

RESEARCH REPORT 2016-006

The Influence of Students' Self-Perceptions and Mathematics Experiences on Learning More Mathematics in the Future

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August 2016

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ABSTRACT

This study explores the relationships among students' perceived learning opportunities in school mathematics, their perceptions of self in mathematics, and their desire to learn more mathematics in the future. Data included student survey responses from eighth and tenth grade students from a state in the Southeast region of the United States. Students were surveyed in the fall ($n = 299$) and spring ($n = 310$). The same analyses were replicated at each time point. Results were consistent at each time point and showed that students' desire to learn more mathematics in the future was a function not only of the extent to which they had classroom opportunities, but also whether they developed positive perceptions of themselves in mathematics. This has notable implications for teachers because teachers influence both school mathematics activities and students' sense of self as a mathematics learner.



INTRODUCTION

The significance of mathematics education in middle and high school as it relates to college and career readiness and success is well documented (National Research Council, 2001). Indeed, algebra (for example) is often referred to as the “gateway” to higher education (Rech & Harrington, 2000) in that success in algebra provides students with fundamental math concepts upon which future mathematics courses build (Harel, Selden, & Selden, 2006). Mathematics in the middle and high school grades also provides opportunity for students to begin to develop a process of abstract thinking (Knuth, et al., 2005). Unfortunately, not all mathematics teaching leads to student success and persistence in the subject. As described by Donovan, Bransford, & Pellegrino (1999), teaching and practicing procedures and algorithms comprises the bulk of secondary math education. And as a result, educational experiences tend not to promote deep understanding of those algorithms or elaborate on the connections to the non-academic world. As a consequence, many K-12 mathematics students do not construct the meaning of core concepts and principles, cannot relate concepts to problem-solving skills and procedures, and view mathematics as a collection of isolated, meaningless procedures to be memorized, not understood (e.g., Carpenter & Lehrer, 1999; Hiebert & Carpenter, 1992; Schmidt, et al., 2001). Many also believe that math understanding is unattainable or unimportant (Meehan & Huntsman, 2004).

The existence of these beliefs—that math is not interesting or that success is unattainable—has led to research focused on better understanding issues of student interest and persistence (Bobis, Anderson, Martin, & Way, 2011; Ellis, Fosdick, & Rasmussen, 2016; Schunk & Meece, 1992). The purpose of the present study was to explore how one particular perspective, students’ mathematics self-perceptions, may influence desire to learn more mathematics in the future, thereby impacting persistence in the domain. This study was informed by previous work with high school students, which highlighted the importance of students’ mathematics self-perceptions and their relationship to student classroom experiences and emerging mathematics aspirations (Frenzel, et al., 2010; Gaspard et al., 2015). This previous literature linked self-perceptions to choices of high school math courses (Simpkins, Davis-Kean, & Eccles, 2006; Watt, 2006; Watt, Eccles, & Durik, 2006), college major (Musu-Gillette et al., 2015), and career aspirations (Nagy et al., 2006). This literature also associates self-perceptions with more active processing of information where students both influence and are influenced by their experiences. Previous research, however, has not explored how instructional opportunities might relate to self-perceptions and mathematics-related outcomes. This study explores both of these aspects for eighth and tenth grade students and the degree to which the relationships among them may be consistent across multiple mathematics curriculum settings.



More specifically, this study addresses the following research questions:

1. Do students' mathematics self-perceptions relate to wanting to learn more mathematics?
2. Do mathematics experiences influence students' mathematics self-perceptions?
3. Is the influence of mathematics experiences on their wanting to learn more mathematics similar across students with different mathematics self-perceptions?

This study directly addresses concerns about the reproducibility of results of small educational studies, like these, by exploring whether results from one sample is replicated in a second sample (Open Science Collaboration, 2015). To build greater confidence in educational research methodology and findings, this study provides a replication and offers increased openness and transparency in the research process (Nosek et al., 2015; Open Science Collaboration, 2012, 2015).

