and which are not. To inform strategies that address this challenge, this study examined whether student knowledge in five math domains in grade 7 was associated with Algebra I achievement in grade 8. It found that students' scores in all five domains were associated with Algebra I achievement. The *expressions and equations* domain had the strongest association. The association between the *number system* domain and Algebra I achievement was stronger for English learner students than for non-English learner students. The associations between the five grade 7 domains and Algebra I achievement did not significantly differ for students who were receiving special education services and those who were not.

## Why this study?

Increasing numbers of students are enrolling in Algebra I in middle school in order to take more advanced math courses in high school (Star et al., 2015), including about 20 percent of grade 8 students in Missouri (Data Recognition Corporation, 2016, 2017; Missouri Department of Elementary and Secondary Education, 2015, 2016). But students who take Algebra I in grade 8 and skip other math courses, such as grade 8 general math, might miss opportunities to build the foundational knowledge and skills needed to perform well in Algebra I (Domina, McEachin, Penner, & Penner, 2015; Pillay, Wilss, & Boulton-Lewis, 1998). As a result, educators' efforts to accelerate students' progress may have unintended consequences: students placed directly in Algebra I may wind up struggling, actually decreasing the likelihood that they will go on to take higher level math courses that open doors to the widest possible variety of college and career options (Clotfelter, Ladd, & Vigdor, 2012; Loveless, 2008; National Mathematics Advisory Panel, 2008).

About a third of students who are insufficiently prepared for an accelerated progression of math courses leave the progression and take non-college preparatory courses (Dougherty, Goodman, Hill, Litke, & Page, 2017), thus defeating the purpose of taking Algebra I in middle school. To inform strategies that address these concerns, the Regional Educational Laboratory Central—in partnership with the Missouri Department of Elementary and Secondary Education—conducted this study on the association between scores in the five math domains assessed by the 2016/17 Missouri Assessment Program in grade 7 (box 1) and Algebra I achievement in grade 8.

A large body of research has examined the types of experiences that students need in order to be successful in Algebra I (for example, Blanton, 2008; Blanton, Levi, Crites, Dougherty, & Zbiek, 2011; Carpenter, Levi, Berman, & Pligge, 2005; Carraher, Martinez, & Schliemann, 2008; Dougherty, 2008; Dougherty, Bryant, Bryant, Darrough, & Pfannenstiel, 2015). Researchers have found that Algebra I achievement is strongly associated with the number system and with knowledge of expressions and equations (see appendix A). But research conducted to date focuses more on instructional strategies to prepare students for Algebra I and less on ways to identify students who are ready for Algebra I.

For additional information, including a literature review, technical methods, supporting analysis, and additional analyses, access the report appendixes at <https://go.usa.gov/xwuzB>.

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### Box 1. Math domains assessed by the 2016/17 Missouri Assessment Program in grade 7

- *Ratios and proportional relationships.* Analyzing proportional relationships and using them to solve real-world and mathematical problems.
  - *The number system.* Applying and extending understandings of operations with fractions (addition, subtraction, multiplication, and division) to rational numbers.
  - *Expressions and equations.* Using properties of operations to generate equivalent expressions and solving real-life and mathematical problems using numerical and algebraic expressions and equations.
  - *Geometry.* Drawing, constructing, and describing geometrical figures (including two-dimensional shapes and cross sections of three-dimensional shapes) and describing relationships between them; and solving real-life and mathematical problems involving angle measure, area, surface area, and volume.
  - *Statistics and probability.* Using random sampling to draw inferences about a population; drawing informal comparative inferences about two populations; and investigating chance processes and developing, using, and evaluating probability models.
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The Missouri Department of Elementary and Secondary Education has not issued guidelines for determining which students are ready to enroll in Algebra I in grade 8, so approaches to acceleration vary across the state. Some districts have accelerated all grade 8 students into Algebra I (L. Sireno, personal communication, June 12, 2019). Other districts consider such factors as previous enrollment in an honors track and parent request.

All districts have access to information about students' math aptitude in grade 7, when grade 8 math placement decisions are being made. But it is unclear how many educators factor math domain scores on the Missouri Assessment Program in grade 7 into their decisionmaking. By examining the association between those scores and Algebra I achievement in grade 8, this study provides information that might help Missouri educators distinguish students who are ready for Algebra I from students who need more support before enrolling.

