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Title

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Journal

Proceedings of the Annual Meeting of the Cognitive Science Society, 38(0)

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Publication Date

2016

Peer reviewed

Exploring the Relationship between Adolescents' Interest in Algebra and Procedural Declines

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Abstract

Algebra I is considered a gatekeeper course for higher education, high-paying jobs, and access to STEM careers, yet many students find themselves struggling to learn algebra. Prior research links intrinsic motivation for learning math with mathematics achievement, particularly during adolescence. The current study measured middle school students' interest in algebra and their procedural skills across the span of an algebra unit to determine whether students who show declines in algebraic problem-solving also show a decline in a particular type of intrinsic motivation – interest in algebra. Pre-test and post-test scores were used to categorize participants into those who showed declines in problem-solving skills and those who did not. Of the overall sample (N = 367), a group of 25 students showed declining skills over the course of the unit. These students also showed significant declines in interest in mathematics from pre- to post-test in comparison to students who did not show procedural declines. Our findings support the relationship between performance and motivation in the classroom, particularly in algebra class. Educational implications are discussed.

Keywords: algebra; motivation; achievement; procedural skills; procedural skill decline; education

Introduction

Prior research has examined mathematical cognition and problem solving in an attempt to understand and, thus, improve students' mathematics abilities. Problem solving skills can be defined as using the cognitive tools needed to solve a given mathematical problem (Schoenfeld, 1992). These problem-solving abilities become more important as students advance in mathematics, particularly when they are in algebra classrooms (Mayfield & Glenn, 2008). An understanding of how to apply procedural skills is also known to contribute to mathematical performance (Star, 2005). Failure to develop these skills leads to poor mathematics performance, specifically in middle school (Lein et al., 2015). Prior research has also suggested that a

student's attitude towards mathematics can affect their performance in the classroom (Middleton & Spanias, 1999). It has been well established that achievement and motivation in mathematics are closely linked during adolescence (Wang, 2013).

In early motivation research, being *intrinsically* motivated, or motivated to engage in a task for the sake of the task itself, was deemed more positive than being *extrinsically* motivated, or motivated to engage in the task for an external reward (Deci & Ryan, 1985). This line of research also found that students whose motivational orientations were more aligned with an intrinsic motivation (e.g., mastery orientation, value, interest) tended to persist and succeed more academically. However, the distinction between and value given to intrinsic and extrinsic motivation is not always accepted (Cameron & Pierce, 1994; Ryan & Deci, 1996). Researchers today tend to focus on particular motivation constructs that may be more useful in explaining students' academic behavior than general categories or dichotomies such as intrinsic and extrinsic motivation.

Wang and Pomerantz (2009) found that students who initially had more positive achievement motivation (e.g., mastery orientation) in the fall of the seventh grade had better academic performance in the spring of eighth grade than students whose motivation-orientation would traditionally be considered less positive. They also found that over time students in the United States showed general declines in positive achievement motivation orientations, such as becoming less mastery oriented and valuing mathematics less. Ma (1997) suggests that there is a reciprocal relationship between the development of attitudes towards mathematics and the development of math ability. Fisher, Dobbs-Oates, Doctoroff, and Arnold (2012) found that high interest in mathematics coincided with strong math skills in preschool aged children. However, Fisher and colleagues did not examine adolescents, which makes it

difficult to ascertain the applicability of these findings to the relationship between adolescent student achievement and interest in math. According to the 2012 Programme for International Student Assessment (PISA), adolescents across the United States struggle with mathematics, ranking below average nationally in comparison to other industrialized nations (Kelly, Nord, Jenkins, Chan, & Kastberg, 2013). Further, this same data revealed that 50% of students in the United States have low levels of interest in mathematics. While we know that math achievement and math motivation are related (e.g., Wang & Pomerantz, 2009), little research has assessed the relationship between adolescents' *interest* in mathematics and their mathematical problem-solving abilities.

It is likely that interest in a particular topic or subject area develops over time with experiences; for example, students' various experiences with mathematics, over the course of their schooling, may contribute to interest in mathematics. It is also possible that struggling to develop skills important to success in a particular domain, such as procedural skills in mathematics, may relate to declines in interest in that particular domain.

Achievement in mathematics is linked with success in future employment (Lein et al., 2015). Algebra I in particular is often considered a gatekeeper course for higher-level math courses as well as select science courses (Matthews & Farmer, 2008). When learning algebra, mathematical problem-solving becomes particularly more challenging than problem-solving with arithmetic. Not only do concepts become more difficult (Booth, 2011) but procedures do as well. Procedural knowledge is an important component of mathematical cognition (Star, 2005). Being able to overcome this challenge and maintain or fine-tune one's problem-solving skills may be related to maintaining or increasing levels of interest in mathematics. Experiencing a loss or decrement in problem-solving skills may be related to declines in interest in math as well.