Students' Mathematics Self-Perceptions

Self-perceptions include "students' thoughts, beliefs, and feelings about themselves, other persons, and events" (Schunk, 1992, p. 4). Self-perceptions include diverse theoretical perspectives. For example, self-perceptions includes self-concept, "one's collective self-perceptions that are formed through experiences with, and interpretations of, the environment, and that are heavily influenced by reinforcements and evaluations by significant other persons (Hansford & Hattie, 1982; Marsh & Shavelson, 1985; Shavelson & Bolus, 1982)" and self-efficacy, an individual's belief of what they think they can do (Bandura, 1977; Bong & Skaalvik 2002; Schunk & Pajares, 2009). Self-perceptions also include cognitive perspectives on motivation such as the amount of perceived control that one has over outcomes (Rotter, 1966; Seligman, 1975; Skinner, Wellborn, & Connell, 1990) or the connection between perceived achievement goals, reward structures, attributions and achievement behaviors (Weiner, 1990). What these different theoretical perspectives have in common is that perceptions represent "complex processes that are influenced by a variety of factors and that have diverse effects in school" (Schunk, 1992, p. 5).

There has been conflicting research regarding gender and its influence on students' mathematical self-perceptions (Gaspard et al., 2015; Musu-Gillette et al., 2015; Nagy et al., 2006). Nagy and others (2006) investigated the relationship between self-concept, intrinsic value, and subject specific achievement in upper secondary school and found that males reported a higher intrinsic value of mathematics as well as a higher self-concept than females. In the same study, male students were found to be more than twice as likely to enroll in advanced mathematics classes than female students. Nagy et al. (2015) also found students' choice to take advanced classes related to future career ambitions. Gaspard et al. (2015) also observed a gap between males and females. The researchers found their intervention did not eliminate the gap, however, it did keep it from growing. Musu-Gillette et al. (2015) observed no gender difference in interest, self-concept or value of mathematics.



Gaspard and colleagues (2015) wanted to show that it was possible to change high school students' value beliefs using classroom interventions. These interventions were used to help participants see the relevance of studying mathematics. For one of the interventions, participants were asked to write about the usefulness of mathematics; for the other intervention, students were asked to make connections to their everyday lives by reflecting on arguments written by college students about the utility of mathematics. Unlike previous research, the participants' value beliefs about mathematics did not decrease with time. Musu-Gillette, Wigfield, Harring, and Eccles (2015) conducted a study to describe the change in student interest, and beliefs about the value of mathematics and classified their results into three classes: High-Self Concept Trajectory, Slow Decline Self-Concept Trajectory and Fast Decline Self-Concept Trajectory. The researchers found that students with more positive views on their mathematical abilities and values were more likely to select a college major that was mathematics intensive while students in the groups where their self-concepts declined were very unlikely to enroll in majors that required a high usage of mathematics. Researchers did not find significant differences based on gender and achievement for the different classes. Musu-Gillette et al. (2015) found that students' interest in mathematics decreased over time. Students with the least interest in mathematics remained uninterested in mathematics over time. However, students in the other two groups became more interested in mathematics in the upper secondary years. There were no significant gender differences between the three groups.

This study considers an expectancy-value achievement motivation approach to understanding self-perceptions. Expectancy-value theory focuses on how students' choices, persistence and performance are influenced by their beliefs about how well they will do on the activity and the extent to which they value the activity (Atkinson, 1957; Eccles et al., 1983; Wigfield, 1994; Wigfield & Eccles, 1992, 2000). The development of a student's beliefs and values are important with this particular theoretical framework because it influences academic outcomes and choices.

Expectancies are beliefs or expectations about how well one will do on a given task. Pintrich & Schrauben describe the expectancy component as the answer to the basic question: Can I do this task? (p. 152) and includes "an individuals' beliefs about their ability to perform a task, their judgements of self-efficacy and control, and their expectancy for success at the task" (p. 154). In other words, beliefs about current competencies might answer the question: Can I do this task now?; whereas expectancies for success in the future might answer the question: Do I expect to do this task later this year? (Eccles et al., 1983).

