Finding One's Place or Losing the Race?
The Consequences of STEM Departure for College Dropout and Degree Completion*

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ABSTRACT

The following paper estimates the impact of initially declaring and then departing from a STEM major on college dropout and degree completion rates for students in the Beginning Postsecondary Students Longitudinal Study. The results show that students who initially declared a STEM major and switched to a "non-STEM" area of study were less likely to complete a bachelor's degree and more likely to dropout of college than those who stayed in their initially declared major. These outcomes were most severe for students who switched early in their academic trajectory and among those whose parents do not have a bachelor's degree.

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The Consequences of STEM Departure for College Dropout and Degree Completion

Bolstering undergraduate recruitment and persistence in science, technology, engineering and mathemetics (STEM) has become a taken-for-granted priority among higher education researchers and policymakers. By far the most prevalent rationale for this exacting focus is one of economic vitality (e.g., National Science Board, 2010), which rests on the assumption that STEM education is crucial to economic stability because of a projected skills gap between employer needs and available labor (Carnevale, Smith, & Melton, 2013). Given the assumption that STEM fields are linked to vital positions within the economic system, and the significant wage advantages among those with STEM degrees (Melguizo & Wolniak, 2012), many researchers and policymakers have also argued that it is imperative to address social inequities in these fields (Estrada et al., 2016; Ong, Wright, Espinosa, & Orfield, 2012).

As part of these efforts, researchers have focused substantial attention on understanding patterns of persistence in undergraduate STEM majors. The emphasis on persistence is rooted, in part, in the perception that many undergraduates depart from STEM majors because of conflicts they experience in the academic, social, and cultural conditions encountered in these fields of study (Gasiewski, Eagan, Garcia, Hurtado, & Chang, 2012; Ong et al., 2012; Seymour & Hewitt, 1997; Wieman, Perkins, & Gilbert, 2010). In other words, it is believed that a meaningful proportion of the 48% of students who initially declare and later depart from STEM majors

(Chen, 2013) would otherwise stay if these conditions were changed (Malcom & Feder, 2016; PCAST, 2012). As a result, researchers and funding agencies have invested a great deal of effort to learn about the social, cultural, and academic factors that stifle and bolster rates of persistence in undergraduate STEM majors.

While much has been learned about why students depart from undergraduate STEM majors, surprisingly little attention has been given to the consequences of this decision for longer-term persistence patterns. That is, very little is known about what happens to former STEM students' persistence patterns once they switch to a "non-STEM" area of study. This is noteworthy given the extent to which prevailing theories of undergraduate persistence (Melguizo, 2011) anticipate that the decision to switch from a STEM major to another field of study may negatively impact the likelihood of undergraduate persistence and timely degree completion. Most notably, Tinto's (1975, 1993, 1997) theory of student departure suggests that this switch could disrupt processes of social and academic integration and increase the likelihood of dropping out. Furthermore, prior research focusing on the relationship between socioeconomic background and STEM persistence (Dika & D'Amico, 2016; Gayles & Ampaw, 2011) hints that this disruption will be especially harmful for students who lack the socioeconomic resources needed to successfully navigate these institutional pathways.

The following analysis explores these theoretical propositions using data gathered from the 2004/2009 cohort of undergraduate students who participated in the Beginning Postsecondary Student Longitudinal Study (BPS:04/09). In particular, we examine whether or not initially declaring a STEM major and then switching to a non-STEM area of study is associated with changes in rates of drop-out, persistence, and timely bachelor's degree completion while holding constant a range of covariates related to academic preparation and performance, family background, and institutional context. In the process, we pay attention to whether or not the timing and frequency of switching majors appears to shape these persistence outcomes. Finally, we test if the main effects of switching majors are conditional upon parental education and income in order to determine if the decision to switch is more or less consequential for students from disadvantaged populations.

Our decision to focus on the change from STEM to a non-STEM major – as opposed to changing majors across all fields of study – is rooted in a need to understand whether or not there are risks associated with current efforts to bolster recruitment into undergraduate programs in STEM fields. Recent evidence suggests that the number of students entering undergraduate programs intending to enroll in a STEM area of study has increased approximately 10 percent over the last decade (Eagan, Hurtado, Figueroa, & Hughes, 2014). In general, the merits of these efforts are unquestioned by policymakers and STEM advocates, as it is taken-for-granted that a robust pool of STEM graduates contributes to both individual and societal growth (Malcom & Feder, 2016; PCAST, 2012). Thus, even though it may be interesting to know if switching majors from business to education negatively impacts student persistence, we argue that the emphasis on STEM carries more immediate significance in the current policy climate.

The emphasis on STEM also has the potential to influence the work of higher education researchers. If there are negative consequences for persistence outcomes among students who declare and later depart from STEM majors, then researchers need to explore the conditions under which the consequences emerge. This is especially true if these consequences are observed net academic preparation and performance, as this would indicate a problem that goes well beyond the current emphasis on academic support programs. Furthermore, if disadvantaged students' persistence outcomes are more vulnerable to STEM departure, this would identify a previously unknown institutional pathway through which social inequalities are produced during the transition from high status majors (i.e., STEM) to other programs of study. Such an insight would open the door to future work that can build upon our current understanding of social inequality in higher education in general (Armstrong & Hamilton, 2013; Mullen, 2010; Roksa, 2011) and STEM fields in particular (Dika & D'Amico, 2016; Ong et al., 2012; Xie, Fang, & Shauman, 2015).

Beyond the implications for policymakers and researchers, the findings from our analysis have the potential to provide further evidence of the need for targeted programs to support socioeconomically disadvantaged students who initially enter STEM fields and eventually leave for other areas of study. While substantial resources are already being channeled to support first generation college going and low-income students in STEM, little attention is given to those students who make the decision to leave these academic majors. If disadvantaged students are, in fact, more vulnerable to dropping out after leaving STEM – even while controlling for academic preparation and performance – this would suggest that programs need to pursue a more holistic and longitudinal approach that involves proactive care and community building in addition to simply focusing on academic scaffolding (Lane, 2016).

Background

The choice of a college major can have a strong impact on one's life chances, especially as it relates to potential earnings (Melguizo & Wolniak, 2012). Not surprisingly, the process by which students select into certain majors has thus received significant attention in prior research. This work has emphasized mechanisms such as person-environment fit (Porter & Umbach, 2006), expected earnings (Montmarquette, Cannings, & Mahseredjian, 2002), and the influence of parental socioeconomic status (Davies & Guppy, 1997; Goyette & Mullen, 2006). In addition, a robust area of literature has examined the process of selection into STEM fields (Wang, 2013), with special emphasis on racial and gender differences (Morgan, Gelbgiser, & Weeden, 2013; Riegle-Crumb & King, 2010).

While choice of major has received substantial attention, the decision to switch majors has received far less. This is surprising given that changing majors is a common feature of students' higher education experience. In the NELS:88 cohort, half of the students who completed a bachelor's degree had switched their major at some point in the process (Adelman, 2006). Using the BPS:04/09 cohort, Chen (2013) found that switching majors varied across disciplinary groups, however. For example, the highest switching rates from one disciplinary group to another were in the health sciences (57% switched to a non-health science field), education (62%), and humanities (56%), whereas the lowest rates were in the social/behavioral sciences (45%) and STEM fields (48%). Regardless of these differences, though, switching majors is a common occurrence in all disciplines. As noted above, we emphasized STEM in this study due to the more immediate policy implications as well as accumulated prior reseach that points to distinct social and academic barriers between STEM and non-STEM degree programs.

Theoretical Foundations

Although little attention has been given to the consequences of switching from a STEM major to a non-STEM area of study, there is a strong theoretical basis for anticipating a negative relationship between switching and student outcomes. In particular, switching from a STEM to a non-STEM major may present unanticipated risks related to processes of academic and social integration known to shape dropout decisions (Braxton & McClendon, 2004; Tinto, 1975, 1993, 1997). Switching majors reflects a shift in a student's commitment to their academic goals, which can constrain both forms of integration. A student who switches from biology to sociology, for example, may find it difficult to integrate into the socio-cultural and academic milieu of a non-STEM area of study. This disruption may be heightened for those students switching out of STEM degree programs, as these fields differ dramatically in coursetaking requirements (Mann & DiPrete, 2013), perceived difficulty (Mundfrom, 1991), grading practices (Gasiewski et al., 2012; King, 2015; Ost, 2010), and labor market prospects (Carnevale et al., 2013; Melguizo & Wolniak, 2012). Tinto's theory of student departure thus suggests that the transition might lead to forms of anomie and a greater likelihood of dropping out of school.

Although Tinto's theory does not speak directly to switching majors, the general assumptions of the model also suggest that the timing of switching between STEM and non-STEM degree programs may be important for student outcomes. On the one hand, students who switch early in their postsecondary career may face challenges to their integration efforts during an already vulnerable time along their academic trajectory (i.e., the transition from high school to college). The timing might, in effect, "take the wind out of their sails" since, according to Tinto (1993), a student's commitment to their academic and social environment is the driving force behind successful integration. On the other hand, switching later may require re-taking a greater number of foundational courses and prerequisites that could delay degree completion. However, it is also possible that a later switch would provide students more time to successfully integrate into the broader social and academic contexts of their higher education environment before re-adjusting their commitments to a new area of study.

Socioeconomic differences in processes of integration. While Tinto's theory of student departure anticipates a negative relationship between changing from STEM to a non-STEM major and student persistence outcomes, scholars of higher education have identified a number of limitations of this theory (Museus, 2014). Most notable to the obectives in this paper, Tinto's theory does not adequately anticipate the ways that processes of integration may vary for students from different backgrounds. Tierney (1992, 1999), for example, has argued that Tinto's theory fails to appreciate the heightened challenges underprepresented students face when negotiating the transition from high school to college. While Tierney was specifically referencing students of color, the argument extends to any group of students whose background may not be aligned to the organizational cultures typically encountered on college campuses.