The study also explores the relationship between grade 7 Missouri Assessment Program scores and Algebra I achievement for English learner students and students with disabilities. The Missouri Department of Elementary and Secondary Education (2015) has noted some variation by subgroup in middle school Algebra I coursetaking. In 2014, 6 percent of English learner students in grades 7 and 8 and 2 percent of students receiving special education services in grades 7 and 8 took Algebra I. The department is committed to providing advanced coursework to all students who are ready to take it. Thus, this study also provides information about whether the foundational knowledge and skills associated with Algebra I achievement differ for these subgroups of students who are under-represented in Algebra I in grade 8. This information can be used to better identify students from these subgroups who are ready for Algebra I and those who will need more targeted support before enrolling.

### Research questions

The study examined associations between scores in the five math domains of the 2016/17 Missouri Assessment Program in grade 7 (see box 1) and scale scores on the Algebra I End-of-Course Assessment in grade 8. It addressed three research questions:

1. To what extent are scores in the five math domains associated with Algebra I achievement?
2. How do the associations vary by English learner status?
3. How do the associations vary by special education status?

It is important to note a limitation of the study: the relationship between grade 7 Missouri Assessment Program scores and Algebra I achievement in grade 8 is based on only students who were accelerated. The study findings

provide only a partial window into how grade 7 scores on individual math domains are associated with Algebra I achievement. Many students assessed on the grade 7 Missouri Assessment Program were not accelerated into Algebra I in grade 8 but followed the traditional path into grade 8 general math. The findings would likely differ if the study had included outcomes for both accelerated and nonaccelerated students.

The report discusses the associations that are observed for two types of variables: standardized and unstandardized. Standardized variables allow for easier comparison across the five math domains of the Missouri Assessment Program by indicating the standard deviation change in scale score on the Algebra I End-of-Course Assessment that would be expected from a one standard deviation change in score in each domain. Unstandardized variables help in interpreting the findings by maintaining the original scale of the assessment score. With unstandardized variables the association is described as the number of points a student's Algebra I End-of-Course Assessment scale score would be expected to change with each additional question answered correctly in a particular domain. To add further perspective, the report presents the change in the actual scale score on the Algebra I End-of-Course Assessment as a percentage of the score range for the basic and proficient achievement levels of the assessment.

A summary of the data sources, sample, and methods used in the study is in box 2. Further details are in appendix B.

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## Box 2. Data sources, sample, and methods

**Data sources.** The study used four types of administrative data from the Missouri Department of Elementary and Secondary Education:

- Scores in the five math domains of the 2016/17 Missouri Assessment Program in grade 7.
- Scale scores on the Algebra I End-of-Course Assessment in grade 8.
- Student background characteristics, including whether students were English learner students or were receiving special education services.
- District and school identifiers, including the school that each student attended and the district in which it was located.

**Sample.** The study sample included 11,298 students who took the Algebra I End-of-Course Assessment in grade 8 at the end of the 2017/18 school year and had grade 7 assessment data with domain scores available for the 2016/17 school year. The majority of the students in the sample were White, slightly more than half were female, and slightly more than a quarter were eligible for the national school lunch program (an indicator of socioeconomic disadvantage). About 2 percent of students in the sample were English learner students, and about 2 percent were receiving special education services. (See table B1 in appendix B for additional sample characteristics.)

**Methodology.** The study team used multilevel regression models that account for the likelihood that students who were in the same schools or districts were more similar to one another than they were to students in other schools or districts. To allow for comparison of coefficients across predictors with different standard deviations, all assessment scores were standardized by subtracting the mean from each student's score and then dividing it by the standard deviation. The models examined the association between each math domain score and Algebra I achievement above and beyond the association of the other four domains. Follow-up analyses examined whether the strength of the association with Algebra I achievement differed across domains. Only associations that were significant at  $p < .01$  are discussed.

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## Findings

This section first presents the results of preliminary analysis of the math performance of the study sample on the Algebra I End-of-Course Assessment in grade 8. It then describes the associations between scores in each of five math domains in grade 7 and Algebra I achievement in grade 8 for all students, English learner students, and students receiving special education services.