Values include attainment value or importance, intrinsic value, utility value or usefulness of the task and cost (Eccles et al. 1983; Wigfield & Eccles, 1992, 2000). Attainment value is the value or importance one assigns to doing well on a particular task. Intrinsic value is the enjoyment one assigns to doing well on a particular task. Utility value or usefulness is the value one perceives the task fitting future plans and when considering cost, one weighs decisions of how engaging in one task might limit access to another task.



This framework was initially proposed and tested in the mathematics achievement domain (Eccles et al., 1983) but has been widely used in other domains such as science (Eccles & Wigfield, 2002; Schunk, Meece, & Pintrich, 2014; Simpkins et al., 2006). There are consistent relationships between achievement motivation and achievement related choices. Students with more positive expectancy-value achievement motivation are defined as students who believe that they can do a particular task, and are interested in and value the task. Students with lower expectancy-value achievement motivation are defined as students who do not believe they can do a particular task, are not interested in, and do not value the task. In mathematics education, we might describe a student with higher achievement motivation as one who tends to be more actively engaged in whole class mathematical discussions by volunteering their own thinking or adding on to or challenging the ideas of other students; whereas a lower achievement motivation student might be a student who does not pay much attention to such discussions. We focus on this perspective because we are particularly interested in the role school mathematics experiences play in both students' mathematics self-perceptions and their interest in academic choices (wanting to take more mathematics in the future). In line with the ideas about effective teaching and learning found in NCTM's Principles to Actions (NCTM, 2016) and Adding it Up: Helping Children Learn Mathematics (National Research Council, 2001), we are interested not only in the tasks in which students engage but the instructional opportunities and experiences which may foster or hinder their engagement. This requires understanding the opportunities afforded to students in their mathematics classrooms, whether these opportunities promote reasoning and problem solving (NCTM, 2016) and how these opportunities influence students' self-perceptions and interests in math. This study contributes to the extensive literature on achievement motivation by bringing together self-perceptions of opportunities to learn school mathematics and students' mathematics self-perceptions.



METHODOLOGY

Data included student survey responses from eighth and tenth graders from a state in the Southeast region of the United States. Teachers who volunteered to participate in a statewide professional development program recruited their students to participate in this study. The training is a content-focused professional development program that includes in-person meetings, online lessons, and ongoing support from expert teachers. The program focuses on building conceptual understanding to increase students' mathematics understanding and interest in mathematics. All teachers were mathematics teachers who were in their first year of the professional development program. Teachers taught a range of mathematics courses but only students enrolled in their Algebra I and Algebra II classes were recruited to participate. The reason for focusing on this particular group of students is that student achievement scores were available for these particular grade levels and content areas. Achievement data were analyzed as part of the larger evaluation effort about the influence of professional development on student outcomes. While the teachers were new to this particular professional development program, they were not novice teachers - the average number of years teaching was 13.5. Teachers signed letters of agreement indicating that they would participate in the study and implement the professional development curriculum to at least 80% fidelity. Teachers also agreed to document implementation through surveys, online teacher logs, and classroom observations. There were 67 mathematics teachers from 39 schools in the initial cohort. 73% of the teachers signed letters of agreement to participate in the study. However, only 29 teachers recruited students to complete surveys. Email reminders were sent by the research project director and professional development coordinators. In addition, the professional development coordinators visited schools and encouraged teachers to participate in the study.

A set of forty paper copies of student surveys were mailed to each teacher in the fall and the spring. Teachers were asked to mail the completed surveys back to a central location within three months. Data were entered and 20% of the data were randomly against the original copies to ensure accuracy. Undergraduate students flagged student responses with missing or odd responses. An example of an odd response was if a student filled out the same response options for all survey items. There were 1,165 survey responses received in the fall and 360 survey responses received in the Spring. Approximately 12% of the survey responses were dropped due to missing responses and 8% dropped due to odd responses which resulted in a final sample size of 299 in the fall and 310 in the spring. Due to the Human Subjects agreement, we did not collect identifiable information from students. We were not able to match student responses in the fall and spring and were not able to match student responses to other sources of information such as student achievement or student demographic information. We included items for students to self-report gender and ethnicity but were not able to verify this information with other sources.



