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Beyond STEM attrition: changing career plans within STEM fields in college is associated with lower motivation, certainty, and satisfaction about one's career

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Abstract

Background Research and policy often focus on reducing attrition from educational trajectories leading to careers in science, technology, engineering, and mathematics (STEM), but many students change career plans *within* STEM. This study examined how changing career plans within STEM fields was associated with psychological indicators of career readiness. We conducted a large online survey of undergraduate students ($N = 1{,}727$) across 42 courses covering every major STEM discipline at a large U.S. research-intensive public university. Students reported about their career plans, whether plans had changed, motivation for those career plans, and satisfaction with and certainty of persisting with those plans. A trained team of coders classified whether students reported having STEM career plans at the time of the survey and at the beginning of college.

Results Students who said they had changed career plans within STEM fields during college also reported lower motivation for their new career plans, satisfaction with those plans, and certainty of persisting in them, compared to students who retained consistent STEM career plans. With few exceptions, these associations held across students' gender, race, year in school, and STEM field of study. Within-STEM career plan changes were very common, reported by 55% of fourth-year STEM students. Women reported changing career plans within STEM fields more often than men.

Implications Results suggest that changing career plans within STEM is an important phenomenon to consider in preparing a qualified and diverse STEM workforce. Students who change career plans within STEM fields may need additional supports for their career motivation and satisfaction compared to students who do not change plans.

Keywords Career planning, Expectancy-value theory, Gender, Motivation, STEM education

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Introduction

Significant national resources have been devoted to understanding and reducing *STEM attrition*, or the phenomenon of students leaving STEM or STEM-related career paths for non-STEM ones. Researchers argue that studying STEM attrition is essential both to increase students' participation in careers where there are labor market shortages, and to help address ongoing gender and racial/ethnic disparities in STEM career participation (Chen, 2012; National Science Board, 2022; President's Council of Advisors on Science & Technology, 2012). Yet, a sole focus on reducing attrition is not likely to be sufficient to prepare diverse students for STEM workforce success. The STEM economic sector includes hundreds of potential career options, and during college many students change career plans *within* STEM (Rosenzweig et al., 2021a). For example, students may shift from wanting to be an engineer to wanting to be a computer scientist. Students who shift plans within STEM often go undiscussed in workforce policy and research, which can seem to imply that students are "on track" for career success so long as they stay in STEM. The present study challenges this assumption, examining whether college students who change career plans within STEM fields report lower scores on various psychological indicators of motivation and readiness for post-graduation career plans compared to their peers who retain consistent STEM career plans throughout college.

Situated expectancy value theory and STEM career readiness

All students who plan to pursue STEM career paths are not equally likely to achieve STEM career success. In considering what factors predict students' satisfaction with, persistence in, and engagement with STEM career paths, Eccles and colleagues' situated expectancy-value theory of motivation is a useful theoretical framework. According to situated expectancy-value theory, individuals' achievement-related decisions and engagement with achievement-related tasks are most proximally influenced by their motivational beliefs, and these beliefs are the major lenses through which individuals internalize their past experiences, socialization histories, and broader self-beliefs with respect to thinking about upcoming achievement tasks (Eccles & Wigfield, 2020). Situated expectancy-value theory suggests that there are two major types of motivational beliefs that determine engagement with and choices of academic activities, including preparing for and persisting in an STEM career: competence-related beliefs and task values (Eccles [Parsons] et al., 1983; Eccles & Wigfield, 2020).

Competence-related beliefs are individuals' beliefs about whether they are capable of success in a particular career. Competence-related beliefs are often described as relating to the question of "Can I do this task?"; if students think they cannot achieve success on a task, they will not be motivated to engage with it (Eccles & Wigfield, 2020). Traditionally, situated expectancy-value theory defined competence-related beliefs only in terms of expectations of success on an upcoming task (Eccles [Parsons] et al., 1983). However, expectancies of success overlap empirically with a number of broader competence-related beliefs including individuals' academic self-concepts in particular fields, broader ability beliefs, and self-efficacy (Bong & Skaalvik., 2003; Marsh et al., 2019). For this reason, many researchers including us examine the broader concept of competence-related beliefs instead of studying one particular belief (e.g., Muenks et al., 2018; Simpkins et al., 2006). Extensive research shows that individuals' competence-related beliefs for STEM fields of study, majors, or careers predict varied outcomes including their emotions during STEM courses (Jiang et al., 2018), their performance in STEM courses during high school and college (Guo et al., 2015a, 2015b; Jiang et al., 2018; Perez et al., 2014, 2019), their choices of whether or not to pursue STEM coursework or majors (Guo et al., 2015b; Lent et al., 2003; Musu-Gillette et al., 2015; Perez et al., 2019), and their plans to take or choices to pursue STEM career paths (Guo et al., 2015a; Lauermann et al., 2017; Rosenzweig & Chen, 2023).

Task values refer to individuals' beliefs about whether a career is worthwhile and generally these beliefs relate to the question of "Do I want to do this task?" Even if students believe they are capable of success at a particular task, they may not be motivated to engage with it if it lacks perceived value. Researchers working within situated expectancy-value theory often discuss value in terms of four components: how useful a career is assumed to be (i.e., utility value), how relevant it is to one's identity (i.e., attainment value), how interesting or enjoyable it is (i.e., intrinsic value), and, conversely, how much it requires individuals to sacrifice time, effort, or emotional resources (i.e., cost) (Eccles-Parsons et al., 1983; Eccles & Wigfield, 2020). Each of the four components of task values has also been found to predict varied learning and engagement outcomes, including students' engagement with and emotions during STEM courses (Jiang et al., 2018), academic performance (Guo et al., 2015a, 2015b; Jiang et al., 2018), STEM course-taking choices or major persistence (Guo et al., 2015a; Guo et al., 2015b; Musu-Gilette et al., 2015; Safavian, 2019; Safavian & Conley, 2016), and STEM career intentions or career pursuit (Guo et al., 2015a; Lauermann et al., 2017).