In the present context, then, there is a need for a critical view of social and academic integration that is more attentive to socioeconomic (i.e., parental income and education) inequality. The approach being advocated here connects more generally to work that utilizes quantitative data sets to examine systemic inequalities in higher education (Stage, 2007; see also Wells & Stage, 2015). For example, although prior research suggests that parental income and education do not impact entry into STEM degree programs (Crisp, Nora, & Taggart, 2009), Gayles and Ampaw (2011) found that, once students declared a STEM major, higher levels of parental education and income were associated with an increased probability of degree completion (see also Anderson & Kim, 2006). Furthermore, Chen (2013) found that low-income students who initially declared a STEM major were more likely to dropout of college than their higher income peers (net a range of covariates related to academic performance).

Additional evidence suggests that first generation college going students may have a more difficult time integrating into the social and cultural contexts of non-STEM majors. For instance, in a study that analyzed a subsample of first generation college going students, Dika and D'Amico (2016) found that perceived social and academic fit were positive predictors of third-semester persistence for those majoring in non-STEM fields, but these perceptions had no impact on persistence among those majoring in physical science, engineering, math, and computer science fields. Instead, the key predictive factors among first generation students majoring in these latter fields were rooted in perceived and actual performance (perceived math preparation and first-year GPA). These results suggest that finding the right fit may be especially important for first generation college going students entering non-STEM fields of study.

Determining the best academic and social fit may prove to be especially challenging for first generation college going students. For example, literature suggests that parents with higher education more readily cultivate science aspirations in their children than do less formally educated parents (Archer et al., 2012). In this regard, researchers have suggested that success in STEM relies heavily on embodying a social class-based identity that resonates with the types of dispositions required to “do science” (Archer et al., 2010; DeWitt, Archer, & Mau, 2016). Prior research has also established that students whose parents have completed college and have stable economic resources tend to have more available information and support when making decisions related to higher education (Bourdieu, 1996; Goldrick-Rab, 2006a, 2006b; McCormick, 2003) – especially in the sciences (Archer et al., 2012; Sjaastad, 2012; Xie et al., 2015). Indeed, Astin (1993) found that engineering majors reported higher levels of parental involvement in their educational pathways. As Armstrong and Hamilton (2013) detailed, this process is connected to the ways parents with professional occupations—and the associated education credentials—actively insert themselves into their children’s decisions related to academic majors (see also Leppel, Williams, & Waldauer, 2001; Mullen, 2010; Seymour & Hewitt, 1997). In contrast, the parents of first generation college going students were found to offer less helpful advice as their children contemplated the decision to pursue a college major (Armstrong & Hamilton, 2013).

In the absence of institutionally-valued information from parents, students from socioeconomically disadvantaged backgrounds must create their own social capital to access the forms of information (i.e., cultural capital) that facilitate academic decision-making on college campuses. Yet, this process is often more challenging for socioeconomically disadvantaged students. Prior work has demonstrated that first generation college students in engineering, for example, often face greater financial and non-academic work related burdens that constrain their acquisition of social capital, which complicates processes of navigating the institution and the requirements of their academic major (Fernandez, Trenor, Zerda, & Cortes, 2008; Trenor, Yu, Waight, & Zerda, 2008). This work is consistent with a broader body of literature that has detailed the challenges that disadvantaged students face in creating social capital across a wide variety of postsecondary contexts (Kim & Schneider, 2005; Rios-Aguilar & Deil-Amen, 2012; Winkle-Wagner & McCoy, 2016)

To summarize the theoretical perspective underlying the present study, Tinto’s (1975, 1993, 1997) theory of college student departure anticipates that switching from a STEM to a non-STEM area of study may present risks to crucial processes of social and academic integration. This is especially relevant in the transition from STEM to non-STEM majors due to the unique requirements and opportunities these fields of study offer. Crucially, we argue for a critical view of Tinto’s theory that anticipates heterogeneous effects for students from different socioeconomic backgrounds. Thus, our theoretical framework assumes a signficant interaction between socioeconomic background and the consequences of switching from STEM to a non-STEM area of study for students’ persistence outcomes.

Existing Research on Switching Majors and Student Outcomes

Despite a strong theoretical rationale for expecting a negative relationship between switching from a STEM to non-STEM major and persistence outcomes, very little is known about the consequences of switching overall or from STEM to non-STEM in particular. The limited body of research that has explored the relationship between switching majors and student outcomes has shown mixed results. Looking across all areas of study, Kojaku (1971) found the process of switching majors between freshman and senior year resulted in homophily—that is, greater between (and less within) disciplinary variability across a range of attitudinal, behavioral, socioeconomic, aptitude, and academic variables. Adelman (2006) found that switching academic majors was not associated with changes in degree completion among students in the NELS:88 cohort, but the measure was collinear with college transfer due to the way switching was defined. Some institution-specific analyses have found both positive and negative associations between switching majors and degree completion overall (Foraker, 2012; Micceri, 2001), yet these studies have been limited by a lack of available covariates and thus the theoretical perspective outlined above could not be tested.

Few researchers have examined the relationship between changing majors and student outcomes in the context of STEM. Maltese and Tai (2011) found that, among all students who completed college in the NELS:88 cohort, switching majors was a practice associated with a decreased probability of completing a degree in STEM. In other words, conditional on completing a bachelor's degree, students who switched majors during their undergraduate trajectory were more likely to graduate with a degree in a non-STEM area of study. This relationship remained significant after controlling for numerous variables, including those related to student performance in college, high school performance, and family background. Although these findings reveal that changing majors is more commonly associated with non-STEM degree completion, they do not lend direct insight into what happens to those students who initially declare a STEM major and later switch to a non-STEM area of study.

The most direct attempt to address this hypothesis came from an institutional analysis of a Midwestern university that found no difference in the likelihood of degree completion between those who stayed in STEM and those who switched to non-STEM majors (Whalen & Shelley, 2010). Although the latter study made use of controls for academic performance, the lack of family background characteristics did not allow for an analysis of the variable effects of parental education and income. There is a significant gap, then, in our understanding of whether or not changing from a STEM major to a non-STEM major is associated with variation in persistence outcomes such as dropping out or bachelor's degree completion when accounting for family background and academic characteristics, and if these variables interact in ways that lead to socioeconomic advantages and disadvantages.

Working from the theoretical assumptions outlined above, we addressed this gap in the literature by asking the following three questions:

1. To what extent, if at all, do students who switch from a STEM major to a non-STEM area of study face a greater risk of dropping out or lower rates of persistence and bachelor's-degree completion relative to students who remain in a STEM major?
2. Do students who switch from a STEM major to a non-STEM area of study earlier in their academic trajectory experience different rates of dropping out and timely degree completion than those who switch later?
3. Do the outcomes associated with switching from a STEM to a non-STEM major vary across students' socioeconomic backgrounds?

These questions represent an initial attempt to explore the implications of switching from a STEM to a non-STEM area of study for students' persistence outcomes, especially for those students facing socioeconomic disadvantages.

Data and Methods

Data

The data for this study came from the 2004/2009 cohort of the Beginning Postsecondary Student Longitudinal Study (BPS: 04/09) conducted by the U.S. Department of Education. BPS: 04/09 began following a cohort of first-time postsecondary students at the end of their first academic year (2003-04). The original cohort comprised 18,640 first-time beginning students (FTBs) at any type of postsecondary institution in the United States. They were surveyed again at the end of their third (2005-06) and sixth (2008-09) years after entry into postsecondary education and, finally, 16,680 FTBs were classified as BPS:04/09 respondents. The FTBs declared and/or switched their majors en route to bachelor's degree completion. To identify these disciplinary pathways, we classified major fields into seven broad disciplinary groups: STEM (engineering/technologies, bio/life sciences, physical sciences, mathematics, and computer and information sciences), social/behavioral sciences, humanities, business, education, health sciences, and other fields (see Chen, 2013).

Analytic Sample

Among the disciplinary pathways identified in the analysis, we focused on two in this study: 1). Initially declaring and staying in a STEM major, and 2). initially declaring a STEM major and switching to a non-STEM major (e.g., STEM to business or STEM to education). Thus, the sample used in this study included students who began their postsecondary education in a bachelor's degree program and declared their first major as STEM from the first academic year of 2003-04 through the 2008-09 academic year, yielding 1,530 beginning bachelor's degree students. We defined "switchers" as students who switched their declared STEM majors into other disciplinary groups (N=590) and "non-switchers" as those who stayed in their initially declared STEM disciplinary group (N=940) through 2009.

Students who delayed the process of declaring a major (i.e., were undeclared at the time of the initial BPS survey) were still included in our sample. In cases in which students initially declared STEM majors by their third academic year (i.e., the first follow up wave in 2005/06), they were classified into one of the two disciplinary pathways described above (i.e., either initially declaring and remaining in a STEM major, or initially declaring and switching out of STEM to a non-STEM major). Students whose information on their declared major was collected in only one survey wave (e.g. those who attrited from survey waves after declaring their initial major, or initially declared their major during the last wave) were not included in the analysis because their switching patterns were hardly identifiable.[1] In addition, robustness checks that included these students in our analyses did not change the results presented below.

Measures

The primary dependent variables are 1). a dichotomous outcome of bachelor's degree completion through 2009—the end of the sixth year after entry into postsecondary education, and 2). a dichotomous outcome of dropping out inidicating whether or not a student dropped out of college (not enrolled without a degree) before 2009 and did not come back by the end of the 2009 academic year. Because our measures were limited to six years since students began their bachelor's program, we identified a group of students who still persisted toward a degree upon conclusion of the BPS (approximately 13% of the analytic sample, $N = 190$), but had not yet completed their bachelor's degree at the end of the sixth year after entry into college. For such students, there is no way of knowing if they completed a bachelor's degree or dropped out of college. Thus, given the nature of the dataset, there are not only students who did not complete a bachelor's degree on time, but also those who persisted toward a degree at least up to the sixth year of their bachelor's program. Therefore, the nature of the dataset allowed us to explore whether or not on-time degree completion and drop-out reveal different academic pathways in relation to students' disciplinary pathways.[2]

We estimated a series of logistic regressions for the two dichotomous outcomes (BA completion & dropout) on the disciplinary pathways described above and their interactions with socioeconomic background as measured by parental education and income. Because the timing of declaring a major and the frequency and timing of switching majors may affect students' persistence and attainment outcomes, we added dummy variables for students who switched multiple times and for students who switched from or initially declared a major late in their academic trajectory. Students' majors were measured across three survey waves as noted above. We categorized students who switched their major between the base-year (the end of first academic year in 2003/04) and the first follow up (the end of third academic year in 2005/06) wave as 'early switchers,' those who switched between the first and the second follow up wave (the end of six academic year in 2008/9) as 'late switchers,' and those who switched both between the base-year and the first follow up and between the first and the second follow up wave as 'multiple switchers.' Students who initially declared their major either at the first or second follow up wave were defined as 'late declarers.' While we focused on students' switching majors from STEM to non-STEM fields, switching majors within STEM or non-STEM fields may also impact students' timely degree completion. To account for this possible effect, we included a dummy variable for students who switched their major between STEM discplines or between non-STEM disciplines after they moved into non-STEM fields.