Variables Included in Analyses

Students' Perceived Opportunities to Participate in Mathematics

Nine survey items measured students' perceived opportunities to regularly participate in school mathematics activities (Table 1). The items were part of the OECD Program for International Student Assessment (PISA) 2012 student questionnaire. PISA is an international survey administered to 15-year old students worldwide. PISA includes information about student performance in reading, mathematics and science, student background, student approaches to learning, and the organization of the schools. The student questionnaire includes questions about the student, their family and home, learning mathematics, their mathematics experiences, and their school. We selected nine items focused on student mathematics experiences to describe student perceptions of what their mathematics teacher taught (e.g., Thinking about the mathematics teacher that taught your last mathematics class, how often does each of the following happen?). There were four response options: never, in some lessons, in most lessons, in all lessons. Student responses for these nine items were highly correlated for the fall ($\alpha = .71$) and spring ($\alpha = .83$). While these items do not represent the full range of mathematics experience, they were sufficient to represent activities comprising the professional development program. We created a composite variable that combined these items into a single variable referred to as opportunities to learn mathematics. A higher value on this variable indicated a student reporting more opportunities to participate in mathematics.



Table 1

Descriptive Statistics

	<i>Fall (n=299)</i>		<i>Spring (n = 310)</i>	
	<i>Mean</i>	<i>SD</i>	<i>Mean</i>	<i>SD</i>
Perceived Opportunities to Participate in School Mathematics¹				
My teacher asks questions that make me reflect on the problem.	0.70	0.46	0.74	0.44
My teacher gives problems that require me to think for an extended time.	0.72	0.45	0.75	0.43
My teacher asks me to decide on my own procedures for solving complex problems.	0.45	0.50	0.54	0.50
My teacher presents problems for which there is no immediately obvious method of solution.	0.52	0.51	0.58	0.50
My teacher presents problems in different contexts so that students know whether they have understood the concepts.	0.79	0.41	0.77	0.43
My teacher helps me to learn from my mistakes.	0.82	0.39	0.81	0.40
My teacher asks me to explain how I solved a problem.	0.75	0.43	0.75	0.43
My teacher presents problems that require me to apply what I have learned to new contexts.	0.88	0.33	0.84	0.37
My teacher gives problems that can be solved in different ways.	0.81	0.39	0.83	0.38
Mathematics Self-Perceptions²				
I am good at mathematics.	0.85	0.36	0.79	0.41
Compared to other students in my class, I am one of the best in mathematics.	0.48	0.50	0.48	0.50
Compared to my other school subjects, I am better at mathematics.	0.47	0.50	0.44	0.50
I expect to do well in mathematics this year	0.93	0.26	0.88	0.32
I am good at learning new things in mathematics.	0.76	0.43	0.75	0.43
What I learn in mathematics is useful outside of mathematics class.	0.54	0.50	0.55	0.50
For me, being good at mathematics is very important.	0.85	0.36	0.85	0.36
Working on mathematics assignments is very interesting.	0.42	0.49	0.37	0.48
I really like doing mathematics.	0.50	0.50	0.49	0.50

¹Dichotomous variables where 1 = most lessons, 0 = not most lessons²Dichotomous variables where 1 = agree, 0 = disagree

Students' Mathematics Self-Perceptions

Nine survey items comprised our measure of students' mathematics self-perceptions (Table 1). These items are from the expectancy-value achievement motivation theory framework (Eccles, et al., 1983; Wigfield, 1994; Wigfield & Eccles, 1992, 2000) which suggests that student performance and persistence are influenced by their beliefs in their abilities and the extent to which they value the activities that they participate in (Simpkins, et al., 2006; Wigfield, et al., 1991). There were three items related to ability beliefs (I am good at mathematics; Compared to other students in my class, I am one of the best in mathematics; Compared to my other school subjects, I am better at mathematics), two items related to expectancy beliefs (I expect to do well in mathematics this year; I am good at learning new things in mathematics), and four items related to usefulness, importance, and interest (What I learn in mathematics is useful outside of mathematics class; For me, being good at mathematics is very important; Working on mathematics assignments is very interesting; I really like doing mathematics). Student responses for these items were highly correlated in the fall ($\alpha = .87$) and spring ($\alpha = .88$). There were four response options for these items: strongly disagree, disagree, agree, and strongly agree. Due to skewed distributions, we converted the response categories into two categories with a "1" indicating that the student "strongly agreed" or "0" indicating that the student did not strongly agree. All nine items were then summed together with higher values on the composite indicated more positive mathematics self-perceptions.

