Journal of Vocational Behavior 95–96 (2016) 21–30

Contents lists available at ScienceDirect

Journal of Vocational Behavior

journal homepage: www.elsevier.com/locate/jvb

Building the STEM pipeline: Findings of a 9-year longitudinal research project

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ARTICLE INFO

Article history:
Received 19 May 2016
Received in revised form 8 July 2016
Accepted 13 July 2016
Available online 15 July 2016

Keywords:
P-E fit
Quantitative ability
Interest fit
STEM
Longitudinal study
Cross-lagged model

ABSTRACT

This research addresses the call for identifying the human capital for the U.S.'s future STEM workforce. Using a national dataset tracking 34,744 middle school students up to six years after their first enrollment in a four-year college, we investigated the developments of two individual difference predictors of STEM success based on the Person-Environment fit (P-E fit) model, quantitative ability and STEM interest fit, from adolescence to early adulthood. Results show that these individual difference factors are reciprocally related and thus mutually develop over time. They are relatively stable at adolescence and meaningfully predict the probability that the students obtained a college degree in STEM approximately nine years later. This finding has important theoretical implication as it helps resolve conflicting perspectives regarding the causal relationships between interests and abilities. Finally, we also found that the development and prediction of quantitative ability and interest fit are similar for both men and women, suggesting that they can be useful to identify future STEM participants at early age.

1. Introduction

In this era of ever increasing global competition, the importance of Science, Technology, Engineering, and Mathematics (STEM) to a nation's economy can hardly be overemphasized. Recognizing the critical needs for talents to fill the U.S. STEM pipeline, the National Science Board recently called for research and practices aiming at identifying the future STEM innovators by implementing "talent assessments at multiple grade levels" (National Science Board, 2010). Heeding the call, much research has been devoted to shedding light on the social, socioeconomic, and individual factors underlying STEM participation, especially factors that determine one's early decision to pursue a STEM education and eventually a career in the STEM fields (Chen & Ho, 2012; Kokkelenberg & Sinha, 2010; Leuwerke, Robbins, Sawyer, & Hovland, 2004; Wang & Degol, 2013). Among the variables examined, academic abilities and vocational interests have emerged as two important individual difference factors that reflect the notion that people tend to seek environments that "fit" their characteristics (P-E fit model; Dawis & Lofquist, 1984; Holland, 1997).

Notably, a recent longitudinal study addressed the question by tracking 207,093 students enrolled in 51 four-year colleges (Le, Robbins, & Westrick, 2014). Academic ability (measured by ACT score and high school GPA) and interest fit (a measure reflecting the extent to which the student's occupational interest profile is similar to the typical profile of those currently enrolling in the STEM fields) assessed at the time the students applied to colleges were found to meaningfully predict their subsequent choice of and persistence in college STEM majors two years later. That study also found differential effects of these predictors on

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http://dx.doi.org/10.1016/j.jvb.2016.07.002
0001-8791/

STEM choice and persistence for men and women, which partially explain why men are more likely to enroll in a STEM major than women. These findings suggest the two individual difference factors may play a vital role in determining future STEM participation of high school graduates, the future workforce of the economy (also see Lubinski, Benbow, Shea, Eftekhari-Sanjani, & Halvorson, 2001).

Yet as promising as those results are, they provide only tentative evidence for the effects of an individual's academic ability and interest fit on his/her actual STEM degree attainment, which is a more direct measure of success in pursuing a career in the STEM fields. Also importantly, despite a vast but conflicting literature theorizing about how abilities and interests co-develop from early childhood, it is not yet clear how these two critical individual difference factors actually develop and change over time, especially prior to the point when students apply to colleges (Tracey, Robbins, & Hofsess, 2005). Understanding the development and stability of the factors is crucial for determining the extent to which they can be used for identifying and shaping potential candidates at an early enough stage to not only fill but maintain the STEM pipeline until degree completion.

