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The incremental validity of beliefs and attitudes for predicting mathematics achievement

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ABSTRACT

STEM-related industries are a major driver of U.S. economic growth and possessing mathematics skills is a central component of success in STEM fields. Thus, it is important to identify predictors of mathematics achievement in high school students. Some previous research has shown that students' beliefs and attitudes are important predictors of their mathematics grades and achievement. In the present paper, we examined the ability of mathematics beliefs and attitudes to predict ACT mathematics test scores by analyzing data from a questionnaire designed using the Theory of Planned Behavior framework given to high school juniors and seniors who had recently taken the ACT. Results revealed that mathematics attitudes, subjective norms, perceived control, and intentions were all significantly correlated with mathematics course grades and ACT mathematics scores. Attitudes also incrementally predicted ACT mathematics scores over several key variables. The article concludes with a discussion of limitations and future directions.

1. Introduction

Scientific innovation is a major driver of the national economy (e.g., Adkins, 2012; Rothwell, 2013). The U.S. Department of Labor estimates that 50% of the U.S.'s economic expansion is due to workers employed in science and engineering fields (Adkins, 2012). Clearly, it is in the national interest for students to graduate with the skills taught in science, technology, engineering, and mathematics (STEM) fields. However, it has been estimated that only 6% of entering postsecondary students graduate with a STEM degree (Carnevale, Smith, & Melton, 2011). One explanation for these low numbers is that many entering postsecondary students have not yet developed the requisite skills necessary to succeed in STEM majors. Key among those skills are mathematics skills (Carnevale et al., 2011).

A recent report underscores the fact that many students are lacking the mathematics skills to succeed in STEM. Specifically, the most frequently taken mathematics course by first year STEM majors is Calculus 1 and the ACT mathematics score associated with 50% chance of earning a B or higher in that course is 27 (Mattern, Radunzel, & Westrick, 2015). However, most STEM students are not ready to succeed in Calculus 1; only 32% of STEM majors from the 2005 through 2009 cohorts reached a 27 on the ACT mathematics test (Mattern et al., 2015). Far fewer non-STEM majors reach that score. It thus seems possible that improving math achievement in high school may lead to greater readiness to succeed in STEM, and improved outcomes for individual students and the U.S. economy as a whole. An important question remains: What are the most important predictors of mathematics achievement? In this paper, we propose that student beliefs and attitudes are important factors in mathematics achievement and we expand on previous work to further examine this issue.

1.1. Beliefs and attitudes

Students acquire new knowledge ($12 \times 5 = 60$) and experience new situations ("I was nervous yesterday when I had to solve a math problem in front of the class") daily. The extent to which they believe this knowledge or experience is true ("I'm very confident that $12 \times 5 = 60$"; "I'm not sure how nervous I really was yesterday") is called a *belief* (Wyer & Albarracin, 2005). During the course of his/her education, each student develops a set of beliefs about mathematics. Some example beliefs about mathematics may be, "math is easy," "math can help me get a job one day," "my friends do not like math," or "boys are good at math". Beliefs are typically formed from one's own experience or from learning about another's experience (Bandura, 1977) and, accordingly, math beliefs are formed from one's own, or another's, experiences with math. Over time, students can develop beliefs about their future interactions with math. These beliefs about the future are called *expectations.*

When an evaluation becomes attached to a belief (e.g., "I was nervous yesterday when I had to solve a math problem in front of the class and I HATED it!"), then an *attitude* is formed (e.g., Ajzen, 1991;

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Eagly & Chaiken, 1993). Attitudes are evaluations of people, objects, or events (Eagly & Chaiken, 1993). Beliefs and attitudes can have powerful effects on behavior and educational outcomes (e.g., Bandura, 1977; Lee, 2014; Lipnevich, MacCann, Krumm, Burrus, & Roberts, 2011; Nye, Su, Rounds, & Drasgow, 2012; Rounds & Su, 2014; Wigfield & Eccles, 2000). For example, Eccles and colleagues (e.g., Wigfield & Eccles, 2000) have put forth an expectancy-value theory that states that, among other constructs, *intrinsic value* (how interested one is in a topic; how much they like doing the activity) and *utility value* (how much they believe an activity will help them achieve a goal) influences the extent to which a student engages in a topic. Recent cross-cultural research employing data from the PISA 2009 international dataset has demonstrated the importance of intrinsic value in predicting educational attainment (Lee, 2014). Specifically, enjoyment of reading predicted PISA reading scores in each of the 13 countries examined. Furthermore, there is evidence that another type of attitude, *interests*, or preferences to perform certain activities (Rounds & Su, 2014), serve to motivate behavior. Accordingly, a recent meta-analysis found that interests predicted important performance outcomes both at school and at work (Nye et al., 2012). Furthermore, beliefs in one's ability to perform certain behaviors are known as *self-efficacy* beliefs. Research has found that those high in self-efficacy tend to expend more sustained effort and are more resilient to failure than those low in self-efficacy (Bandura, 1993).

Other work has successfully predicted achievement by utilizing similar belief and attitude-based constructs as those discussed above. For example, using the framework of the *Self-Systems Model* (Skinner, Kindermann, Connell, & Wellborn, 2009), Green et al. (2012) conducted a longitudinal study of 1866 Australian students over a period of one year, finding that positive attitudes toward school predicted achievement test scores. This relationship was mediated by class participation, homework completed, and absenteeism. Furthermore, attitude toward school was predicted by adaptive motivation, impending motivation, maladaptive motivation (negatively), and academic self-concept. Interestingly, most of these constructs also consist of attitude and belief components. Adaptive motivation, impending motivation, and academic self-concept are measured, in part, by items such as "learning at school is important to me" (attitude), I'm often unsure how I can avoid doing poorly at school" (belief), and "I am good at most school subjects" (belief), respectively.