Desire to Study Mathematics in the Future

Students were asked about their desire to study and engage in mathematics in the future (I would like a career involving mathematics; I would like to take more mathematics courses; and I would like to study mathematics after high school. Student responses to these three items were highly correlated in the fall ($\alpha = .78$) and spring ($\alpha = .77$). The response options for these items were agree (1) or disagree (0). Three items were summed together with higher values on the composite indicated a greater desire to study mathematics in the future. These variables were used in a series of regression analyses that considered the nested structure of the data. For example, to address the first research question, we considered the relationship between students' mathematics self-perceptions and wanting to learn more mathematics. By estimating the relationship between these two variables after controlling for gender and ethnicity, we had evidence of whether students' mathematics self-perceptions related to wanting to learn more mathematics. We then replicated the same analyses for data from both time points. While information about classrooms and teachers were not included in our analyses, we accounted for the non-independent nature of the student survey data by clustering standard errors for students within the same classroom.



RESULTS

There were no gender differences in the reporting of opportunities to learn mathematics in the fall ($t(297) = .31, p = .75$) or spring ($t(308) = .75, p = .45$). There were also no ethnicity differences in terms of student perceived opportunities to learn in the fall ($t(297) = -0.50, p = .61$) or spring ($t(308) = -0.06, p = .95$). There were also no statistically significant differences by gender or ethnicity for student self-perceptions. There were, however, gender differences for professed interest in mathematics; in the fall, males ($M = 1.78, SD = 1.27$) reported more interest in mathematics than females ($M = 1.29, SD = 1.20, t(297) = 3.42, p < .001$). Similarly, in the spring, males ($M = 1.68, SD = 1.27$) reported more interest in mathematics than females ($M = 1.27, SD = 1.17, t(308) = 2.91, p < .01$). There were no statistically significant differences by gender for wanting to learn more mathematics in the future.

Relationship Between Students' Mathematics Self-Perceptions, Opportunities to Learn Mathematics and Wanting to Learn More Mathematics

The positive relationships between mathematics self-perceptions and interest in mathematics were consistent across both samples (Table 2). Students with higher mathematics self-perceptions were more likely to want to take more mathematics courses in high school and college and have a career that involves mathematics compared to students with lower mathematics self-perceptions. This relationship was present even after adjusting for gender and ethnicity and for the nested structure of the data (Figures 1, 2). Similarly, there were positive relationships between opportunities to participate in mathematics and mathematics self-perceptions (Table 2). When both perceived learning opportunities and self-perceptions are included in the model, there were significant relationships between self-perceptions and wanting to take more math as well as between perceived learning opportunities and self-perceptions. However, for both time points, the relationship between opportunities to participate in mathematics and interest in mathematics was not significant, which suggests that mathematics self-perceptions plays an important role in mediating the effect of opportunities to participate in mathematics activities and interest in mathematics. Indirect effects using approaches proposed by Sobel (1982, 1986; see also Bauer, Preacher, & Gill, 2006; Kenny, Korchmaros, & Bolger, 2003; Krull & MacKinnon, 1999, 2001; MacKinnon, 2008; MacKinnon, Lockwood, & Williams, 2004; MacKinnon, Warsi, & Dwyer, 1995) were statistically significant for the fall (Sobel's $z = 3.69, p < .001$; magnitude of indirect effect = 0.07, standard error = 0.02) and spring, (Sobel's $z = 4.36, p < .001$; magnitude of indirect effect = 0.09, standard error = 0.02). In addition, bootstrap confidence intervals for the indirect effects of 20,000 bootstrapped samples (Preacher & Hayes, 2008) did not include zero for the fall (CI [0.03, 0.12]) or spring (CI [0.05, 0.13]). Taken together, these results suggest a non-zero indirect effect for both the fall and spring data. That is, it appears that opportunities to participate in mathematics indirectly affect interest in learning more math through student mathematics self-perceptions.