Though each of the major constructs of situated expectancy-value theory significantly predicts a variety of achievement-related outcomes, the beliefs do not

all predict all types of outcomes in the same ways. There are some general trends in the literature suggesting that different specific beliefs most strongly predict unique types of STEM achievement outcomes. First, competence-related beliefs, compared to task values, tend to predict grades and academic performance more strongly, whereas task values tend to predict more strongly academic choices and decisions (e.g., courses to take, majors to pursue, whether or not to persist in STEM fields) (e.g., Bong et al., 2012; Meece et al., 1990; Safavian & Conley, 2016; Safavian, 2019; see Wigfield & Eccles, 2020 for review). Second, within task values, intrinsic value tends to predict momentary decisions like engagement and emotions, whereas utility and attainment value tend to predict longer-term decisions like what courses or majors to pursue (Rosenzweig et al., 2022). Third, perceptions of cost have been studied less than the other components of task values, and thus the outcomes likely to be affected by cost are less well-understood. However, cost perceptions generally seem to predict individuals' decisions to avoid or disengage from challenging tasks or drop out of particular fields of study (e.g., Jiang et al., 2018; Perez et al., 2014). The trends just noted should not be taken to suggest that certain constructs *exclusively* predict certain STEM outcomes. Competence-related beliefs and attainment, utility, and intrinsic value all relate positively to one another over time (and often also relate negatively to perceived cost), and students' academic outcomes influence one another over time as well (e.g., academic performance influences participation) (Chen, 2012; Durik et al., 2006; Jacobs et al., 2002; Ost, 2010). For this reason, each of the SEVT constructs has potentially multifaceted impacts on individuals' academic preparation and persistence.

In this study, we operationalize "career motivation" in accordance with situated expectancy-value theory and examine students' competence-related beliefs and the four dimensions of task values for their chosen career plans at the time of the study as indicators of STEM career motivation. Our key assumption, grounded by the extensive research just reviewed, is that if students report lower scores on each of these indicators of motivation for an STEM career (or higher cost perceptions), they will be less likely to persist at that career over time, less likely to enjoy and feel satisfied with it, and less likely to engage with career preparation or day-to-day work activities associated with it. Most specifically, we might expect that if students report lower competence-related beliefs for a career they might perform less well in courses or career preparation activities en route to it, if they report lower utility or attainment value for a career they might be less likely to choose to persist in it, if they report lower intrinsic value for a career they might be less satisfied with it, and if they report higher perceived cost they may be more likely to disengage with in-the-moment career preparation tasks or opportunities.

Understanding within-STEM career plan changes to promote STEM workforce participation

To help ensure that more students are on track to succeed in STEM careers, educators and researchers can identify students who have low competence-related beliefs and/or task values for STEM career plans and provide them with supports to enhance their motivation. Prior research has examined this topic, but that research predominantly focuses on one group of students with low motivation: students who intend to leave or actually do leave STEM career paths for non-STEM ones (i.e., those who are likely to engage in STEM attrition). For example, much prior research has examined what motivational beliefs predict whether students want to do STEM fields of study/career paths versus non-STEM ones (i.e., Guo et al., 2016; Lauermann et al., 2017; Musu-Gillette et al., 2015; Perez et al., 2014, 2019). This work demonstrates that students' competence-related beliefs and task values are key predictors of students leaving STEM fields for non-STEM alternatives.

Though important, this body of work overlooks the experiences of a group of students who do not leave STEM careers, but still may have lower career motivation in STEM: students who change career plans *within* STEM fields of study. These students are often assumed to be "on track" for STEM career success because they continue to pursue STEM career paths. However, students who change career plans within STEM fields may have lower career motivation for their new chosen career plans compared to their peers who do not change plans, for reasons discussed in the next paragraph. Having lower motivation, according to situated expectancy-value theory, would make these students more likely not to prepare effectively for their chosen career path, not to succeed at obtaining the career they want, and/or not to persist at their chosen STEM career after college. If we as a society want a qualified STEM workforce where employees are satisfied, productive, and remain engaged with in-demand STEM careers, it is essential to identify and support all students who might have relatively low STEM career motivation, not just those who wish to leave STEM careers for non-STEM ones.

There are two reasons why changing career plans within STEM fields may be associated with students having lower career motivation. First, students with lower overall motivation for an STEM field may in turn be less motivated for any careers within that field, and as a result they may be more likely to change plans within STEM more often than their peers. If individuals start college

