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Changes in implicit theories of ability in biology and dropout from STEM majors: A latent growth curve approach ☆

Ting Dai *, Jennifer G. Cromley

Department of Psychological, Organizational and Leadership Studies, Temple University, 1301 Cecil B. Moore Ave., Philadelphia, PA 19122, USA

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ABSTRACT

This longitudinal study was designed to investigate the associations between changes in implicit theories of ability in biology and college students' dropout from STEM majors. We modeled the one-year growth patterns of entity and incremental beliefs about ability in biology with 4 time points of self-reported data and two covariates—biology domain knowledge and inference making and gateway course grade, and predicted STEM dropout with the growth trajectories of implicit theories. Results indicated that students' entity beliefs increased, while incremental beliefs decreased over time, which provides support for the changeability of implicit beliefs over a short period of time. The growth of incremental beliefs was directly associated with STEM dropout above and beyond biology course grade and biology domain knowledge and inference making. Low intercept and negative slope of incremental beliefs predicted leaving STEM majors; however, the decline of entity beliefs did not have significant effects on dropout. Interestingly, the effect of biology domain knowledge and inference making on STEM dropout was mediated by biology course grade and incremental beliefs. The findings imply the importance of monitoring changes in students' implicit beliefs and gateway course achievement in order to better understand and promote STEM retention.

1. Introduction

The shortage of students who persist in science, technology, engineering, and mathematics (STEM) majors and the consequent shortage of STEM professionals have caused educational and economic concerns in the United States (National Science Board, 2012). As early as in 1996, a steady decline over the previous few decades in first year undergraduates majoring in science was reported (National Academy of Sciences—National Research Council, 1996). In the 2003–2004 cohort of undergraduates, 13.7% had the intention of majoring in STEM; compared to the 1995–1996 cohort, this was a decrease of 10% (Planty et al., 2009). In addition, approximately 40% of students who entered college intending to major in STEM eventually switched to non-STEM majors in the undergraduate years (National Science Board, 2012). The high rate of attrition from STEM majors has been one of the main reasons for the decline in the overall number of students in college STEM programs and STEM graduates. This calls for more research focusing on predictors of retention in and prevention of dropout from STEM majors (Scott, Tolson, & Huang, 2009).

1.1. Predictors of retention in STEM majors

Ample research effort has been invested to understand the considerable flow of undergraduates leaving STEM majors. Important predictors of STEM retention and persistence have been identified in prior research (e.g., economic, socio-cultural, academic, institutional-classroom, and personal factors; Seymour & Hewitt, 1997; Tinto, 1993, 2010). Among these different types of predictors, previous studies have identified a number of factors that are especially critical for early STEM students (i.e., college freshman and sophomore students; Daempfle, 2004; Gore, 2010; Rigali-Oiler & Kurpius, 2013): (1) student prior achievement (Daempfle, 2004; Rask, 2010; Shaw & Barbuti, 2010) and pre-collegiate educational experiences (Wai, Lubinski, & Benbow, 2009; Wai, Lubinski, Benbow, & Steiger, 2010), (2) student academic performance in college-level gateway STEM courses (Gasiewski, Eagan, Garcia, Hurtado, & Chang, 2012; Jones, Barlow, & Villarejo, 2010; Lawson, Banks, & Logvin, 2007; Shaw & Barbuti, 2010), (3) teacher

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* Corresponding author. Address: Department of Psychological, Organizational and Leadership Studies, Temple University, 1301 Cecil B. Moore Ave., COE/POLS RA 283, Philadelphia, PA 19122, USA. Fax: +1 215 204 6013.

E-mail addresses: ting.dai@temple.edu (T. Dai), jcromley@temple.edu (J.G. Cromley).

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and classroom factors (Christe, 2013; Howles, 2009), (4) availability of learning interventions and mentoring (Koenig, Schen, Edwards, & Bao, 2012; Packard, 2004; Wilson et al., 2012; Wischusen, Wischusen, & Pomarico, 2010), and (5) academic motivation, identity, and affect (Ackerman, Kanfer, & Beier, 2013; Gore, 2006; Hernandez, Schultz, Estrada, Woodcock, & Chance, 2013; Perez, Cromley, & Kaplan, 2013; Zare, 2009).

Most of these studies, however, have only focused on one type of predictor, which limits understanding of achievement and retention. In the present research, we attempt to examine the joint effect of several predictors of STEM retention identified by prior research—cognition and prior knowledge (Feldon, Timmerman, Stowe, & Showman, 2010; Wai et al., 2010), course achievement in gateway STEM courses (Gasiewski et al., 2012; Jones et al., 2010), and beliefs and motivation (Perez et al., 2013; Rigali-Oiler & Kurpius, 2013). We studied college students' implicit theories (Dweck, 1999; Dweck, Chiu, & Hong, 1995a) in terms of changes over one year, and how these changes together with prior knowledge and cognition and achievement in a gateway science course may be associated with students' decision to leave STEM majors.

We foreground implicit theories in this study of STEM retention for four reasons. First, implicit theories of ability lie at the heart of achievement motivation (Dweck, 2002a), and therefore are of utmost theoretical importance. Second, implicit theories of ability have been found to play a crucial role in academic achievement and persistence (e.g., Blackwell, Trzesniewski, & Dweck, 2007; Bråten & Olaussen, 1998; Bråten & Strømsø, 2005). Third, implicit theories have been under-studied in STEM research. Finally, research has demonstrated little overlap between implicit theories and cognition (Greene, Costa, Robertson, Pan, & Deekens, 2010), thus providing unique perspective of explaining STEM retention beyond cognitive variables.