The current study focuses on students who demonstrate this depreciation in procedural problem-solving skills over the course of an algebra unit. In particular, the current analyses explore whether students who show declines in algebraic problem-solving also show a decline in interest in algebra.

Methods

Participants

Middle school students enrolled in Algebra I ($N = 367$) from classrooms of eight different teachers across three public school districts in the US Midwest participated in the current study. One of the school districts could not release demographics data; this school district made up 41.1% of the sample ($n = 151$). Of the two school districts that did provide demographic data 50.8% were female, 29.1% were underrepresented minority (URM) students, 14.6% were

classified as receiving special education, and 7% were classified as Limited English Proficient by their districts.

Procedure

The current data comes from a larger experimental study that assessed the effectiveness of a worked examples intervention. However, for the purposes of the current research question, the data was collapsed across conditions to increase power due to the small sample size. It is important to note that results were consistent when running the same analyses by condition.

Each classroom completed the study over the course of one of three possible math units. The unit was selected by the teacher to coincide with their syllabus. These units included pre-algebra (58.9%), properties of exponents (15.3%), and solving quadratic equations (25.9%).

Students individually completed a 20-item motivation survey using a seven point Likert scale. This survey assessed various motivation constructs including *interest in algebra*. Interest in algebra is defined as the intrinsic value or enjoyment that one experiences when working on an algebra task (see Simpkins, Davis-Kean, & Eccles, 2006 for a similar interest in math measure). After completing the motivation survey, students completed a unit pre-test. Unit tests were created to reflect material students should have learned within the unit regardless of condition; the problems were based on items from standardized math tests used in public schools. Students were given the entire math period to finish the test. After the pre-test, students then completed four worksheets that coincided with teacher instruction on the particular unit. The motivation survey was re-administered after completion of the unit, followed by a post-test that was identical to the pre-test.

This data was collected to answer the following research question:

Do students who show declines in algebraic problem-solving show a decline in interest in algebra as well?

Measures

Interest in Algebra Participants completed a survey that measured several motivation constructs. The items for interest in algebra asked students to answer using a seven point Likert scale. One represented "Not at all" and seven represented "Yes, definitely." Interest in algebra was measured with three items, which were: "(1) Do you enjoy doing algebra very much?", "(2) Do you think algebra is fun?", and "(3) Do you think algebra is boring? [reverse scored]". Higher means represent high levels of interest in algebra.

Decline in Procedural Skill Students were categorized into two groups based upon whether they showed declines in procedural skill or not. This was done using their performance on the unit tests taken pre- and post-instruction. Procedural problem-solving skill was

demonstrated by knowing how to solve a problem, such as solving a quadratic equation using graphing. Assessments differed based upon whether students were currently studying a pre-algebra unit, a quadratics unit, or a unit on properties of exponents. Pre- and post-test scores were computed by percent of problems solved correctly. Then, a difference score was computed for each student based on subtracting their pre-test score from their post-test score. Most students maintained their skill or demonstrated increases ($n = 342$). However, 25 students declined from pre- to post-test; these students were categorized as the Declining group. These two categories of students were then compared on interest in algebra from pre- to post-test.

Results

Table 1: Descriptives.

	Declining Skill Group ($n = 25$)		Non-Declining Skill Group ($n = 342$)	
	Mean	<i>SD</i>	Mean	<i>SD</i>
Pre-test Procedural	.542	.291	.190	.191
Post-test Procedural	.371	.265	.437	.249
Pre-test Interest	4.28	1.61	4.03	1.52
Post-test Interest	3.83	1.74	4.14	1.52

Interest in algebra at pre-test was positively and significantly correlated with procedural scores at pre- ($r = .258, p < .001$) and post-test ($r = .235, p < .001$). Interest in algebra at post-test was also positively and significantly correlated with procedural scores at pre- ($r = .142, p = .007$) and post-test ($r = .211, p < .001$). However, the purpose of the current study was to examine differences in interest for students who showed declines in procedural skills rather than the normative learning pattern. Thus, to answer our research question, each participant was first classified into either the Declining Skill group or the Non-Declining Skill group based on whether their performance in solving procedurally-based problems decreased from pre- to post-test. Descriptives are presented in Table 1. Then, a 2 (Time) \times 2 (Group) repeated measures ANOVA was conducted to assess whether changes in interest from pre- to post-test differed by group.