with relatively less motivation for their chosen field of study (i.e., lower perceptions of competence-related beliefs intrinsic value, attainment value, or utility value, or higher cost perceptions) this may translate into correspondingly lower levels of those same motivational beliefs for any careers within those fields. Prior research supports this idea by showing that students' general competence-related beliefs translate into competence-related beliefs for specific sub-tasks within those fields, and that students are more strongly motivated to engage with and put forth effort on specific tasks that are congruent with their broader interests and identities (Eccles, 2005; Master et al., 2016; Muenks et al., 2020). Thus, students who are more confident about their ability to succeed in a particular STEM domain, like computer science, are likely to feel more confident about their ability to succeed in career plans within that domain compared to students who feel less confident. Similarly, if students perceive a particular STEM domain as less central to their identity, interesting, or useful, they may be likely to think of career paths within that domain as being less valuable compared to students who perceive that domain to be more valuable. Even if students who change career plans report somewhat higher motivation for their new career path than they used to report for their old path, they still might have lower career motivation for their new path compared to those who never changed plans, because the students with consistent plans are just that highly motivated for studying their chosen career. At the same time, students with lower levels of career-related motivational beliefs may choose to change career plans more often than their peers who have relatively higher motivational beliefs, given the extensive research outlined in the prior section showing links between the different expectancy-value motivational beliefs and choices to leave STEM career paths. Taken together, this evidence suggests that changing plans within STEM would serve as an indicator of a group of students who are particularly low on motivation for their chosen STEM careers and thus need support, but the process of changing plans itself would not have caused students to have lower motivation.

A second reason why students who change career plans within STEM may report lower career motivation is that the process of changing career plans within STEM fields may *cause* students to be less motivated for their new career plans. Students who change career plans during college have less time to take coursework or pursue professional development that provides skill-building related to their new career paths. This might prevent them from having success experiences that support their skill development in their new careers. Having an opportunity to develop skills hands-on is one of the strongest factors impacting the development of students' competence-related beliefs for particular academic tasks, so in this case failing to have sufficient experiences to develop skills would lead students to report lower competence-related beliefs for their chosen career path (Bandura, 1997; Butz & Usher, 2015). Additionally, similar to competence-related beliefs, interest in a field is thought to develop as a result of repeated experiences over time that help students increasingly see the relevance of a particular area of study to their lives and other interests (Hidi & Renninger, 2006). Students in turn are thought to develop deeper sources of value, such as utility and attainment value, via initial experiences of interest where they connect activities to their personal goals and identities (Priniski et al., 2018). If students change career plans, they may not have as many opportunities to engage in self-relevant activities that deepen their interest in their new career paths or allow them to see how those paths fit with their identities. As a result, students may not have an opportunity to develop as much attainment and/or utility value for their new career path as they might have had they had more opportunities to engage in career preparation. There is not much existing research about the developmental antecedents of perceived cost, so it is unclear whether this phenomenon would affect cost perceptions as well.

There are hundreds of career possibilities within STEM, and many college students report that career decision-making is a source of psychological stress (Fouad et al., 2006). These facts make the two mechanisms just discussed very salient to students during college. Indeed, even minor career shifts may indicate (or cause) differences in students' motivation; career changes do not need to be substantive. With respect to the first potential explanation for effects, students who are feeling like they are not capable or who perceive low value in their career choice may be more likely to shift careers in both major or minor ways. With respect to the second mechanism, if students need additional experiences to prepare for any new career path (even if that new path is as minor as pursuing one type of engineering career versus another), they may still doubt their competence for the new path or have concerns about whether the new career is valuable, more so than would individuals who have always maintained consistent plans and had opportunities to explore them throughout college.

Regardless of the mechanism for effects, if students who change career plans within STEM fields do report lower motivation for their new career paths compared to those retaining consistent STEM career plans, this fact has critical implications for research and practice. From a research perspective, STEM motivation research almost exclusively examines students who stay in versus leave STEM, essentially assuming that students who

remain in STEM fields are motivated and on track for career success. However, these students might need to be studied in depth to shed light on heterogeneity in career preparation among individuals in STEM fields. From a practice perspective, students who have changed plans within STEM or who are considering changing may be an essential group for whom to provide extra supports and resources to ensure that they are motivated for success in the STEM careers that they do choose. For this reason, the goal of the present study was to examine whether changing career plans within STEM was associated with career motivation, as well as with two other indicators of career readiness thought to be affected by motivation (career satisfaction and certainty).

A secondary goal was to examine the *prevalence* of changing career plans within STEM. A recent study reported that 46% of college students pursuing biomedical careers at a 4-year U.S. state university changed career plans within biomedical fields, which was more than 50% larger than the estimate of the rate of attrition out of biomedical careers in that sample (Rosenzweig et al., 2021a). Identifying how many students change career plans within STEM can shed light on the scope of the issue of heterogeneity in career motivation among students who remain in STEM fields of study. These findings are important to provide new insights around labor market shortages in particular STEM- or STEM-related career paths (e.g., physicians or computer programmers, Association of American Medical Colleges, 2021; Xue & Larson, 2015). Any student who leaves an in-demand STEM career path contributes to shortages in that career, even if the student ultimately chooses some other STEM career path. If students change careers within STEM more often than they leave STEM, then researchers or educators might best address some career shortages by studying and supporting students who switch careers within STEM, instead of focusing solely on preventing students from leaving for non-STEM career paths.

Student characteristic differences in changing career plans within STEM fields

A final major study goal was to explore whether findings were robust to students' gender, race/ethnicity, year in school, or field of study. We examined this topic because there have been differences in STEM attrition rates observed in prior studies as a function of each of these student background variables (e.g., Chang et al., 2014; Cheryan et al., 2017; Maltese & Tai, 2011; Shaw & Barbuti, 2010); these findings suggest that students' background may shape how they respond to different types of STEM learning experiences and contexts. It is theoretically possible that each of these background characteristics are important in shaping how students think about career planning and motivation and thus might influence students' likelihood of retaining consistent STEM career plans versus changing plans within STEM and/or the strength of the association between changing plans and career motivation/satisfaction. We discuss each specific characteristic in turn in the paragraphs that follow. However, we also note that our goal in conducting these analyses was largely exploratory. We believed it was equally possible that the general trends just discussed would hold regardless of students' background characteristics.