Parental education was measured using three categories: less than bachelor's degree, bachelor's degree, and greater than bachelor's degree. These categories were preferred over a binary (e.g., bachelor's or less) measure in order to assess whether the parental education effect compounded at higher levels of education or leveled off once the bachelor's level was reached (for an insightful discussion of measuring parental education, see Toutkoushian, Stollberg, & Slaton, 2018). Family income was measured with a natural logarithm of Adjusted Gross Income (AGI) reported in 2002. Beyond these variables of interest, we followed previous literature (see above) by including the following covariates that may affect both switching majors and bachelor's degree completion: students' high school academic preparation (incoming college credits) and achievement (ACT or SAT scores, GPA); first-year academic performance in college (GPA, measured in 2004; taking calculus in first year of college [see Crisp et al., 2009]; STEM GPA compared to non-STEM GPA [see Chen, 2015]); college transfer status (lateral: 4-year to 4-year, or reverse: 4-year to 2-year, see Goldrick-Rab, 2006a); academic and social integration[3] in 2004); the financial contexts of their higher education (employment, loans, tuition); and characteristics of the institutions (Historically Black Colleges and Universities [HBCUs], Hispanic Serving Institutions [HSIs], doctoral-granting). A correlation matrix of the covariates indicated moderate values and limited evidence of multicollinearity.

We included two additional covariates to account for students' academic performance and college experience after they switched their initial majors: academic performance in college after switching majors (average GPA either after switching majors for switchers or during sophomore, junior, and senior years for non-switchers), and academic and social integration in college during sophomore or junior years (measured in 2006). By including the academic and social integration variables during sophomore or junior years, we are making the assumption that these measures can be an appropriate proxy of their college experience after switching. This assumption is not without limitations, but these variables are the best available proxy given the limited measures in the BPS:04/09 data set. Finally, to account for disciplinary heterogeneity of initially declared STEM fields, we added a series of dummies for specific STEM majors. Detailed variable descriptions are presented in Appendix A and descriptive statistics for the covariates are presented in Table 1 (see below).

Analysis

The following analysis utilized a hierarchical regression approach in which predictors were entered cumulatively according to a pre-specified order based on the theoretical framework and prior research.[4] In particular, we attempted to explain the (net) relationship between disciplinary pathway and degree completion (as well as retention; see M1 in Tables 3 and 4), and the extent to which the latter relationships were mediated by the following sets of variables: college students' academic career decisions (M2); their demographic and family background (M3); college readiness (M4); and college performance and experience (M5). In addition, the timing of switching majors was examined with the full list of covariates (M6). Finally, the interactions between switching and the socioeconomic background of students (i.e., parental education and family income) were examined with a full list of covariates by adding interaction terms in M5 and M6.

All analyses were weighted and adjusted to account for the complex survey design of the dataset using the Stata survey commands. We used the BPS:04/09 panel weight 'WTB000' to analyze study respondents for the base-year study (NPSAS:04), the first follow up (BPS:04/06), and the second follow up (BPS:04/09). The strata and primary sampling unit variables for variance estimation were 'BPS09STR' and 'BPS09PSU,' respectively (Wine, Janson, Wheeless,

& Hunt-White, 2011). To handle missing information, we used a multiple imputation (MI) technique by chained equations in the Stata MI program (Morris, White, & Royston, 2014; Royston & White, 2011; White, Royston, & Wood, 2011). We created 10 complete datasets for the analysis (Graham, Olchowski, & Gilreath, 2007). Interactions of disciplinary pathways with parental education and income were considered in the imputation process. We present marginal effects from logit regressions in tables and focus on predicted probabilities of bachelor's degree completion and dropout for each pathway and the interactions of these pathways by family income and parents' education. All unweighted sample entities were rounded to the nearest tenth to minimize disclosure risks in this paper.

Results

Among those students who initially declared a major in a STEM discipline, non-switchers (70.5%) were substantially more likely to attain a degree within six years than students who switched out of STEM (44.8%, see Table 1).[5] In contrast, students who switched out of STEM were more likely to stay in college without a degree up to six years after entry into college (20.9% vs. 11.5%) and to drop out of college (34.0% vs 17.6%) than non-switchers who stayed in STEM. These descriptive patterns show significant delays in obtaining a bachelor's degree and higher risks to dropping out of college for STEM switchers than non-switchers.

<Table 1 about here>

<Table 2 about here>

Table 2 shows the observed heterogeneity in the probabilities associated with degree completion, persistence without a degree, and dropout across different levels of parental education and income. For example, without controlling for any covariates, regardless of disciplinary pathways, students whose parents had less than a bachelor's degree and who were in the lowest income quintile were less likely to complete a bachelor's degree within six years and more likely to drop out of college than those with bachelor's-educated and upper-income parents. However, the gaps between socioecomically advantaged and disadvantaged students were much greater for students who switched out of STEM than those who stayed in STEM. Table 2 shows that lower SES students were most disadvantaged en route to completing their degree when they switched from a STEM major to a non-STEM area of study. Almost half of switchers whose parents had less than a bachelor's degree dropped out of college (46.5%), whereas less than 20% of their peers who stayed in STEM did so regardless of the level of parental education. This pattern was consistent across family income quintiles.

Leaving STEM and Bachelor's Degree Completion

Without controlling for any covariates, switching from STEM to a non-STEM discipline was negatively associated with bachelor's degree completion (ref. staying in STEM; see M1 in Table 3). Consistent with the descriptive patterns shown in Table 1, students who switched out of STEM had a significantly lower probability of completing their degree within six years than non-switchers (25.7%). While still significant, this gap was reduced by more than half after accounting for other types of switching patterns (e.g., switching a major within STEM, the timing and frequency of switching, the timing of declaring a major, and institutional pathways), demographic and family background, and college readiness (10.8%; M4 in Table 3, $p < 0.001$). Most notably, it appears that the timing of declaring a major, institutional transfer, gender, ethnicity (Hispanic), and college readiness (High school GPA and incoming college credits) significantly contributed to changes in students' bachelor degree completion rates while mediating the effect of switching out of STEM.

<Table 3 about here>

After controlling for the full range of covariates that includes variables related to college experience and performance, the negative association of switching out of STEM with bachelor's degree completion diminished and was no longer statistically significant (4.6%; M5 in Table 3). As anticipated by Tinto's theory of student departure, academic integration (specifically during sophomore or junior years as measured in 2006) as well as college GPA and STEM coursework (taking calculus in the first year) significantly explained variance in bachelor's degree completion and its relationship with switching out of STEM. Students' financial contexts of higher education (working more than 10hrs per week and cost of attendance) were also significantly associated with degree completion and helped account for the relationship between degree completion and disciplinary pathways.

Assuming that the timing of switching a major may be associated with different academic trajectories en route to degree completion, we tested whether early switchers experienced different rates of timely degree completion than late, multiple, and non-switchers (see M6 in Table 3). The comparisons between early switchers and those who switched late or multiple times were not statistically significant. While early switchers were 6.1% less likely than non-switchers to attain their bachelor's degree, the difference fell short of statistical significance (p = 0.068). Thus, the timing of switching does not appear to explain any variation in bachelor's degree completion when controlling for all other variables in the model.

Leaving STEM and Dropping Out

<Table 4 about here>

When changing the outcome to dropping out of college, the results were both similar and different from the model of bachelor's degree completion. Table 4 shows that, without taking the covariates into account, students who switched out of STEM were also 16.5% more likely than those who stayed in STEM to drop out of college rather than completing a degree or persisting without a degree (M1 in Table 4, $p < 0.001$). Similar to the results for degree completion, this significant disadvantage remained even after accounting for other types of switching patterns, demographic and family background characteristics, and college readiness (7.9%; M4 in the Table 4, $p < 0.05$), but is again no longer significant after additional factors related to students' college experiences and performance were included (4.6%, M5 in the Table 4, $p > 0.05$). Further analyses suggested that academic integration and college GPA were most responsible for the significant drop of the switching coefficient. However, in the case of dropouts, this finding obscures heterogeneity in the timing and frequency of switching. As shown in M6 of Table 4, early switchers had the highest probability of dropping out of college (34%), which was also significantly higher than late (16.6%), multiple (23.8%), and non-switchers (22.2%) – even after accounting for all covariates.

The Interaction of Switching and Parental Education

In the results above, we found evidence that the main effect of switching out of STEM may vary across different levels of parental education. To explore this finding further, we tested interactions between switching and parental education to determine if the outcomes students experienced through switching majors were shared equally across levels of parental education.[6] We added interaction terms of switching from STEM into non-STEM disciplines with parents' education in our final models across each outcome (i.e., M5 and M6 in Tables 3 and 4). To simplify the presentation of results, we illustrate significant interaction effects through predicted probabilities in Figures 1 and 2 (See also the figures in Appendix B and C).[7]

<Figure 1 about here>

As with the descriptive results in Table 2, we found that the disadvantage of switching out of STEM in completing a bachelor's degree was significant for students whose parent(s) had less than a bachelor's degree even after controlling for all covariates (see Figure 1). These students were the least likely to obtain a bachelor's degree within six years and significantly behind their peers who switched out of STEM with bachelor's-educated parent(s) ($p < 0.05$). However, parents' education did not play a significant role in predicting bachelor's degree completion for non-switchers. Furthermore, this disadvantage was evident for early switchers whose parent(s) had less than a bachelor's degree (see the figure in Appendix B for an illustration). While not different from multiple switchers, the effect of parents' education on early switchers' degree completion was significantly different from late switchers and non-switchers ($p < 0.05$).