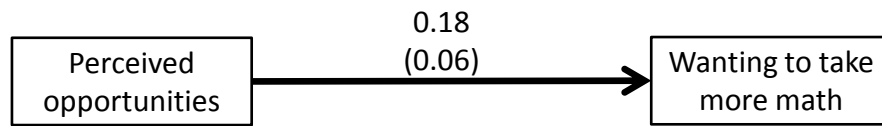
Table 2

Summary of Regression Analysis

<i>Fall (n = 299)</i>	<i>B</i>	<i>SE B</i>	β	<i>B</i>	<i>SE B</i>	β	<i>B</i>	<i>SE B</i>	β
Perceived opportunities to participate in school mathematics	0.12	0.03	0.21*				0.03	0.02	0.05
Mathematics self-perceptions				0.31	0.02	0.60*	0.31	0.02	0.59*
<i>R</i> ²			0.10			0.41			0.41
<i>F</i>			11.58*			171.67*			121.47*
<hr/>									
<i>Spring (n = 310)</i>									
Perceived opportunities to participate in school mathematics	0.12	0.02	0.21*	0.30	0.02	0.63*			0.04
Mathematics self-perceptions							0.29	0.02	0.62*
<i>R</i> ²			0.07			0.42			0.42
<i>F</i>			32.74*			138.62*			99.28*

**p* < .001.

a) Direct Path



b) Indirect Path

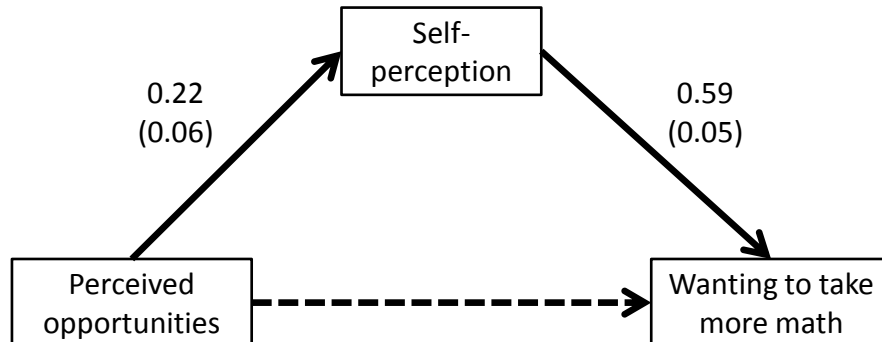
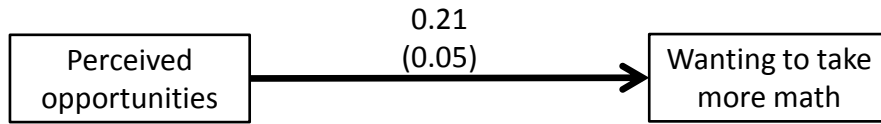


Figure 1. Standardized regression coefficients for the relationship between perceived opportunities to participate in mathematics and wanting to take more mathematics mediated by mathematics self-perceptions for fall.

Note. Numbers on the solid lines are statistically significant ($p < .01$) multilevel standardized regression coefficients (standard errors in parentheses). The dotted line indicates a nonsignificant coefficient.