Thinking about gender, we expected that there might be differences in the proportion of students changing plans as a function of gender. Inequities in STEM workforce participation persist between women and men (e.g., National Science Board, 2022). These are driven by differences in relative career participation patterns by gender *within* STEM fields. For example, women are underrepresented in more careers within computer science and engineering than in the life sciences (e.g., Cheryan et al., 2017). When considering why these relative differences in STEM participation exist, one contributing factor may be that women change from one STEM career plan to another more often than men do. Research shows that women receive social messages leading them on average to prefer careers that offer work–life balance and afford communal values (Diekman et al., 2017; Eccles, 2009; Starmer et al., 2019). Communally oriented careers are not traditionally associated with STEM (Diekman et al., 2010). As women learn more about required career training and preparation in college, they may be more attuned to finding which career paths within STEM most readily afford such opportunities and they may be more likely to change career paths within STEM as a result (e.g., switching from being a doctor to a physician assistant, Rosenzweig et al., 2021a). We did not expect based on the literature that gender was likely to moderate the associations between changing plans and career motivation, satisfaction, and certainty, but we examined those analyses to test for robustness of findings as a function of gender.

With respect to race, we thought that the proportion of students changing plans within STEM might differ by whether of not students' racial or ethnic identity was historically marginalized in STEM. In terms of how many students change plans within STEM, there are inequities in STEM workforce participation between White students and students from historically marginalized racial/ethnic groups (e.g., AAUW, 2010; National Science Board, 2022). In addition, within STEM, Black/African American and Hispanic/Latino/a students have larger participation gaps compared to White or Asian/Asian American students in engineering careers compared to life sciences careers (e.g., Cheryan et al., 2017; National Science Board, 2022; Pew Research Center 2021). Similar

to what was reported for gender, these trends may be due to race-based differences in changing career plans within STEM fields of study. Black and Hispanic/Latino/a students, similarly to women, have been found to receive more social messages about the importance of engaging with STEM careers that afford communal opportunities (Brown et al., 2015) and thus may also be more likely to shift career plans within STEM fields more readily to find STEM careers that meet these needs. Racially marginalized students in STEM also might experience discrimination or encounter non-welcoming professional climates that lead them to change career plans more readily within STEM fields (Seals, 2016). Like with gender, we did not have an a priori theoretical reason to expect race to moderate the association between changing plans and career motivation or career readiness, so those analyses were treated as exploratory robustness checks.

With respect to field of study, we thought it would be possible to observe differences both in terms of the proportion of students changing plans within STEM, and in terms of the association between changing plans and career motivation, satisfaction, and certainty. Some fields of study in STEM (e.g., biology) are associated with a large number of career paths whereas others (e.g., engineering) lend themselves more to a specialized set of careers with particular training. Change within STEM might be more common in domains that are associated with a broader set of potential career options. In terms of associations between changing plans and outcomes, some STEM sub-fields require more commitment and preparation for careers than others. For example, in the life sciences, many students want to become doctors which entails a heavy pre-requisite course load, so the time required to prepare for a new career path may be higher than in another field. These differences may lead changing career plans to be more negatively associated with career readiness indicators in life sciences versus other subfields.

Finally, with respect to year in school, we also had some reasons to expect differences in both the proportion of students changing plans within STEM fields and the associations between changing plans and career motivation, satisfaction, and certainty. For proportion of students changing plans, it would be expected that in a cross-sectional data set, the percentage of students who report having made within-STEM changes would be higher at each year in school. This is because students have more time to change career plans on average the longer they are in college. For associations with outcomes, it may be more detrimental to career readiness if students change plans later in college, because there is less time to prepare for a new career. Because this data was cross-sectional, we were not able to test directly how the same students' decisions unfolded across college, but this data provides a starting point for comparing students' responses at different points in the college experience.

The present study

Given the potential importance of changing plans within STEM for career motivation and readiness, and the potential high number of students engaging in this type of career shift, the present study aimed to examine the phenomenon in more depth. We had the following questions:

1. What proportion of college students report having changed career plans within STEM fields during college?
2. How is changing career plans within STEM fields during college associated with students' motivation for their current career plans (i.e., perceived competence-related beliefs and perceptions of task values for that career plan), satisfaction with their current career plans, and certainty of pursuing those career plans after college?
3. Do findings differ as a function of gender, race/ethnicity, year in school, or STEM field of study?

Methods

Participants

Participants were 1,727 students, who were both enrolled in STEM courses and pursuing STEM career plans, at a large, public Southeastern U.S. research-intensive state flagship university during the Spring 2022 semester. Participants were 68.9% women, 29.9% men, 0.9% non-binary or other gender identities, and 0.4% stated that they preferred not to disclose gender. They were 69.7% White, 23.9% Asian or Asian American, 7.7% Black or African American, 5.6% Hispanic or Latino/a, 0.4% Native American, and 0.6% other racial/ethnic identities (participants could select multiple racial/ethnic identities). They were primarily first-year students (50.4%), with 22.2% second-year students, 17.7% third-year students, 7.7% fourth-year students, and 2.1% students not in a typical year of college. Of the sample, 18.4% indicated that they were first-generation college students (i.e., neither parent had obtained a college degree). The most common groups of majors pursued by students in the sample were majors related to biology (i.e., biology, biological science, biochemistry and molecular biology, genetics, ocean science, microbiology, plant biology, cellular biology, ecology, entomology), computer science (i.e., computer science, data science), and engineering (i.e., agricultural, biochemical, biological, civil, computer systems, electrical/electronics, environmental, mechanical).