<Figure 2 about here>

The disadvantage of switching out of STEM for students whose parent(s) had less than a bachelor's degree was also significant for dropout rates (see Figure 2). That is, students who switched out of STEM with less than bachelor's-educated parents were significantly more likely to drop out of college than all other groups across both disciplinary pathways ($p < 0.05$). Most notably, Figure 2 shows that the predicted probabilities of dropping out of college among switchers whose parents had less than a bachelor's degree were 13.3% higher than switchers with bachelor's-educated parents and 15.1% higher than switchers whose parents had a graduate degree or greater. Once again, the risk of dropping out was most evident for early switchers whose parent(s) had less than a bachelor's degree (see the figure in Appendix C for an illustration). These students experienced significantly higher dropout rates than late and multiple switchers as well as those who stayed in STEM across all levels of parental education ($p < 0.05$).

Robustness Checks and Limitations

The results above suggest that early switchers, especially those with less educated parents, were at a greater risk than late switchers of experiencing the negative effects associated with changing from a STEM to a non-STEM major. To explore the robustness of this finding, we split the sample and conducted separate analyses of early and late switchers.[8] These sub-sample analyses also allowed for more appropriate specification of pre- and post-major switching experiences (e.g. academic & social integration, college GPA after switching major), particularly in the analyses of early switching. Results from the sub-sample analyses were consistent with the pooled sample analyses. That is, the negative effects of switching on degree completion and dropout were evident for early switchers, and much more evident for early switchers whose parent(s) had less than a bachelor's degree. Meanwhile, the negative effect of late switching on degree completion was much weaker and almost entirely explained by high school and college experiences, and the effect on dropout was consistently non-significant across models.

Whether using the pooled sample or sub-sample analysis, the correlational research design limited our ability to make causal assertions on the relationship between switching a major and dropout and degree completion. The potential for endogeneity remains due to unobserved characteristics related to motivation and interest alignment. In particular, switching majors could be a result of misalignment between students' interest in majors and their actual declared major, which could also negatively impact timely degree completion. To address this potential source of bias, we utilized students' ACT Interest Inventory scores included in the BPS:04/09 data set, which was originally derived from Holland's (1997) theory of careers and intended to measure vocational interests (i.e., science, arts, social science, business contact, business operations, and technical). Since only half of the analytic sample took the ACT test, we did not include these scores in our primary analyses. Instead, we tested whether students' vocational interests before entering college changed our estimated effects by analyzing the sub-sample with ACT Interest Inventory scores. Based on only negligible changes in this supplementary analysis, we believe that bias arising from the misalignment between students' interest and their declared major to be minimal.

Another limitation concerns the use of proxies to measure college performance and experience after students switch majors. As an appropriate proxy of college experience after switching, we included two additional covariates to account for students' academic performance and college experience after they switched their initial majors: academic performance in college after switching majors (average GPA either after switching majors for switchers or during sophomore, junior, and senior years for non-switchers), and academic and social integration in college during sophomore or junior years (measured in 2006). Even though these variables are the best available proxy given the limited available measures in the BPS:04/09 data set, we acknowledge that these measures do not perfectly reflect switchers' college experience after they transition to their non-STEM majors. For example, early switchers' disadvantages were not fully explained even after the inclusion of post-major switching experiences. This suggests that further studies with more complete measurements of post-major switching experiences are necessary to more fully understand early switchers' disavantages through their disciplinary pathways.

In addition, because our measures were limited to six years since students began their bachelor's program, we have no way of knowing if students who still persisted toward a degree upon conclusion of the BPS finally completed a bachelor's degree or dropped out college. Alternatively, we conceptualized a model of on-time degree completion and drop-out to overcome the limitation of the BPS dataset. However, we acknowledge that our analyses are limited to provide evidence on the longer-term impact of switching on students' retention and degree completion beyond six years. In particular, the longitudinal duration of six years would not be sufficient to completely capture late switchers' persistence (especially drop-out) after switching out of STEM during their 4^{th}, 5^{th}, or 6^{th} academic year. This suggests caution in interpreting the results on late switchers, especially for the sub-sample analyses.

Finally, it is plausible that there is heterogeneity in our findings across students' initially declared STEM majors and switchers' destination non-STEM majors. However, we were unable to test for such heterogeneity due to sample size limitations in the data set. In addition, it is possible that the difference in effect between early and late switching could be due to differences in the non-STEM degree programs that students entered. To assess this concern, we combined social/behavioral sciences, business, and education into one category, which are the disciplines that early switchers in the BPS dataset were more likely to represent. We also combined humanities and other fields into another category that late switchers were more likely to represent. When these two dummy variables were added into our analytic models, we found no substantial changes in our findings regarding the difference in effect between early and late switching.

Discussion and Conclusion

The primary objective in this paper was to examine whether initially declaring and then departing from a STEM major was associated with negative consequences for college dropout and degree completion rates. This objective was approached through multiple questions that explored issues concerning the main effects of switching, timing and frequency, and factors connected to parental income and education. Overall, evidence was found that supports the theoretical assumption that switching from STEM to a non-STEM area of study is associated with lower degree completion rates and higher dropout rates. These differences appeared to be explained through a variety of factors, especially academic performance, social and academic integration, and family background characteristics.

One of the primary theoretical assumptions guiding the analysis was that switching from STEM to non-STEM fields of study would potentially disrupt processes of academic and social integration and lead to a greater likelihood of dropping out of school (Tinto, 1975, 1993, 1997). In the analysis above, academic integration and college GPA were found to play a substantial role in accounting for the impact of switching on college dropout and degree completion, which supports the assumptions that the difficulty of integrating into the academic milieu of a non-STEM area of study might have negative consequences for persistence outcomes. This conclusion is generally consistent with prior research that has found no difference in degree completion among students who persist in or switch from STEM when controlling for academic performance (Whalen & Shelley, 2010). However, the present analysis adds additional layers to this understanding by suggesting that, in addition to college readiness and family background, the negative outcomes associated with switching out of STEM may be an indication of a broader problem associated with experiences once on campus.

The theoretical framework used in this study also guided an exploration of whether or not the timing and frequency of switching had any impacts on the student outcomes associated with changing from STEM to a non-STEM major. One of the potential hypothesizes identified above was that early switchers may fare better than students who switched late in their academic trajectory due to the timing associated with additional coursework and the need to re-integrate into a new academic mileau. However, the exact opposite was found to be the case. Early switchers faced more risk of dropping out than late and multiple switchers even after accounting for academic and social integration and academic achievement. A plausible reason for this finding is that switching early may disrupt the commitment that drives students' initial social and academic integration (Tinto, 1993). In contrast, switching later may be advantageous since the change would likely occur after a student had already integrated into the broader campus community. Future research should explore this relationship in more detail to unpack the processes through which the timing of changing majors appears to impact student persistence outcomes.

Although Tinto's theory served as a theoretical point of departure for the analysis, prior critiques of this theory suggested that the processeses of social and academic integration within institutions of higher education are differentially shaped by students' cultural and socioeconomic backgrounds. In particular, the contingency of these processes is often rooted in conflicts between institutional and community-based meaning systems (Museus, 2014; Tierney, 1992). Within the context of the present study, prior research suggested that students from more disadvantaged socioeconomic backgrounds may face more negative consequences to persistence when switching out of STEM fields of study (Dika & D'Amico, 2016; Xie et al., 2015). As anticipated, robust evidence was found indicating that switchers whose parents attained less than a bachelor's degree were significantly less likely to complete their bachelor's degree and more likely to dropout of college than switchers whose parents had a bachelor's degree or greater. This finding was more pronounced for those students who switched earlier in their academic trajectory. These results reveal a previously unknown context through which higher education outcomes are stratified across socioeconomic background. Although parental education is widely understood to shape students' patterns of higher education persistence and attainment

(Armstrong & Hamilton, 2013; Bourdieu, 1996; Dika & D'Amico, 2016; Goldrick-Rab, 2006a; Pascarella, Pierson, Wolniak, & Ternzini, 2004), the findings above suggest that students from less educated families face harsher consequences for leaving STEM – even when controlling for college readiness, performance, and numerous other factors known to shape persistence and attainment outcomes.

One possible reason why parental education shapes the association between leaving STEM and the outcomes of interest is that these majors tend to have prescribed curricular requirements that result in uniquely more homogeneous coursetaking patterns relative to all other majors (Mann & DiPrete, 2013). As a result, students who initially declare a STEM major and then switch to non-STEM fields are likely to do so with little experience and information about other areas of study. Parents with a bachelor's degree or greater can serve as a rich source of information about other academic contexts given their own familiarity with higher education (Armstrong & Hamilton, 2013; Astin, 1993; Mullen, 2010). This information would be of great value in helping to find the best fitting destination major. In the absence of social ties that provide access to this information, students would likely face greater constraints while attempting to navigate institutional pathways in higher education (Rios-Aguilar & Deil-Amen, 2012; Trenor et al., 2008). This is especially true for early switchers who have yet to accumulate institutional knowledge about other degree programs and associated career trajectories. To test this hypothesis directly requires data about the sources of information that students consult when making these switching decisions, as well as the ways students identify with degree programs and associated career trajectories. This line of inquiry may provide a deeper understanding of how social inequalities emerge through students' decision-making processes along various stages of their education attainment trajectories (Morgan, 2005).