Specific to mathematics, attitudes and beliefs have been shown to predict mathematics performance and achievement, although effect sizes are often small (e.g., Hembree, 1990; Lipnevich et al., 2011; Ma & Kishor, 1997; Simzar, Martinez, Rutherford et al., 2015). For instance, *math anxiety,* which is related to negative math attitudes, predicts lower performance on math achievement tests (Hembree, 1990). Consistent with this, Bong, Cho, Ahn, and Kim (2012) found that test anxiety was negatively related to math achievement in a sample of Korean elementary and middle-school students. Furthermore, they found that self-concept predicted math achievement in most of their analyses. More recently, Simzar et al., (2015) found that mathematics self-efficacy predicts achievement test scores in 10th grade students. Furthermore, Lipnevich et al. (2011) predicted mathematics grades in 8th grade students incrementally over math achievement scores using a questionnaire they developed that asked students about their math attitudes and beliefs.

The questionnaire developed by Lipnevich and colleagues was based on a well-established model for behavioral prediction from the field of social psychology known as the *Theory of Planned Behavior* (TPB; Ajzen, 1991). In the TPB, behavior is directly predicted by *intentions*. Intentions, in turn, are predicted by one's attitude and two types of beliefs. The first belief type is *subjective norms*, which refers to perceived social pressure from important others (e.g., friends, family) to perform, or not perform, the behavior. The second belief type is *perceived control*, which refers to the belief that one is capable of performing the behavior. The TPB has been used to predict numerous types of behaviors, with one meta-analysis finding that intention predicted behavior ($r = 0.47$); while attitudes ($r = 0.49$), subjective norms ($r = 0.34$), and perceived control ($r = 0.43$) all predicted intentions (Armitage & Conner, 2001). Very little of the research on the TPB, however, has been conducted in the field of education (see Fishbein & Ajzen, 2010 for a review). One notable exception is the work conducted by Lipnevich et al. (2011).

As briefly stated above, Lipnevich and colleagues predicted mathematics grades in 8th grade students in the United States incrementally over math achievement scores with a 22 item questionnaire developed based on the principles of the TPB. Example items included: Intention, "I will try to work hard to make sure I learn math"; attitude, "I enjoy studying math"; subjective norms, "My friends think that math is an important subject"; and perceived control, "If I invest enough effort, I can succeed at math". A structural equation model showed that intention predicted math grades ($\beta = 0.64$), and attitude ($\beta = 0.45$), subjective norms ($\beta = 0.18$), and perceived control ($\beta = 0.32$) all predicted intention. The TPB structure was later replicated in a sample of Belarusian students. Given the success of this study, it is somewhat surprising that little-to-no work has been done to replicate and extend this work. It is worth noting that the TPB was used as a theoretical framework in the development of the background variables for the PISA 2012 mathematics assessment (OECD, 2014). To our knowledge, however, no peer-reviewed papers have yet to be published on the results of this data collection.

1.2. The current study

The purpose of the current study is to replicate and extend the Lipnevich et al. study in several ways. First, whereas Lipnevich et al. tested 8th graders; we administered a TPB-based mathematics questionnaire to a large sample of 11th and 12th grade students in the United States who had recently completed the ACT. Additionally, Lipnevich et al. used the TPB questionnaire to predict grades incrementally over achievement scores, whereas we use the TPB questionnaire to predict ACT mathematics scores incrementally over high school mathematics grades, number of mathematics courses taken, gender, race/ethnicity, and socioeconomic status. Finally, we also administered a measure of conscientiousness (e.g., tendency to work hard and be organized; Benet-Martinez & John, 1998) to examine whether the TPB predicts ACT mathematics scores incrementally over that construct. Meta-analysis has found that conscientiousness predicts academic performance at all levels of education (Poropat, 2009).

In the current study, we tested two research questions. First, does the structure of the TPB model for mathematics beliefs and attitudes hold for high school students? Second, do the individual components of the TPB (intentions, attitudes, subjective norms, perceived control) predict ACT mathematics test scores incrementally over the host of variables listed above?

2. Method

2.1. Participants

A total of 1958 students (65% female; 35% male) who took the ACT in December of 2014 participated. Students were in either their Junior (48%) or Senior (52%) year of high school with the following the most frequently self-reported race/ethnicities: White (60%), Black/African American (12%), Hispanic/Latino (12%), Asian (7%), and other/multi-race (8%). This is close to the general U.S. ethnic composition of 2014 ACT test takers (56% White, 13% Black/African American, 15% Hispanic/Latino, 4% Asian, 4% other/multi-race) (ACT, 2014) but statistically different in gender composition (57% female, 43% male; X^2 (1) = 548,575, $p < 0.05$). Likewise, survey respondents had a higher Mathematics Course GPA ($M = 3.48$, $SD = 0.62$) than 2014 ACT test takers ($M = 3.04$, $SD = 0.83$; $t(598{,}541) = -11.89$, $p < 0.05$); they had a higher ACT Mathematics test score ($M = 23.15$, $SD = 5.33$) than the national average ($M = 19.72$, $SD = 5.05$; $t(621{,}956) = -14.54$, $p < 0.05$),

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