Participants were recruited from 42 STEM courses (26 unique course titles, with some having multiple sections participate that were taught by multiple professors) across the university as well as five large listservs (pre-health, computer science, engineering, ecology, and microbiology). These courses and listservs were chosen to represent as wide a range of STEM disciplines as possible and included biology, ecology, genetics, microbiology, chemistry, physics, engineering, computer science, and mathematics. In 30 of the 42 courses, participants received a small amount of extra credit in exchange for participation. Students recruited through the other courses and listservs were offered entry into a gift card drawing in exchange for study participation. All participants were treated in accordance with APA ethical guidelines, and this study was approved via this university's Office of Research.

The final sample of 1,727 represents the number of participants after exclusions. This study focused specifically on career plan changes *within* STEM fields, so we only included participants in the present manuscript who had pursued STEM career plans across the course of college. Our data collection in the STEM courses initially provided 2,312 valid participants, but 422 did not have career plans that were clearly classifiable as being in STEM or non-STEM fields, and another 163 reported having non-STEM or non-classifiable career plans either at the point of the survey or when starting college (see Measures section and Additional file 1 for full description of the career classification process we used). Such students were excluded from the analyses, resulting in the final sample of 1,727 used in the present study.

Procedure

Students received information via electronic announcements from listservs or course professors inviting them to participate in an online study taking 15–30 min. Among other questions, students provided information about their major/field of study, their long-term career plans, their satisfaction with and certainty of pursuing those plans, whether or not those plans had changed, their motivational beliefs for pursuing those career plans, and background information.

Measures

Identifying students who pursued STEM career paths throughout college

Only students who reported having STEM career paths both at the time of the survey and at the beginning of college were included in the analyses. To determine eligibility for this study, we used a coding process adapted from prior research (Rosenzweig et al., 2021a). First, a team of trained research assistants classified students' self-generated career plans as being related to STEM or non-STEM fields, by matching their write-in long-term career plans to career titles from the O*Net Database, which is a career database run by the U.S. Department of Labor (see SOM for detailed description of this process). If students reported changing career plans during college, we also asked them to write in what their initial career plans were at the beginning of college and we classified both their initial and long-term career plans as being in STEM, non-STEM, or unable to classify. Any students whose career plans were not clearly in STEM fields, either initially during college or at the time of the survey, were excluded from the sample (i.e., students who did not have clearly classifiable career plans in STEM or non-STEM at either time point, who entered STEM careers during college, who left STEM careers during college, or who never were interested in STEM careers; see SOM for complete description).

Identifying students who changed career plans

To identify students who changed their career plans during college, we examined students' responses to a yes/no question, "Have your long-term career plans changed since the beginning of college?" Students who indicated yes were categorized to have changed their career plans.

In taking this approach, our goal was to examine the psychological correlates of having changed career plans within STEM *in any way that seemed meaningful in students' minds.* That is, small career changes within one major (e.g., moving from being a biology Ph.D. to a biology lab technician) or within one career category (e.g., moving from one type of physician career to another) constituted a career plan change in this study, so long as students considered that to be a change in their minds. Our goal in using this approach was to capture the varied and sometimes subtle nature of career plan changes that might be meaningful to students. Such changes could not be captured well using "objective" indicators of career affiliation (e.g., looking at whether students reported pursuing the same or different majors or career categories at different points in college) because those indicators may be too coarse to capture meaningful changes that students undertake. We hoped to demonstrate that even students making subtle changes in career plans report different levels of career motivation, satisfaction, and certainty compared to their peers who report not changing plans, and that these students are worth supporting more in STEM environments.

Self-reported motivation for career plans

Students completed a questionnaire assessing their motivational beliefs regarding their current long-term career plans, which was adapted from prior questionnaires

grounded in situated expectancy value theory. Items were adapted from prior studies (which typically focus on motivation for a particular subject areas or courses) to reference students' perceptions of their career plans (e.g., becoming a biological engineer, becoming a physician assistant). All items were answered on 7-point scales ranging from *Not at All True* to *Very True*. Confirmatory factor analyses showed excellent data-model fit of the measure, and the measure showed appropriate discriminant and predictive validity (see SOM for details and complete list of items). Students' *competence-related beliefs* were assessed with four items measuring how well students thought they would do in their career (adapted from Eccles & Wigfield, 1995; $\alpha = 0.81$). Students' perceptions of *intrinsic value* were measured with five items assessing how exciting and enjoyable a career would be (adapted from Conley, 2012; $\alpha = 0.91$), perceptions of *attainment value* were measured with five items assessing the personal importance of pursuing a career (adapted from Conley, 2012; $\alpha = 0.85$), and perceptions of *utility value* were assessed with four items assessing how practical and/or useful a career would be (adapted from Conley, 2012; $\alpha = 0.76$). Students' perceptions of *cost* were assessed with three items evaluating the effort required by a career, the valued alternatives one must give up to pursue a career, and anticipated negative emotional consequences of engaging with a career (adapted from Beymer et al., 2021; $\alpha = 0.72$).

Satisfaction with and certainty of pursuing career plans

Students completed one item measuring career satisfaction, "How satisfied are you with your current long-term career plans?" They also completed one item measuring career certainty, "How certain are you that you will pursue this career?" These single-item measures were created by the researchers to represent the outcomes of most direct interest with respect to career readiness. Both were answered on 7-point scales ranging from *Not at All* ___ to *Very* ___.