Implications

The attention to information and decision-making may also shed light on why early switchers within this subgroup experienced higher levels of dropout and lower levels of degree completion. Without the informational resources available through their parents, delaying the decision to switch may provide more time to assess other academic fields and find the best fit. The results from this study thus signal to academic advisors that first generation college students switching from STEM to a non-STEM field are at an increased risk of dropping out. Such students may benefit from more targeted avising related to the choice of a destination major, particularly in the early stages of matriculation when they appear to be at the greatest risk of dropping out. In addition, advisors in the destination field of study and academic support services should consider programmatic infrastructure to facilitate the social and academic integration of first generation college students during the transition. These recommendations are consistent with prior research on the positive impact of academic advising on student persistence among first generation college students (Kirk-Kuwaye & Nishida, 2001; Swecker, Fifolt, & Searby, 2013). The present results point to a specific context in which proactive advising may prove effective, especially considering the central role of non-family members in academic decision-making among first generation students (Horn & Nunez, 2000).

Beyond the implications for advisors, the findings presented above raise important questions about policies aimed at recruitment and retention efforts in these majors and the overall expansion of the STEM work force. The available evidence suggests that enrollment in these degree programs has increased approximately ten percent over the past decade (Eagan et al., 2014), a trend that reflects the objectives of policymakers at state and federal levels. For example, in a widely cited report, the President's Council of Avisors on Science and Technology

(2012; see also National Science Board, 2010) called for dramatically increasing the number of college graduates in STEM fields in order to address a forecasted labor shortage (Carnevale et al., 2013). These policies, however inadvertently, may lead interested yet underprepared students to dropout of school or otherwise not complete a bachelor’s degree in a timely manner. More problematically, first generation college going students are at an increased risk of dropping out even when controlling for preparation and performance. Thus, the policy objective of bolstering recruitment into STEM majors and occupations may contradict broader efforts to address rates of retention and degree completion in higher education (Adelman, 2006).

Finally, the findings from this study illustrate that researchers should pay closer attention to student mobility through the disciplinary contexts of higher education. Scholars have long understood that academic disciplines represent differentiated social spaces in which status hierarchies are produced and reproduced (Bernstein, 1977; Bourdieu, 1988; Young, 1971), and a significant amount of recent research has sought to understand why students choose certain academic majors (especially STEM) over others upon entry into higher education (Davies & Guppy, 1997; Dickson, 2010; Goyette & Mullen, 2006; Mann & DiPrete, 2013; Morgan et al., 2013; Riegle-Crumb, King, Grodsky, & Muller, 2012; Stinebrickner & Stinebrickner, 2011; Wang, 2013). However, not enough attention has been given to the disciplinary pathways students take after they initially declare a major. Instead, the common sense understanding has been that changing one’s major is either a benign activity or, perhaps, a positive and rational process to align interests, skills, and aspirations. The work presented above represents a step toward investigating disciplinary pathways as organizational forms of social inequality that may contradict common assumptions and have serious consequences for student experiences and outcomes. Additional research can expand the understanding of these practices and, in the process, offer valuable information to educators, advisors, and policymakers working to bolster student retention and degree completion across all fields of study.

Notes

[1] Students who stopped out, but came back by the end of 2008/09 academic year were included in our analyses when information on their declared major was available in at least two survey waves.

[2] Analytically, a multinomial logistic regression approach was considered to compare those students who completed a degree within six years, persisted without a degree, and dropped out of college. However, the small sample size of students who persisted without a degree relative to our extensive list of covariates could lead to unreliable estimates and lower statistical power. Furthermore, in conceptualizing on-time degree completion and drop-out, we argue that two dichomotous variables (whether or not students completed a degree within six years, and whether or not students dropped out of college) are conceptually more appropriate than conditional comparisons among each group. Nonetheless, as a supplementary analysis, multinomial logistic regression models were tested and did not substantially change our interpretations.

[3] Academic integration is a composite variable on the frequency of interactions with faculty, advisors, peers, and study groups. Social integration is a composit variable on the frequency of participation in fine art activites, instramural or varsity sports, and school clubs.

[4] We considered employing multilevel logistic modeling to take into account the nested structure of the BPS dataset in which students are nested within institutions. However, due to small cluster sizes (e.g. 70% of institutions have less than five respondents) in the analytic sample, we determined that a multilevel approach would be innappropriate in this study. Supplementary analyses with cluster standard errors showed no substantial change in our findings.

[5] This finding was not unique to STEM. Across all non-STEM areas of study, students who did not switch out of their initially declared major group had a substantially higher probability of degree completion within six years of enrollment than those students who did switch (71.8% v. 50.5%).

[6] Family income did not appear significant in predicting a bachelor's degree completion within six years (Table 2) and dropping out of college (Table 3). Thus, the income interaction was excluded in our final models.

[7] A summary of results from the logistic regressions with interactions is available upon request.

[8] We would like to thank one of the anonymous reviewers for making this suggestion. Detailed results are available upon request.

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Table 1

Descriptive Statistics by Disciplinary pathways
Mean (SE)

	All (N=1,530)	*Staying in STEM (N=940)*	*Switching out of STEM (N=590)*
Degree Completion			
Bachelor's Degree within 6 yrs	0.595 (0.016)	0.705 (0.021)	0.448 (0.026)
Persistence without a Degree	0.155 (0.012)	0.115 (0.017)	0.209 (0.018)
Dropout	0.246 (0.015)	0.176 (0.018)	0.340 (0.025)
Timing of Switching			
Early Switcher	0.230 (0.016)	------	0.540 (0.028)
Late Switcher	0.117 (0.011)	------	0.274 (0.024)
Multiple Switcher	0.079 (0.009)	------	0.186 (0.019)
Switching major within STEM	0.157 (0.011)	0.235 (0.016)	0.053 (0.011)
Late Declared	0.169 (0.012)	0.205 (0.016)	0.120 (0.016)
Lateral Transfer	0.140 (0.012)	0.096 (0.011)	0.200 (0.023)
Reverse Transfer	0.092 (0.008)	0.036 (0.008)	0.169 (0.018)
Demographic & Familiy Background			
Female	0.340 (0.014)	0.324 (0.020)	0.363 (0.023)
White	0.666 (0.020)	0.688 (0.023)	0.638 (0.030)
Black	0.102 (0.015)	0.068 (0.012)	0.149 (0.023)
Hispanic	0.095 (0.012)	0.081 (0.018)	0.114 (0.018)
Asian	0.095 (0.009)	0.123 (0.014)	0.057 (0.011)
Other	0.041 (0.006)	0.040 (0.007)	0.042 (0.010)
Parents' Education			
2-yr college or less	0.369 (0.017)	0.308 (0.019)	0.451 (0.029)
Bachelor's	0.288 (0.014)	0.300 (0.016)	0.271 (0.026)
Above bachelor's	0.343 (0.015)	0.391 (0.020)	0.278 (0.025)
Income	70408.040 (2087.870)	74325.077 (2763.911)	65140.278 (2802.408)
College Preparedness			
Admission test score (ACT or SAT)	1119.161 (7.535)	1162.795 (10.242)	1060.479 (10.474)
High school GPA (3.5~4.0, or A- or A)	0.590 (0.018)	0.668 (0.021)	0.484 (0.029)
Incoming college credits	0.484 (0.017)	0.556 (0.020)	0.386 (0.027)
Academic and Social Integration			
College GPA, 2004	2.964 (0.024)	3.140 (0.025)	2.728 (0.045)
College GPA after Switching Major	3.097 (0.018)	3.187 (0.018)	2.977 (0.031)
Highest College Mathematics (calculus)	0.495 (0.017)	0.623 (0.022)	0.323 (0.027)
STEM GPA compared to non-STEM GPA in the first year			
Lower by at least 1.0 GPA point	0.163 (0.012)	0.114 (0.015)	0.229 (0.023)
Lower by at least 0.5~0.9 GPA points	0.203 (0.013)	0.202 (0.015)	0.204 (0.023)
About the same or higher	0.634 (0.016)	0.683 (0.020)	0.567 (0.026)
Academic Integration, 2004	87.905 (1.455)	88.921 (1.867)	86.540 (2.275)
Academic Integration, 2006	100.582 (1.337)	104.431 (1.874)	95.405 (2.022)
Social Integration, 2004	65.515 (1.703)	69.707 (2.050)	59.877 (2.663)
Social Integration, 2006	72.951 (1.890)	79.028 (2.613)	64.780 (2.835)
Financial Context			
Worked More than 10 hrs per week, 2004	0.348 (0.016)	0.279 (0.020)	0.441 (0.026)
Receiving help repaying loans	0.055 (0.008)	0.049 (0.009)	0.064 (0.012)
Cost of attendance	19628.186 (387.600)	21109.248 (519.165)	17636.406 (476.528)
Institutional Characteristics			
HBCU & HSI	0.103 (0.016)	0.072 (0.021)	0.144 (0.021)
Doctoral granting institution	0.506 (0.022)	0.538 (0.026)	0.462 (0.032)

Table 2

Degree Completion, Persistence Without Degree Completion, and Dropout Rates by Parental Education, Parental Income, and Disciplinary Pathways

	Bachelor's Degree Completion within 6 years		*Persisting up to 6th year without a Degree*		*Dropout*	
	Staying in STEM	Switching out of STEM	Staying in STEM	Switching out of STEM	Staying in STEM	Switching out of STEM
Parent's education						
Less than Bachelor’s Degree	0.649	0.340	0.161	0.195	0.194	0.465
Bachelor’s Degree	0.738	0.504	0.095	0.231	0.169	0.266
Above Bachelor's Degree	0.739	0.590	0.098	0.203	0.163	0.210
Income						
Lowest quintile	0.592	0.311	0.183	0.278	0.227	0.411
Highest quintile	0.775	0.664	0.086	0.167	0.139	0.174
Total	0.708	0.450	0.115	0.209	0.117	0.341

Table 3

Logistic Regression of Bachelor's Degree Completion on Disciplinary Pathway (N=1,530)