There was no significant main effect of group ($F[1, 365] = .014, p = .906, MSE = 4.033, \eta_p^2 < .001$), meaning that groups did not differ by interest collapsed across time points. There was no significant main effect of time ($F[1, 365] = 2.009, p = .148, MSE = .643, \eta_p^2 = .006$), meaning that interest did not differ from pre- to post-test collapsed across the two groups. There was a significant group by time interaction ($F[1, 365] = 5.814, p = .016, MSE = .643$). Participants who did not show declines in procedural skill did not show a decline in math interest from pre- ($M = 4.03, SD = 1.52$) to post-test ($M = 4.14, SD = 1.52$). Participants

who *did* show declines in procedural skill also showed a decline in math interest from pre- ($M = 4.280, SD = 1.61$) to post-test ($M = 3.827, SD = 1.74$).

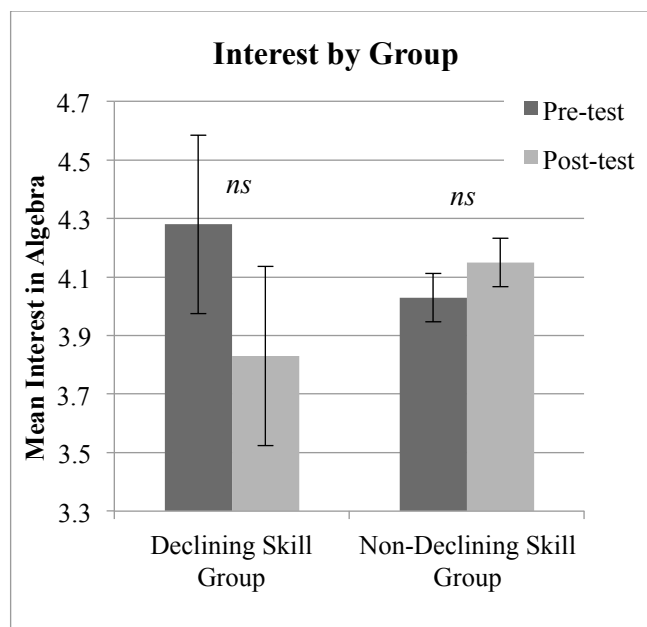


Figure 1: Interest by group.

To test simple effects, two repeated-measures t-tests comparing pre- and post-interest, one per group, were used. The apparent decrease in interest from pre- ($M = 4.28$) to post-test ($M = 3.83$) for students in the Declining Skills group was trending toward significance ($t [24] = 1.905, p = .069$). The apparent increase in interest from pre- ($M = 4.03$) to post-test ($M = 4.15$) for students in the Non-Declining Skills group was trending toward significance ($t [341] = -1.851, p = .065$). Figure 1 displays this finding.

Discussion

It was expected that students who showed declines in interest would also show declines in procedural skills. Our data was consistent with this hypothesis and expands upon prior research. For instance, Wang and Pomerantz (2009) found that positive motivation-orientation is a predictor of math achievement; it is also known that math performance is strongly correlated with interest (Fisher et al., 2012). The results of this study suggest that as a student declines in procedural skills over time, they may also decline in interest. It is important to note that the current data is correlational in nature and directionality of the findings cannot be established. However, we speculate that the findings may be attributed to self-efficacy beliefs, which have been found to have an impact on achievement (Lee, 2009). Low self-efficacy is associated with low levels of other more positive motivation-orientations and achievement. High self-efficacy is associated with high

achievement and more positive forms of motivation (Pajares, 1996).

It is possible that as a student declines in math skill, their self-efficacy beliefs are lowered which in turn lowers their interest in math. After repeated failure experiences, a student may feel less efficacious as well as less interested in the domain. This could perhaps also lead to the student exerting less effort-- leading to even more failure. Moreover, a student's lowered expectations from one failure experience may create a self-fulfilling prophecy and from that, a cycle of below average achievement. However, due to the correlational nature of the data, these speculations need to be explored and validated in future work.

Because of the intricate nature of the development of achievement motivation as well as the quasi-experimental design of the study, we cannot determine the direction of the relationship between interest in math and algebraic procedural skills. Further research should explore the relationship between declines in middle school students' algebraic problem-solving skills and their interest in math. In the interim, it is clear that both students' motivation for math, such as interest in algebra, and procedural skills should be fostered in the classroom as they are both important components of mathematics achievement.

Acknowledgements

Thanks are due to the participating school districts. Research reported here was supported by the Institute of Education Sciences, U.S. Department of Education, through Grant R305A100150 to Strategic Education Research Partnership Institute. Christina Barbieri's continued contribution to this project was supported by Grant R305B130012 from the U.S. Institute of Education Sciences to the University of Delaware. The opinions expressed are those of the authors and do not represent views of the Institute or the U.S. Department of Education.

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