### *On average, the students in the study sample scored in the advanced range on the Algebra I End-of-Course Assessment*

The average scale score on the Algebra I End-of-Course Assessment was about 412 (with a standard deviation of 12.7), which is in the point range (score of 409 or higher) of the advanced achievement level (see table C1 in appendix C). That math proficiency for the average grade 8 student enrolled in Algebra I was in the advanced range is not surprising and suggests that educators are, for the most part, accelerating students who are ready to succeed in Algebra I in grade 8.

### *Scores in all five math domains in grade 7 were associated with Algebra I achievement in grade 8*

The score in each math domain in grade 7 was independently associated with Algebra I achievement in grade 8, above and beyond the associations of scores in the other four domains (table 1). The strongest association (0.21) was for the expressions and equations domain. Getting an additional 3 items correct of that domain's 13 items while scores in the other four math domains stay the same is associated with scoring 2.8 points higher on the Algebra I End-of-Course Assessment in grade 8 (see appendix B for an explanation of how the number of points was calculated). That is more than a quarter of the point range of the basic achievement level and the proficient achievement level.

The ratios and proportional relationships domain had the weakest association (0.10) with scale scores on the Algebra I End-of-Course Assessment, above and beyond the associations of the other four math domains. Getting an additional 2 items correct of that domain's 10 items while scores in the other four math domains stay the same is associated with scoring 1.3 points higher on the Algebra I End-of-Course Assessment in grade 8. That is more than a tenth of the point range of the basic and proficient achievement levels.<sup>1</sup>

**Table 1. Association between scores in the five math domains of the Missouri Assessment Program in grade 7 and scale scores on the Algebra I End-of-Course Assessment in grade 8, 2016/17 and 2017/18**

Domain	Coefficient
Ratios and proportional relationships	0.10***
The number system	0.16***
Expressions and equations	0.21***
Geometry	0.15***
Statistics and probability	0.14***

\*\*\* Significant at  $p < .001$ .

Note:  $n = 11,298$ . Calculated from a three-level multiple regression model that accounted for the nesting of students within schools and districts. Assessment scores were standardized to allow for comparison of coefficients across predictors with different standard deviations.

Source: Authors' analysis of 2016/17 and 2017/18 data from the Missouri Department of Elementary and Secondary Education.

1. Domain scores that are based on more items may provide more reliable information that can better predict Algebra I achievement. In this study, because the number of items varied across math domains, the differences in the associations presented here may have been due in part to differences in the reliability of the domain scores.

***The association between the number system domain in grade 7 and Algebra I achievement in grade 8 was stronger for English learner students than for non-English learner students***

When the strength of the associations between math domain scores in grade 7 and Algebra I achievement in grade 8 was compared for English learner students and non-English learner students, the only statistically significant difference was for the number system domain. The association was about twice as strong for English learner students (.29) as for non-English learner students (.15; table 2). So, for English learner students, getting an additional two items correct of that domain’s eight items (equivalent to a score increase of approximately one standard deviation) while scores in the other four math domains stay the same is associated with scoring 4.1 points higher on the Algebra I End-of-Course Assessment in grade 8, which is more than a third of the point range of the basic and proficient achievement levels. In contrast, for non-English learner students, getting an additional two items correct is associated with scoring 2.0 points higher, which is about a fifth of the point range of the basic and proficient achievement levels.

The sample used for this study was not ideal for investigating whether associations differ by English learner status because it included only a small number of English learner students (228). Further analyses, preferably with a larger sample of English learner students, are needed to support the generalizability of these findings.

***The associations between the five grade 7 domains and Algebra I achievement did not significantly differ for students who were receiving special education services and students who were not***

When the strength of the associations between math domain scores in grade 7 and Algebra I achievement in grade 8 was compared for students who were receiving special education services and students who were not, there were no statistically significant differences (table 3).

The sample used for this study was not ideal for investigating whether associations differ by special education status because it included only a small number of students who were receiving special education services (170). Further analyses, preferably with a larger sample of students receiving special education services, are needed to support the generalizability of these findings.