Student background information

Students self-reported their gender, race/ethnicity, first-generation student status, and year in school. For field of study, students wrote in their majors or intended majors at the time of the survey, after which a trained research assistant classified each response as relating to one or more of the most common fields of study represented in the sample (biology-related fields of study, engineering-related fields of study, computer-science-related fields of study, or other fields of study; see SOM for details). Many students who changed career plans within STEM retained the same field of study/major despite changing career plans (i.e., students could change from a career plan of doctor to that of biomedical lab technician, but retain a biology major), but some students who changed career plans also changed majors within STEM. For those students, the field of study variable used in the present study represents students' *new fields of study* after having changed plans within STEM fields.

College GPA

Students self-reported their college GPA on a 0–4 scale to be used as a covariate in analyses. Self-reported GPAs are argued to be reliable and valid when measured from relatively higher performers and relatively older students (e.g., college students at a somewhat selective institution, Kuncel et al., 2005), which describes the context of this study well.

Analytic strategy

Descriptive statistics were used to indicate the proportion of students changing career plans within STEM fields (Research Question 1). To assess how changing plans was associated with students' motivational beliefs (Research Question 2), linear regression was used to predict each indicator (competence-related beliefs, intrinsic value, utility value, attainment value, perceived cost, career satisfaction, career certainty) from students' reports of whether or not they changed plans (change = +1, no change = 0), while controlling for two covariates in addition to all of the student characteristics examined in Research Question 3. To assess differences by gender, race/ethnicity, field of study, and year in school (Research Question 3), logistic regressions were used to indicate whether students' likelihood of changing plans differed as a function of student characteristics, and interaction terms were added to the regression models for Research Question 2 to assess whether changing plans interacted with any student characteristics in predicting any career readiness indicators. Student-level characteristics were operationalized in the models as follows: gender (men = 0; women = 1), racially minoritized status (historically underrepresented in STEM = 1; not historically underrepresented = 0), year in school (a set of four dummy-codes, representing each year—2nd, 3rd, 4th, or other—compared to the first year), field of study (a set of three dummy-codes, comparing students enrolled in biology-related fields of study, coded as 0, to (a) computer-science-related fields of study, (b) engineering-related-fields of study, or (c) other fields of study, each coded as 1, respectively). All analyses controlled for college GPA (standardized) to rule out the possibility that higher academic performance in general (or group differences in academic performance) drove observed effects on career motivation/satisfaction and on plans changing. All analyses also controlled for first-generation student

status (first-generation student = 1; non-first-generation student = 0).[1]

For the purposes of ensuring adequate statistical power to assess each gender group in the models, we excluded non-binary individuals and those who did not disclose gender from the analyses that included gender. We also grouped together students who were racially minoritized in STEM (i.e., students who indicated a racial identity of Black, Latino/a, and/or Native American) and compared them to students whose race was not minoritized in STEM fields, to maximize power to detect effects in the race/ethnicity moderator analyses. For missing data, a very small number of students were excluded from analyses who did not answer all of the items for a particular measure ($n = 8$ to 39 depending on the measure).

Results

How many students changed career plans within STEM fields throughout college?

A large proportion of students, 32.5%, reported having changed their career plans within STEM fields at some point during college, despite the sample being primarily first- and second-year students. Breaking this number down by students' year in college revealed increasingly higher proportions of students having changed plans in each successive year of college, with a majority of fourth-year students (55.4%) reporting having changed career plans within STEM fields at some point (see Table 1).

Descriptive statistics and correlations among continuous variables

Descriptive statistics and correlations among key study variables are reported in Table 2; descriptive statistics for each variable by whether or not students changed plans are reported in Table 3. All correlations were of the expected magnitudes and directions, with the exception of the correlation between perceived cost and attainment value, which was not significant. On average, students were highly motivated for their chosen career paths, with low perceptions of cost. On average, students who had not changed career plans within STEM fields reported higher scores for each outcome measure compared to students who had changed plans.

[1] Originally, it was our intention to test first-generation student status as another moderating variable in Research Question 3, but when included in models the predictors' variance inflation factor statistics (an indicator of collinearity issues) became too high (> 6). We therefore chose to test only race/ethnicity as a moderator and not first-generation status in the present study, which eliminated the collinearity issues. If analyses omit the covariates of GPA and first generation status, this does not change the significance of any effects, except for one interaction between year in school and plans changing which became non-significant ($p = .054$ in the models without covariates included) and which is not interpreted as a key finding in the present study.

How is changing career plans within STEM associated with indicators of career readiness?

Tables 4, 5, 6 report the results of regression analyses predicting students' expectancy-value motivational beliefs (Table 4 reports competence-related beliefs, Table 5 reports task values) and career satisfaction/certainty (Table 6) from their likelihood of changing career plans. Students who changed their career plans within STEM fields during college reported significantly lower scores for competence-related beliefs, utility value, attainment value, and intrinsic value for their long-term career plans, compared to students who retained consistent STEM career plans, $\beta s = -0.09$ to -0.16, $ps < 0.001$; see Fig. 1 for visualization. Similarly, students who changed their career plans within STEM fields reported lower career satisfaction and lower certainty of pursuing their chosen STEM careers, $\beta s = -0.20$ to -0.22, $ps < 0.001$; see Fig. 1. Perceived cost was the only variable not aligned with this pattern. Changing career plans within STEM fields was associated with students reporting *lower* perceived cost for their new careers (to be consistent with the other findings given the theoretical nature of this construct, one would expect students to report higher perceived cost), $\beta = -0.10$, $p < 0.001$. All effects just noted are small, but they represent the unique effects of plans changing, after controlling for students' gender, racially minoritized status, year in school, field of study, self-reported GPA, and first-generation student status.