This research addresses those uncertainties, thereby clarifying the potential contributions of these individual difference factors in understanding one's success in the pursuit of a STEM career and thus allowing early identification of the individuals who will most likely become members of the future STEM workforce. Specifically, we investigate the changes of students' ability and interest fit from adolescence to early adulthood and examine how these factors subsequently predict the probability of attaining a degree in STEM in a four-year college. We also compare the changes and effects on STEM degree attainment of these two factors between men and women in light of the perennial issue of gender differences in STEM participation (Beede et al., 2011; Ceci & Williams, 2011).

1.1. Abilities and interest fit as predictors of STEM success

The Person-Environment (P-E) fit model postulates that people tend to seek out the environments that match their personal characteristics (Dawis & Lofquist, 1984; Holland, 1997). There are two types of fit that have been the focus of research on the P-E fit model: Ability-Demand fit and Interest-Vocation fit (Lubinski, 2010; Reeve & Heggestad, 2004). Both types of fit are reflected on the theory of work adjustment (TWA; Dawis & Lofquist, 1984) which focuses on the fit between abilities and environmental/occupational demands (satisfactoriness) and between interests and occupational reward structures (satisfaction). Combining these two perspectives, Le et al. (2014) hypothesized that students with (a) high academic ability and (b) interest profile that is congruent with those in the STEM fields (a.k.a. STEM interest fit) were more likely to enroll in a STEM major in college. The hypotheses were supported in their study such that academic ability and interest fit measured at 12th grade collectively predicted student enrolment in STEM majors at the end of their first year in colleges and the extent to which they persisted in those majors at the end of their second year.

Nevertheless, it can be argued that academic ability, including high school GPA and ACT composite score as examined in Le et al. (2014), may be too broad to represent the type of ability that best fits demands in the STEM fields. Past research has in fact often found that quantitative ability (as measured by Math and Science tests) is one of the best predictors of STEM success (Kokkelenberg & Sinha, 2010; Leuwerke et al., 2004; Lubinski et al., 2001; Park, Lubinski, & Benbow, 2007, 2008; Wai, Lubinski, Benbow & Steiger, 2010). Accordingly, in the current study we focus on quantitative ability and expect that it, together with interest fit, will predict student degree attainment in the STEM field, which is a more distant outcome and direct criterion of STEM success than STEM choice and persistence examined in Le et al. (2014).

Past research found that cognitive abilities are relatively stable from early childhood and can predict meaningful life outcomes many years later (Judge, Higgins, Thoresen, & Barrick, 1999). Similar findings regarding the stability of vocational interests, especially interest profiles from which interest fit is derived, have also been established (e.g., Low, Yoon, Roberts, & Rounds, 2005). As such, it is conceivable that quantitative ability and interest fit assessed in early age may predict the probability that students will eventually obtain a college degree in the STEM fields. These links, however, have not been directly examined in earlier research.

1.2. The causal relationship between interests and abilities

As noted earlier, theories specifying how abilities and interests are related abound but they are often conflicting regarding the causal direction of this relationship. On one hand, a well-established theory in education and social psychology, the Social Cognitive Career Theory (SCCT; Lent, Brown, & Hackett, 1994), specifies that interests are influenced by self-efficacy and outcome expectations formed by one's learning experience, which, in turn are partially determined by abilities (among other environmental, social, and personal factors). In other words, abilities cause interests via self-efficacy and outcome expectations. On the other hand, another classical theory in psychology, Cattell's investment theory (Cattell, 1987), postulates the opposite causal relationship such that interest in a specific area directs people to “invest” their fluid abilities to develop crystalized abilities in such an area. Available empirical results based on longitudinal data, however, showed no relationship between abilities and interests from adolescence to early adulthood (Tracey et al., 2005). In this research, we attempt to reconcile the conflicting perspectives about the ability-interest causal relationship by empirically examining a model which links ability and STEM interest fit at adolescence to ability and interest fit at early adulthood.