In the next section, we discuss implicit theories of intelligence and ability in terms of theoretical meaning, empirical evidence, and associations with learning behavior and academic outcomes. We then discuss the idea of *changes in implicit theories*, and revisit research on changing implicit theories and its relations with learning.

1.2. Implicit self-theories of ability

1.2.1. Theory overview

Built on the assumption that people's beliefs form a meaning system that guides individuals' learning behavior, Dweck's (1999) theory of achievement motivation concerns (1) individuals' implicit self-beliefs (or *implicit theories*) about their personal attributes (e.g., intelligence, ability, personality), (2) achievement goal orientations, and (3) attributions. Dweck described individuals' implicit theories or mindsets—i.e., fixed ("entity theories", p. 2) or malleable ("incremental theories", p. 3)—as part of a network of implicit self-beliefs that affect thinking, feeling, behavior, and, ultimately, learning and achievement. Holding entity theories about ability tends to lead students to a performance-goal orientation and such students show less resilience in the face of setbacks, whereas holding incremental theories may lead to a mastery-goal orientation and such students show resilience in the face of setbacks. Implicit theories also affect attributions—to what factors students attribute their academic performance: entity theorists tend to attribute failure to a lack of ability and become discouraged or defensive, whereas incremental theorists are more likely to view setbacks as an inevitable part of learning rather than indictments of the self. It is possible for an individual to hold both theories. Although one theory may be more dominant and influential for other aspects of academic motivation and learning behaviors, the other may be accessible under particular circumstances (Dweck, Chiu, & Hong, 1995b). Implicit theories influence effort, perseverance, strategy use, self-regulation, helpless versus mastery-oriented response to setbacks, and performance in the face of difficulty, which, in turn, affect academic achievement (Dweck, 2002b; Dweck & Molden, 2005).

1.2.2. Empirical evidence for implicit theories

There has been substantial empirical support for the validity of measures of implicit theories of ability and intelligence. In a study that examined the self-report implicit theories and actual intelligence with 592 adults, Spinath and associates found strong supports for the discriminant validity of implicit theories of intelligence—individuals' implicit theories of intelligence were unrelated to their actual intelligence (Spinath, Spinath, Riemann, & Angleitner, 2003). This finding has been supported by other research that investigated the relations between IQ and implicit theories of intelligence (see also Kornilova, Kornilov, & Chumakova, 2009). Research that has tested Dweck's theoretical framework as a whole provides evidence for strong associations among implicit theories, motivation, and achievement, which supports the predictive validity of implicit theories (Dupeyrat & Mariné, 2005; Stipek & Gralinski, 1996). Validation studies have assessed implicit theories about multiple attributes of learners. In their longitudinal studies, Wang and Ng (2012) validated the construct of entity theories about intelligence with two samples of Chinese middle and high school students, and found that entity theories about intelligence and those about school performance were distinguishable and that both were predictive of student-perceived helplessness.

1.2.3. Implicit beliefs and learning

Implicit beliefs about intelligence and ability have been found to make a difference for success in academics (Dweck, 2012). First, implicit theories of intelligence have profound impacts on academic motivation (e.g., Ommundsen, Haugen, & Lund, 2005; $\beta = .24$). Blackwell et al. (2007) revealed that incremental theories were associated with low helpless attribution ($\beta = .60$) and more learning goals ($\beta = .59$). With a sample of 508 sixth graders, Chen and Pajares (2010) found effects of implicit theories on epistemic beliefs ($\beta = .30$), goal orientations ($\beta = .27$), and self-efficacy ($\beta = .05$). With a sample of undergraduate students, In their experimental study, Davis and associates (2011) found that incremental implicit theories of math ability helped enhance student self-efficacy in math, especially for those who had received lower math scores ($\beta = .26$). In their person-centered latent profile analysis of high school students, Chen and Usher (2013) found that students who had strong incremental theories tended to have multiple sources of science self-efficacy and had less physiological and affective arousal.

Research has linked implicit theories with academic emotions and affect. In a longitudinal study with 969 students from 9 high schools, Martin and colleagues found that personality and implicit theories of ability significantly predicted adaptability (appropriate adjustment in uncertainty and novelty; $\beta = .29$) above and beyond socio-demographics and prior achievement, which in turn positively predicted self-esteem ($\beta = .29$), sense of purpose ($\beta = .38$), life satisfaction ($\beta = .26$), school enjoyment ($\beta = .15$), and class participation ($\beta = .18$; Martin, Nejad, Colmar, & Liem, 2013). In their study with 1147 Filipino high school students, King and colleagues found that implicit theories of intelligence predicted academic emotions after controlling for demographic variables and teacher support and achievement goals (King, McInerney, & Watkins, 2012). Specifically, holding entity theories of intelligence positively predicted negative emotions such as anger ($\beta = .19$), anxiety ($\beta = .21$), shame ($\beta = .23$), hopelessness ($\beta = .31$), and boredom ($\beta = .23$). Researchers also provided evidence for the positive effect of incremental theories on active constructive coping ($\beta = .17$), as well as the negative