Do findings differ by gender, race, year in school, or field of study?

Logistic regression analyses were used to predict the likelihood of students changing career plans within STEM during college from their gender, race/ethnicity, year in school, and field of study, controlling for self-reported college GPA and first-generation college student status. Table 7 reports the results of these analyses. Gender was a significant predictor of plans changing within STEM fields, with women being significantly more likely than men to change career plans within STEM fields compared to retaining consistent STEM career plans, $B = 0.31$, $S.E. = 0.14$, $p = 0.021$, odds ratio = 1.37. Year in school was also a significant predictor, with each year corresponding to a significantly higher likelihood of changing career plans within STEM fields compared to the first year of college, $Bs = 0.87$ to 1.61 for the second through fourth years versus the first year, $S.E.'s = 0.14$ to 0.20, $ps < 0.001$, odds ratios = 2.38 to 5.01. Finally, students in engineering-related fields of study at the time of the survey were more likely to report having changed career plans than were students in biology-related fields of study, as were students in "other" fields of study (i.e., not biology, computer science, or engineering) compared

Table 1 Who changes career plans within STEM fields in college

	Changed career plans	Did not change career plans	Total
Overall	561 32.5%	1166 67.5%	1727
Year in school			
First	176 20.7%	674 79.3%	850
Second	143 38.1%	232 61.9%	375
Third	128 42.8%	171 57.2%	299
Fourth	72 55.4%	58 44.6%	130
Other	26 76.5%	8 23.5%	34
Gender			
Woman	386 33.1%	781 66.9%	1167
Man	152 30.0%	354 70.0%	506
Non-binary or prefer not to say	8 38.1%	13 61.9%	21
Race/ethnicity			
Historically marginalized in STEM	72 31.4%	157 68.6%	229
Not historically marginalized in STEM	472 32.2%	992 67.8%	1464
Field of study			
Biology-related field of study	195 28.3%	495 71.7%	690
Computer science-related field of study	56 32.7%	115 67.3%	171
Engineering-related field of study	82 36.9%	140 63.1%	222
Other field of study	223 35.1%	413 64.9%	636

*Percentages reflect the percentage of students in each sub-category who changed versus did not change plans, among those who provided data for each item

Table 2 Correlations and descriptive statistics for key study variables

Variable	1	2	3	4	5	6	7
1. Competence-related beliefs							
2. Intrinsic value	.578**						
3. Attainment value	.496**	.613**					
4. Utility value	.514**	.591**	.599**				
5. Perceived cost	−.204**	−.180**	.019	−.052*			
6. Career satisfaction	.480**	.572**	.431**	.419**	−.160**		
7. Career certainty	.464**	.472**	.402**	.385**	−.103**	.710**	
M	5.379	6.221	5.908	5.889	3.725	5.770	5.500
S.D.	0.922	0.792	0.918	0.847	1.282	1.184	1.261
n	1705	1705	1705	1705	1705	1727	1727

*$p < .05$; **$p < .01$

Table 3 Mean scores for career motivation, satisfaction, and certainty as a function of plans changing within STEM

Variable	Changed career plans		Did not change career plans	
	M	*S.D.*	*M*	*S.D.*
Competence-related beliefs	5.27	0.97	5.43	0.89
Intrinsic value	6.06	0.86	6.30	0.75
Attainment value	5.75	0.98	5.98	0.88
Utility value	5.76	0.91	5.95	0.81
Perceived cost	3.54	1.27	3.81	1.28
Career satisfaction	5.47	1.31	5.91	1.09
Career certainty	5.19	1.35	5.65	1.19

Table 4 Results of regressions predicting competence-related beliefs for expected STEM career plans

Variable	B	S.E.	β	*p*
Intercept	5.54	0.09		
Plans changing	−0.19	0.05	−0.09	< .001
Gender	−0.12	0.05	−0.06	.025
Racially minoritized status	0.01	0.07	0.00	.889
First-generation status	−0.04	0.06	−0.02	.505
Year in school				
Second versus first	0.14	0.06	0.06	.019
Third versus first	0.19	0.06	0.08	.002
Fourth vs. first	0.25	0.09	0.07	.005
Other vs. first	0.37	0.17	0.06	.030
Field of study				
C.S.-related vs. Bio.-related	−0.34	0.08	−0.11	< .001
Eng.-related vs. Bio.-related	−0.03	0.07	−0.01	.705
Other fields vs. Bio.-related	−0.05	0.05	−0.03	.315
College GPA	0.07	0.03	0.07	.006

Plans Changing: Yes = 1, No = 0. Gender: Woman = 1, Man = 0. Racially Minoritized Status: Historically marginalized with respect to racial/ethnic identity in STEM = 1, Non-historically marginalized = 0. First-generation status: first-generation student = 1; non-first-generation student = 0. Year in School: Dummy codes representing each year versus the first year (focal year coded as 1, all other groups coded as 0, with first year as the reference group). Field of Study: Dummy codes representing each field of study versus biology-related fields of study (focal field of study coded as 1, all other fields of study coded as 0, with biology-related fields of study as the reference group). College GPA is standardized for analysis

to students in biology-related fields of study, *B*s = 0.33 to 0.38, *S.E.*'s = 0.13 to 0.18, *p*s = 0.037 to 0.014, odds ratios = 1.39 to 1.47.