**Table 2. Association between scores in the five math domains of the Missouri Assessment Program in grade 7 and scale scores on the Algebra I End-of-Course Assessment in grade 8, by English learner status, 2016/17 and 2017/18**

Domain	English learner students (n = 228)	Non-English learner students (n = 11,070)
Ratios and proportional relationships	0.21	0.10
The number system**	0.29	0.15
Expressions and equations	0.19	0.21
Geometry	0.05	0.15
Statistics and probability	0.09	0.14

\*\* Difference in the association between English learner students and non-English learner students is significant at  $p < .01$ .

Note: For domains without any asterisks the difference in the association between English learner students and non-English learner students is not statistically significant at  $p < .01$ . Calculated from three-level multiple regression models that accounted for the nesting of students within schools and districts. Assessment scores were standardized to allow for comparison of coefficients across predictors with different standard deviations. Separate models were fit for English learner students and non-English learner students. A follow-up model was fit that included interaction terms between each domain score in grade 7 and being an English learner student to test whether the strength of the association for each domain score differed for the two groups. Complete model results are in table C10 in appendix C.

Source: Authors’ analysis of 2016/17 and 2017/18 data from the Missouri Department of Elementary and Secondary Education.

**Table 3. Association between scores in the five math domains of the Missouri Assessment Program in grade 7 and scale scores on the Algebra I End-of-Course Assessment in grade 8, by special education status, 2016/17 and 2017/18**

Domain	Students who were receiving special education services (n = 170)	Students who were not receiving special education services (n = 11,128)
Ratios and proportional relationships	0.16	0.10
The number system	0.21	0.16
Expressions and equations	0.11	0.21
Geometry	0.18	0.15
Statistics and probability	0.12	0.14

Note: None of the differences in the association between students who were receiving special education services and students who were not are statistically significant at  $p < .01$ . Calculated from three-level multiple regression models that accounted for the nesting of students within schools and districts. Assessment scores were standardized to allow for comparison of coefficients across predictors with different standard deviations. Separate models were fit for students who were receiving special education services and students who were not. A follow-up model was fit that included interaction terms between each domain score in grade 7 and receiving special education services to test whether the strength of the associations for each domain score differed for the two groups. Complete model results are in table C13 in appendix C.

Source: Authors' analysis of 2016/17 and 2017/18 data from the Missouri Department of Elementary and Secondary Education.

## Implications

The study findings suggest that Missouri educators might consider adding math domain scores on the Missouri Assessment Program in grade 7, particularly the expressions and equations domain, to the factors they use in determining whether students are ready to take Algebra I in grade 8. Educators might also find the results useful in developing processes for districts to identify students who need additional support to acquire the foundational knowledge and skills most strongly associated with Algebra I achievement. While the findings suggest that instruction in all the domains examined is important, instruction in the expressions and equations domain may be particularly key to preparing students for Algebra I. Thus, educators might use the findings to provide targeted instruction to prepare students to take Algebra I in middle school.

Educators may consider the findings particularly useful because the study relied on data from an assessment that nearly all Missouri students take in grade 7 rather than an additional assessment such as an Algebra I readiness test. The findings are similar to those of previous research that relied on assessments specifically designed to measure Algebra I readiness (for example, Huang, Snipes, & Finkelstein, 2014).

That the number system domain had a stronger association with Algebra I achievement for English learner students than for non-English learner students suggests that Missouri educators might want to pay particular attention to this domain when determining whether English learner students are ready to take Algebra I in grade 8. The study did not provide information that can explain why the association between that domain and Algebra I achievement was stronger for English learner students, but it may be in part because the domain contains a smaller proportion of contextual items, which require students to read and interpret situations before conducting math calculations, than the other math domains do.

The findings for English learner students and students receiving special education services should be interpreted with caution because of the small sample sizes. Additional analyses, preferably with larger samples of students from these subgroups, are needed to support the generalizability of the findings. Furthermore, students receive special education services for diverse reasons, which may have varying associations with math abilities. The study dataset did not include the reasons that students were receiving special education services, and the results could vary by reason.

Future research could examine patterns of advanced math coursetaking and achievement among students predicted to be ready to take Algebra I in middle school based on their math domain scores in grade 7 as well as among students predicted not to be ready. In addition, educators in other states might wish to conduct similar analyses of the association between domain scores on their state assessments in grade 7 and Algebra I achievement in grade 8.

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