Variables	*M1*		*M2*		*M3*		*M4*		*M5*		*M6*	
Disciplinary Pathway (ref. Staying in STEM)												
Switching out of STEM majors	-0.257***	(0.032)	-0.152***	(0.034)	-0.139***	(0.030)	-0.108***	(0.030)	-0.046	(0.029)		
Timing of Switching Major (ref. Early Switching)												
Staying in STEM											0.061+	(0.033)
Late Switching											0.042	(0.044)
Multiple Switching											0.013	(0.059)
Switching major within STEM			-0.022	(0.038)	-0.026	(0.037)	-0.008	(0.035)	0.009	(0.038)	0.004	(0.039)
Late Declared (ref. Early Declared)			0.124**	(0.040)	0.086*	(0.039)	0.085*	(0.039)	0.054	(0.038)	0.043	(0.041)
Lateral Transfer			-0.237***	(0.048)	-0.225***	(0.046)	-0.210***	(0.046)	-0.184***	(0.046)	-0.186***	(0.046)
Reverse Transfer			-0.516***	(0.043)	-0.485***	(0.045)	-0.465***	(0.048)	-0.374***	(0.057)	-0.378***	(0.057)
Female					0.121***	(0.026)	0.097***	(0.027)	0.047+	(0.028)	0.047+	(0.028)
Black					-0.083+	(0.048)	-0.030	(0.047)	-0.035	(0.052)	-0.032	(0.051)
Hispanic					-0.178***	(0.048)	-0.158***	(0.047)	-0.137*	(0.056)	-0.139*	(0.056)
Asian					-0.011	(0.046)	-0.023	(0.045)	-0.076+	(0.044)	-0.076+	(0.045)
Parents' Education (ref. Less than 2yr college)												
BA					0.074*	(0.035)	0.059+	(0.036)	0.058+	(0.034)	0.058+	(0.034)
Above BA					0.079*	(0.034)	0.050	(0.035)	0.033	(0.034)	0.032	(0.034)
Income (log)					0.021*	(0.011)	0.019+	(0.011)	0.014	(0.010)	0.014	(0.010)
College Admission Test Score (ACT or SAT)							0.005	(0.010)	-0.024*	(0.011)	-0.023*	(0.011)
High School GPA (3.5~4.0; A- to A)							0.086**	(0.032)	0.041	(0.031)	0.041	(0.031)
Incoming College Credits							0.107***	(0.029)	0.070*	(0.029)	0.071*	(0.029)
Academic Integration, 2004									-0.002	(0.004)	-0.002	(0.004)
Social Integration, 2004									-0.002	(0.003)	-0.002	(0.003)
Academic Integration, 2006									0.010*	(0.004)	0.010*	(0.004)
Social Integration, 2006									0.002	(0.003)	0.002	(0.003)

Table 3. Cont.

Variables	*M1*	*M2*	*M3*	*M4*	*M5*		*M6*	
College GPA, 2004					0.079***	(0.023)	0.077***	(0.023)
College GPA after Switching Major (2006)					0.055+	(0.031)	0.055+	(0.031)
Highest college mathematics in first year (Calculus)					0.076*	(0.035)	0.076*	(0.036)
STEM GPA vs. Non-STEM GPA in the first year (ref. about the same or higher)								
Lower by at least 1.0 grade point					-0.047	(0.045)	-0.046	(0.045)
Lower by 0.5 to 0.9 grade point					0.006	(0.034)	0.006	(0.034)
Working more than 10hrs per week, 2004					-0.085**	(0.028)	-0.086**	(0.028)
Receiving help repaying loans					-0.018	(0.060)	-0.015	(0.060)
Cost of attendance (log)					0.105**	(0.033)	0.106**	(0.033)
HBCU & HIS					-0.052	(0.056)	-0.052	(0.056)
Doctoral granting Institution (Research & Doctoral)					0.046	(0.032)	0.045	(0.032)
Fields of Study (ref. Engineering/Technologies)								
Bio/life Sciences					0.063	(0.040)	0.061	(0.040)
Physical Sciences					-0.020	(0.048)	-0.022	(0.048)
Mathematics					0.130*	(0.066)	0.129+	(0.066)
Computer and Information Sciences					-0.002	(0.040)	-0.004	(0.040)

Notes. +p<0.1, * p<0.05, **p<0.01, *** p<0.001.

Table 4

Logistic Regression of Dropout on Disciplinary Pathway (N=1,530)

Variables	*M1*		*M2*		*M3*		*M4*		*M5*		*M6*	
Disciplinary Pathway (ref. Staying in STEM)												
Switching out of STEM majors	0.165***	(0.032)	0.106**	(0.033)	0.095**	(0.031)	0.079*	(0.031)	0.046	(0.031)		
Timing of Switching Major (ref. Early Switching)												
Staying in STEM											-0.118**	(0.038)
Late Switching											-0.174***	(0.046)
Multiple Switching											-0.103*	(0.049)
Switching major within STEM			-0.010	(0.032)	-0.005	(0.033)	-0.014	(0.032)	-0.010	(0.030)	0.013	(0.032)
Late Declared (ref. Early Declared)			-0.091**	(0.034)	-0.062+	(0.036)	-0.065+	(0.036)	-0.061	(0.037)	-0.014	(0.042)
Lateral Transfer			0.090+	(0.048)	0.082+	(0.046)	0.071	(0.043)	0.058	(0.041)	0.064	(0.040)
Reverse Transfer			0.281***	(0.054)	0.245***	(0.052)	0.228***	(0.052)	0.176**	(0.054)	0.196***	(0.052)
Female					-0.075**	(0.024)	-0.064**	(0.024)	-0.032	(0.028)	-0.035	(0.027)
Black					0.057	(0.054)	0.039	(0.058)	0.047	(0.057)	0.043	(0.055)
Hispanic					0.048	(0.047)	0.050	(0.048)	0.075	(0.061)	0.083	(0.061)
Asian					-0.042	(0.047)	-0.035	(0.045)	-0.001	(0.049)	0.000	(0.050)
Parents' Education (ref. Less than 2yr college)												
BA					-0.072*	(0.033)	-0.065+	(0.034)	-0.065*	(0.032)	-0.062+	(0.032)
Above BA					-0.082*	(0.036)	-0.066+	(0.038)	-0.061+	(0.035)	-0.057	(0.035)
Income (log)					-0.012	(0.010)	-0.012	(0.010)	-0.009	(0.010)	-0.008	(0.009)
College Admission Test Score (ACT or SAT)							0.003	(0.009)	0.012	(0.010)	0.010	(0.010)
High School GPA (3.5~4.0; A- to A)							-0.022	(0.031)	0.015	(0.032)	0.016	(0.031)
Incoming College Credits							-0.113***	(0.031)	-0.095**	(0.029)	-0.094**	(0.028)
Academic Integration, 2004									0.005	(0.004)	0.006	(0.004)
Social Integration, 2004									0.003	(0.003)	0.003	(0.003)
Academic Integration, 2006									-0.010**	(0.004)	-0.010**	(0.004)
Social Integration, 2006									-0.000	(0.003)	0.000	(0.003)

Table 4. Cont.

Variables	*M1*	*M2*	*M3*	*M4*	*M5*		*M6*	
College GPA, 2004					-0.040+	(0.021)	-0.036+	(0.021)
College GPA after Switching Major (2006)					-0.053+	(0.029)	-0.051+	(0.028)
Highest college mathematics in first year (Calculus)					-0.038	(0.037)	-0.038	(0.036)
STEM GPA vs. Non-STEM GPA in the first year (ref. about the same or higher)								
Lower by at least 1.0 grade point					-0.007	(0.038)	-0.013	(0.037)
Lower by 0.5 to 0.9 grade point					-0.041	(0.036)	-0.039	(0.036)
Working more than 10hrs per week, 2004					0.011	(0.027)	0.013	(0.026)
Receiving help repaying loans					0.102+	(0.056)	0.081	(0.055)
Cost of attendance (log)					-0.033	(0.034)	-0.038	(0.032)
HBCU & HIS					-0.029	(0.052)	-0.033	(0.050)
Doctoral granting Institution (Research & Doctoral)					-0.041	(0.034)	-0.037	(0.033)
Fields of Study (ref. Engineering/Technologies)								
Bio/life Sciences					-0.019	(0.040)	-0.012	(0.039)
Physical Sciences					0.009	(0.047)	0.014	(0.047)
Mathematics					-0.021	(0.068)	-0.012	(0.068)
Computer and Information Sciences					0.046	(0.034)	0.056	(0.035)

Notes. +p<0.1, * p<0.05, **p<0.01, *** p<0.001.