a) Direct Path



b) Indirect Path

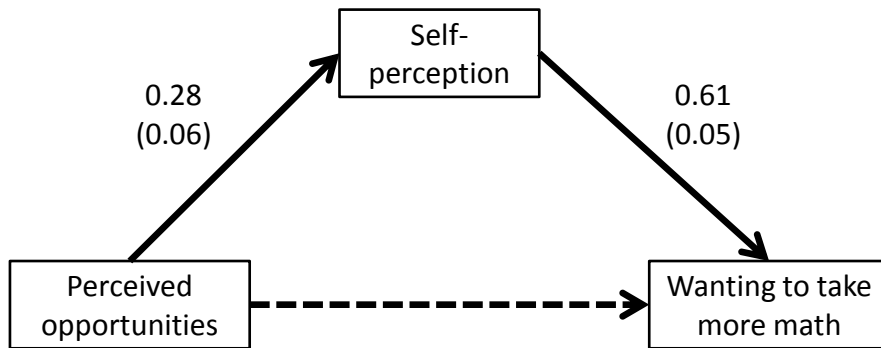


Figure 2. Standardized regression coefficients for the relationship between perceived opportunities to participate in mathematics and wanting to take more mathematics mediated by mathematics self-perceptions for spring.

Note. Numbers on the solid lines are statistically significant ($p < .01$) multilevel standardized regression coefficients (standard errors in parentheses). The dotted line indicates a nonsignificant coefficient.



DISCUSSION & CONCLUSIONS

The results highlight the importance of students' self-perceptions in understanding the effects of mathematics learning opportunities on their desire to learn more mathematics. School mathematics opportunities by themselves are significant, but alone may not be sufficient to increasing student interest in learning more mathematics (Greer, Verschaffel, & Mukhopadhyay, 2007; Jones, Uribe-Florez, & Wilkens, 2011; Ma & Kishor, 1997, NCTM, 2000; Wang, 2012). This has notable implications for teachers because teachers influence both school mathematics activities and students' sense of self as a mathematics learner. The results of this study provide quantitative evidence that students' desire to learn more mathematics in the future is a function of not only the extent to which they have classroom opportunities to learn math, but also whether they develop positive perceptions of themselves in mathematics (Schunk & Richardson, 2011; Wang, Degol, & Ye, 2015).

The data show that students' mathematics self-perceptions played a critical role in mediating the effects of mathematics learning opportunities on their desire to learn more mathematics. Thus, school mathematics opportunities may be necessary but not sufficient to increasing student interest in learning more about mathematics (Meece, Anderman, & Anderman, 2006; Pintrich, 2003). Supporting the desire to learn more mathematics is not simply about providing more of particular types of mathematics opportunities. It also requires paying attention to whether the activities and their implementation allow and encourage students to perceive themselves as the kind of person who can and wants to do mathematics. This finding may help guide teacher-student interactions as well as classroom activity development.

Although classroom and school demographic characteristics were not considered, the relatively small number of classrooms and schools prevented us from controlling for classroom or school level differences beyond statistically accounting for the nested structure of students within classrooms. We hypothesize that there are classroom differences that contribute to both the opportunities to learn mathematics and self-perceptions due to a non-random way in which students may have been assigned to their classrooms (over which we had no control). However, such classroom differences could also reflect different instructional practices and affordances by particular teachers, a possibility consistent with previous research (see for example, Buck, Cook, Quigley, Prince, & Lucas, 2014). Our study suggests two ways teachers may be instrumental in students' learning ambitions. They have considerable choice in which parts of the intended curriculum they enact (which units, specific lessons, and activities within lessons) and how they do so, thus shaping students' opportunities to participate in desirable mathematics activities. In addition, teachers can also influence the way students perceive themselves when engaged in learning mathematics. One implication of our results is that teacher preparation and professional development efforts might be more effective when informed by social practice theory and identity development. Specifically, teachers may need explicit support in why and how to help all students not just to access important mathematics learning activities but also to develop positive self-perceptions as mathematics learners (Boaler,



2016). Teachers may not realize that student interest and persistence in mathematics reflects what they believe their teachers think of their capacity to learn it (Boaler, 2016). Overall, our results reiterate the importance of earlier mathematics education as a critical influence on whether students want to continue learning mathematics in the future. This study also provides important empirical evidence to support improving and providing broad access to not only reform-based learning opportunities but also the identity-forming aspects of mathematics education for all students in order to encourage more students to want to learn mathematics. To further this goal, we advocate the continued development of strong tools and methods for assessing the learning opportunities afforded students in mathematics in mathematics as well as their emerging sense of themselves as capable mathematics learners.



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