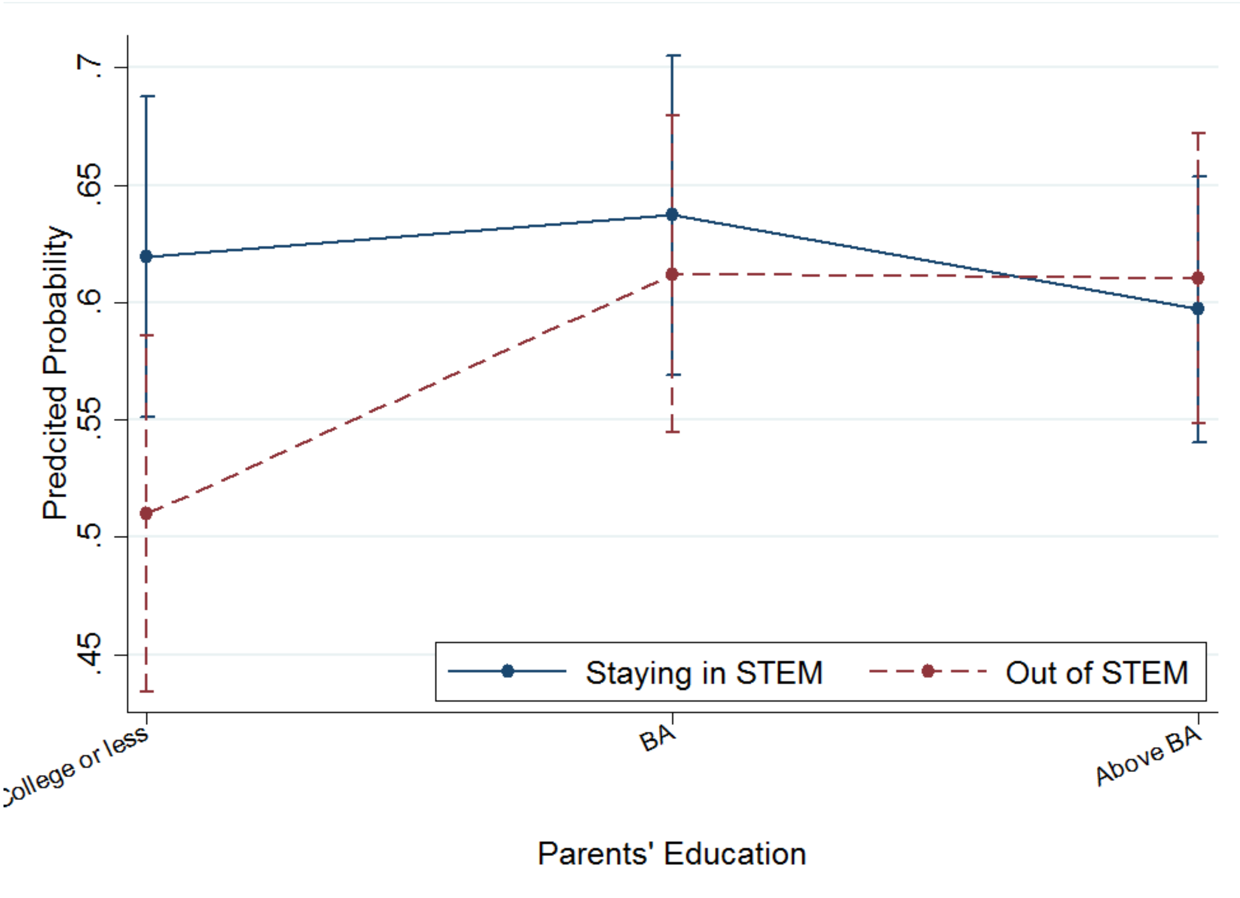


Figure 1. *Predicted probabilities of Bachelor's degree completion by disciplinary pathways and parents' education*

Note. *Predicted probabilities were estimated from an interaction model in which interaction terms between disciplinary pathways and parents' education were added in M5 of Table 3.*

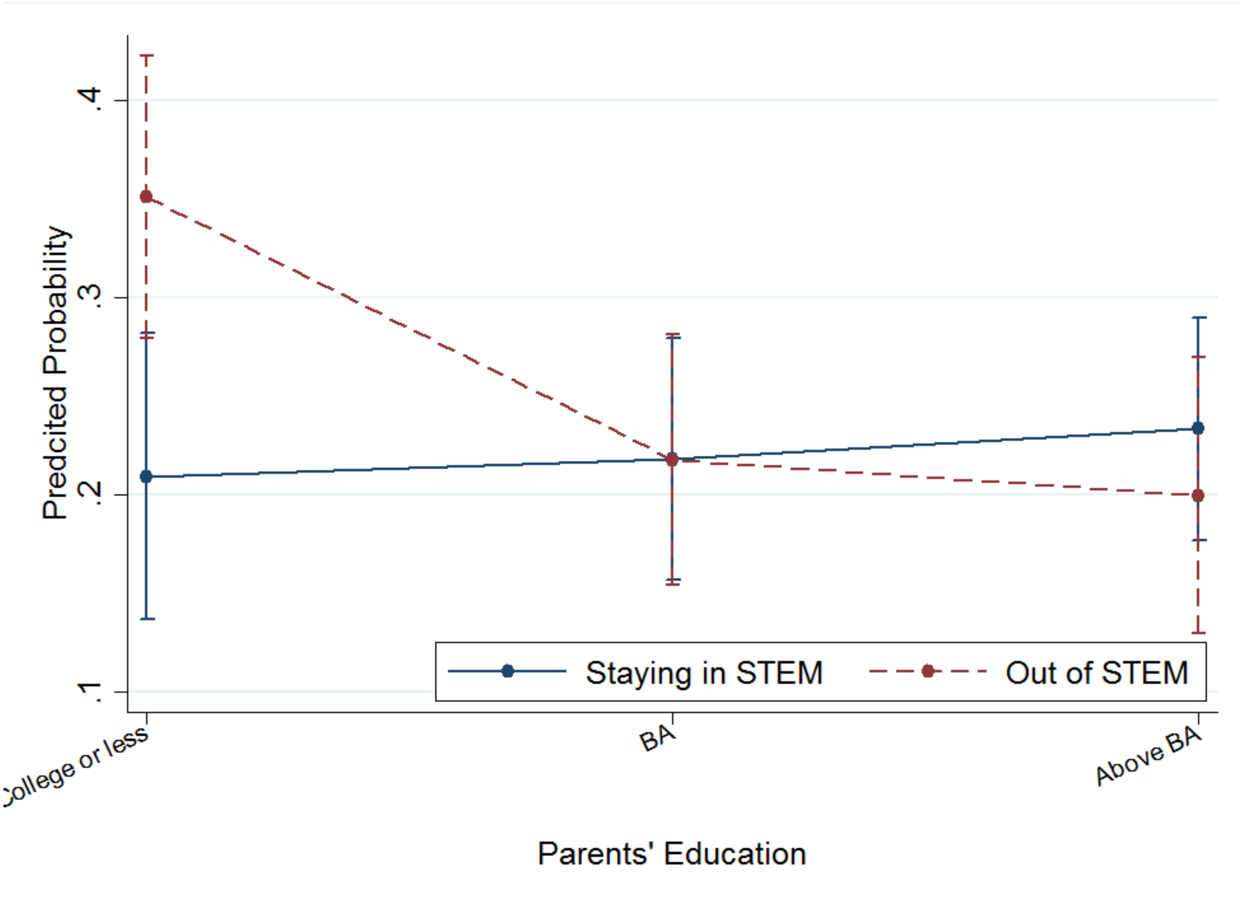


Figure 2. *Predicted probabilities of Dropout by disciplinary pathways and parents' education*
Note. Predicted probabilities were estimated from an interaction model in which interaction terms between disciplinary pathways and parents' education were added in M5 of Table 4.

Appendix A

Variable Descriptions

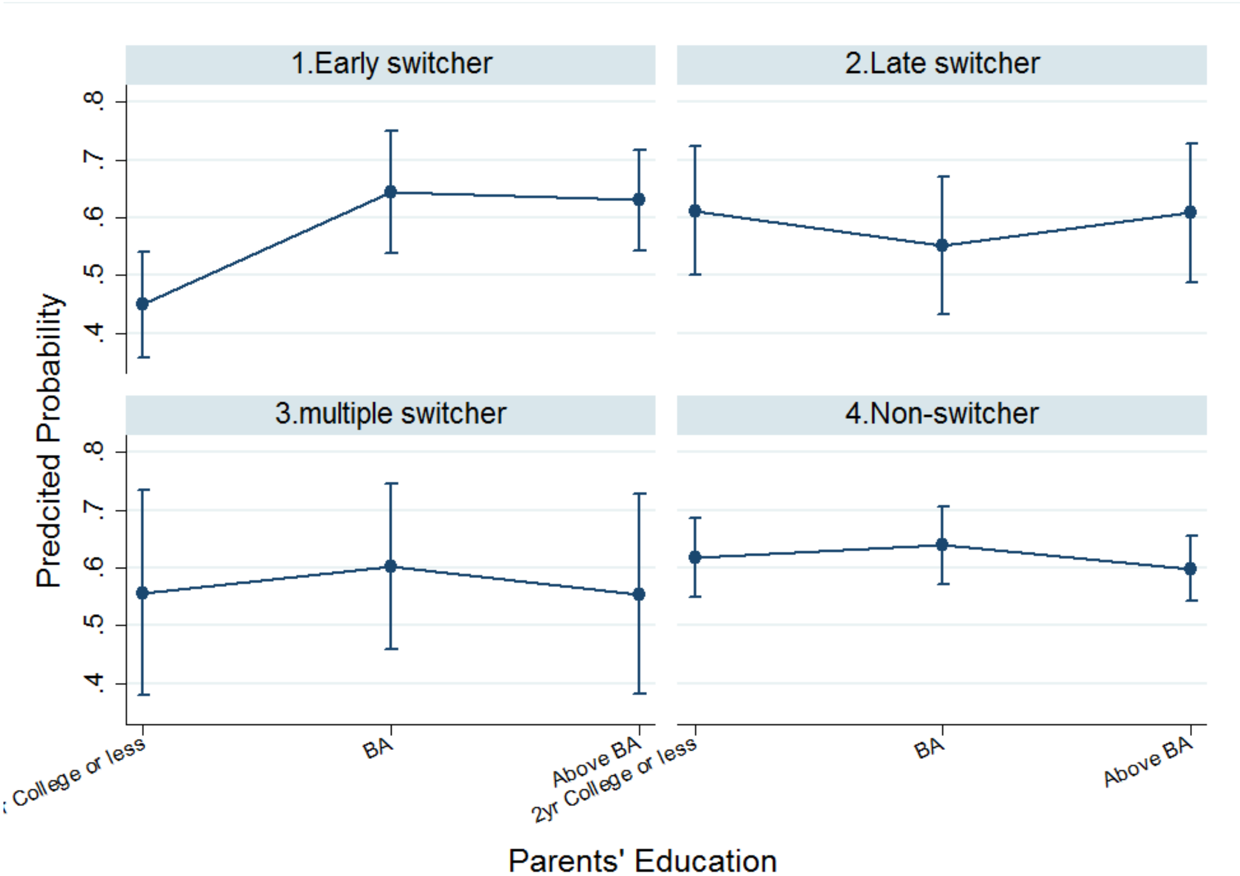
Variables	*Description*
Outcomes and Disciplinary Pathways	
BA Completion	BA completion indicates whether or not a student completed her/his bachelor's degree through the end of the sixth year after entry into postsecondary education (06/2009). This was coded as a dummy variable (BA completion =1; otherwise = 0).
Dropout	Dropout indicates whether or not a student dropped out of her/his college (not enrolled without a degree) before 2009 (01/2009) and did not come back by the end of 2009 academic year (06/2009). This was coded as a dummy variable (Dropout =1; otherwise = 0).
Timing of Switching	The timing of switching was defined as 'early' when major switching occurred between the first (2003/04) and third (2005/2006) academic years, 'late' between the third (2005/06) and sixth (2008/09) academic years, and 'mutiple' when major switching occurred both in early and late periods.
Switching major within STEM	This indicates whether a student switched her/his major within STEM field (e.g. from physical science to biological science).
Late Declared	The late declared indicates a student who undeclared at the time of the initial BPS survey (during the first academic year, 2003/04), but declared her/his major between the first (2003/4) and the third (2005/06) academic years.
Institutional Transfer	Lateral transfer refers to students' institutional transfer from 4yr to 4yr college while reverse transfer refers to institutional transfer from 4yr to 2yr college.
Demographic and Family Background	
Gender	Gender was measured as male (=0) and female (=1). Male is a reference group.
Race	Originally, race was measured as White, Black or African American, Hispanic or Latino, Asian, American Indian or Alaska Native, Native Hawaiian/other Pacific Islander, Other, and More than one race. However, because of the low proportion of some minority groups, eights racial categories merged into five categories; White, Black, Hispanic, Asian, and Other. White and other are a reference group and all others were included as dummies.
Parents' education	Parents' education was measured as the highest level of education of either parent of the respondent during the 2003-04 academic year, and converted into three dummy variables; less than bachelor's degree, bachelor's degree, and greater than bachelor's degree.
Income	Family income indicates the respondents' Adjusted Gross Income (AGI) in 2002. For independent students, this is the AGI for the parents and for independent students, this is the AGI for the respondent. This was transformed with a natural logarithm in the analysis after recoding 0 values into 50.
College Preparedness	
Admission test score (ACT or SAT)	Admission Test Score indicates the SAT I (verbal and math) combined score or the ACT composite score converted to an estimated SAT I, which scales from 400 to 1,600. In the analysis, this score was divided by 100.
High school GPA (3.5~4.0, A- or A)	High School GPA indicates the high school grade point average. This was converted into a dummy (3.5 ~ 4.0, A- to A = 1; 3.0 ~ 3.4, B to A- or less = 0).
Highest level of HS math (Calculus)	Highest level of HS Math indicates the highest level of math the respondent completed among Algebra2, Trigonometry/Algebra II, Pre-calculus, and Calculus. This was converted into a dummy (Calculus = 1; others = 0).
Incoming college credits	Incoming College Credits indicates college credits that the respondent earned while he/she was in high school. This was coded as a dummy (Yes = 1; No = 0).

Appendix A, Cont.

Variables	*Description*
Academic & Social Integration	
College GPA, 2004	First-year College GPA indicates the student cumulative Grade Point Average (GPA) in academic year 2003-2004, which scales from 0 to 400. In the analysis, this was divided by 100.
College GPA after Switching Major	College GPA after Switching Major indicates the average of student cumulative Grade Point Average (GPA) after switching major until completing their degree or academic year 2008-2009. Average GPA from academic year 2004-2005 to completing their degree or academic year 2008-2009 was used for students who did not switch their major.
Highest College Mathematics (calculus) in the first year	This variable indicates the highest level of math courses (calculus or advanced math) in which a student earned one or more credits during the first year of enrollment. This was coded as a dummy (calculus or advanced math =1; others = 0).
STEM GPA compared to non-STEM GPA in the first year	This variable indicates the difference between STEM GPA and non-STEM GPA during the first year of enrollment. Five categories include STEM GPA (1) lower than non-STEM GPA by at least one grade point (Considerably lower), (2) lower than non-STEM GPA by 0.5 to 1.0 grade point, (3) about the same as non-STEM GPA, (4) higher than non-STEM GPA by 0.5 to 1.0 grade point, and (5) higher than non-STEM GPA by at least 1.0 grade point (Considerably higher). The last three categories (3), (4), and (5) were converted into one reference group in the analyses.
Academic Integration, 2004	Academic Integration is a composite variable of how often he/she did the following: (1) had social contact with faculty, (2) talked with faculty about academic matters outside of class, (3) met with an academic advisor, or (4) participated in study groups. Each item was measured during the 2003-2004 academic year. Values for these items were averaged and the average was multiplied by 100.
Academic Integration, 2006	See Academic Integration, 2004. This variable was measured during the 2005-2006 academic year.
Social Integration, 2004	Social Integration is a composite variable of how often he/she did the following: (1) attended fine arts activities, (2) participated in intramural or varsity sports, or (3) participated in school clubs. Each item was measured during the 2003-2004 academic year. Values for these items were averaged and the average was multiplied by 100.
Social Integration, 2006	See Social Integration, 2004. This variable was measured during the 2005-2006 academic year.
Financial Context	
Worked more than 10 hrs per week, 2004	Worked More than 10 hrs per week indicates whether the average hours the respondent worked per week exceeded 10 hours during the 2003-04 academic year (Yes = 1; No = 0).
Receiving help repaying loans	Receiving help repaying loans indicates whether anyone, such as a family member or friend, helped the respondent to repay his/her undergraduate loans as of January 1, 2009 (Yes = 1; No = 0). Respondents who skipped this question were recoded to 0.
Cost of attendance	Cost of attendance indicates the price of attendance or total student budget. This was transformed with a natural logarithm in the analysis.
Institutional Characteristics	
HBCU & HSI	HBCU & HSI indicates whether the first institution the respondent attended during the 2003-04 academic year is designated either as a Historical Black College (or University) or a Hispanic Serving Institution (Yes = 1; No = 0).
Doctoral granting institution	Doctoral Granting Institution indicates the Basic Carnegie classification of the first institution the respondent attended. This was converted into a dummy (research and doctoral institutions = 1; others = 0).
ACT Interest Inventory Scores	ACT Interest Inventory Scores measured students' vocational interests, who took the ACT up through the 2002-2003 year. Six vocational fields were measured: Science, Arts, Social Science, Business contact, Business operation, and Technical. Each section score indicates the sum of scores that how much students would like doing each of the activities related to each field. It ranges approximately from 30 to 80.

Appendix B

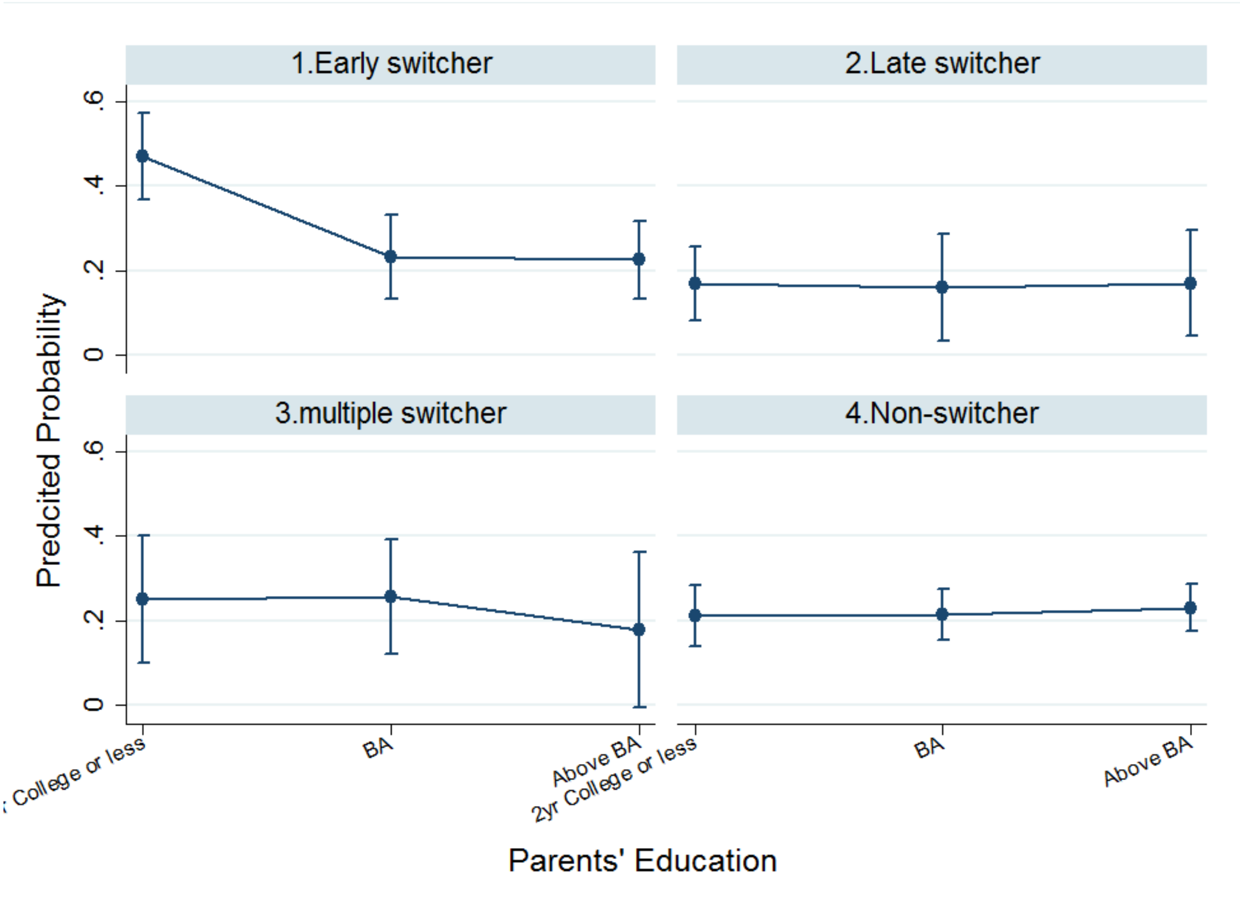
Predicted Probabilities of Bachelor's Degree Completion by Switching types and Parents' Education



Note. Predicted probabilities were estimated from an interaction model in which interaction terms between switching types and parents' education were added in M6 of Table 3.

Appendix C

Predicted Probabilities of Dropout by Switching Types and Parents' Education



Note. Predicted probabilities were estimated from an interaction model in which interaction terms between switching types and parents' education were added in M6 of Table 4.