Although there were some differences in the likelihood of changing plans within STEM by student-level characteristics, there were few interactions suggesting that the *relation* between changing plans and the psychological outcome variables differed as a function of student characteristics. The SOM provides complete description of the statistical output of these analyses and visualization of the few observed interactions. To summarize the findings, no associations between changing plans and career motivation, satisfaction, and certainty differed significantly as a function of race/ethnicity, and there was only one observed interaction across seven possible outcome measures suggesting that results differed by gender. There were only four interactions across the set of all four of the dummy codes for year in school predicting any of the seven outcome measures (i.e., only four significant effects out of 28 possible interactions), and even when accounting for those interactions the same overall trends still were observed. That is, some effects were slightly stronger among second-year compared to first-year students, but the same overall patterns held for almost all outcomes that changing career plans was associated with lower scores on the various measures. Similarly, for field of study, there were only three observed interactions across the set of three dummy codes predicting any of the seven outcome measures (i.e., 21 possible interactions), and the same overall trends were still observed even accounting for those interactions.

Discussion

Students who reported changing career plans within STEM fields during college also reported lower scores on multiple psychological indicators of career motivation—namely competence-related beliefs, intrinsic value, utility value, and attainment value—as well as on satisfaction with and certainty of persisting at their current careers, compared to students who reported retaining consistent STEM career plans throughout college. A large proportion of students also had changed career plans within STEM, and women reported changing more often than did men. These findings demonstrate that researchers, educators, and policy-makers should examine students who switch career plans within STEM fields, not just those who leave STEM careers, to contribute to STEM workforce participation and equity.

The importance of studying students who change career plans within STEM

On every indicator of career motivation examined except perceived cost, individuals who changed career plans within STEM reported lower scores than individuals who retained consistent career plans. Changing one's career plans is not in and of itself a bad thing – research focused on both STEM attrition (e.g., Seymour & Hunter, 2019; Rosenzweig et al., 2021b; Thoman et al., 2017) and within-STEM career plan shifts (Rosenzweig et al., 2021a) suggests that many students are attracted to new career paths positively, because the new plans align better with students' interests and preferences. The findings

Table 5 Results of regressions predicting task values for expected STEM career plans

	Intrinsic value				Attainment value				Utility value				Perceived cost			
Variable	**B**	**S.E.**	**β**	***p***	**B**	**S.E.**	**β**	***p***	**B**	**S.E.**	**β**	***p***	**B**	**S.E.**	**β**	***p***
Intercept	6.16	0.08			5.69	0.09			5.79	0.08			3.67	0.12		
Plans changing	−0.27	0.04	−0.16	< .001	−0.27	0.05	−0.14	< .001	−0.22	0.05	−0.12	< .001	−0.27	0.07	−0.10	< .001
Gender	0.15	0.04	0.09	< .001	0.21	0.05	0.11	< .001	0.13	0.05	0.07	.008	0.06	0.07	0.02	.423
Racially minoritized status	0.00	0.06	0.00	.958	−0.04	0.07	−0.01	.559	−0.01	0.06	0.00	.912	0.16	0.09	0.04	.086
First-generation status	0.01	0.05	0.01	.795	0.14	0.06	0.06	.013	0.04	0.05	0.02	.437	0.22	0.08	0.07	.006
Year in school																
Second versus first	0.06	0.05	0.03	.228	0.10	0.06	0.05	.070	0.05	0.05	0.03	.316	0.11	0.08	0.04	.172
Third versus first	0.16	0.05	0.08	.002	0.18	0.06	0.08	.004	0.15	0.06	0.07	.008	0.16	0.09	0.05	.069
Fourth vs. first	0.27	0.07	0.09	< .001	0.31	0.09	0.09	< .001	0.13	0.08	0.04	.105	−0.10	0.12	−0.02	.395
Other vs. first	0.04	0.14	0.01	.772	0.13	0.16	0.02	.443	0.01	0.16	0.00	.960	−0.28	0.23	−0.03	.226
Field of study																
C.S.-related vs. Bio.-related	−0.26	0.07	−0.10	< .001	−0.33	0.08	−0.11	< .001	−0.30	0.08	−0.10	< .001	−0.61	0.12	−0.14	< .001
Eng.-related vs. Bio.-related	−0.05	0.06	−0.02	.409	−0.21	0.07	−0.08	.004	0.02	0.07	0.01	.768	−0.47	0.10	−0.12	< .001
Other fields vs. Bio.-related	0.01	0.04	0.01	.814	−0.03	0.05	−0.02	.585	0.04	0.05	0.03	.348	−0.31	0.07	−0.12	< .001
College GPA	0.01	0.02	0.01	.791	0.02	0.02	0.03	.315	0.00	0.02	−0.01	.845	0.07	0.04	0.05	.060

Plans Changing: Yes = 1, No = 0. Gender: Woman = 1, Man = 0. Racially Minoritized Status: Historically marginalized with respect to racial/ethnic identity in STEM = 1, Non-historically marginalized = 0. First-generation status: first-generation student = 1; non-first-generation student = 0. Year in School: Dummy codes representing each year versus the first year (focal year coded as 1, all other groups coded as 0, with first year as the reference group). Field of Study: Dummy codes representing each field of study versus biology-related fields of study (focal field of study coded as 1, all other fields of study coded as 0, with biology-related fields of study as the reference group). College GPA is standardized for analysis

Table 6 Results of regressions predicting career satisfaction and certainty for expected STEM career plans

Variable	Career satisfaction				Career certainty			
	B	**S.E.**	**β**	***p***	**B**	**S.E.**	**β**	***p***
Intercept	5.64	0.11			5.48	0.12		
Plans changing	−0.51	0.06	−0.20	< .001	−0.59	0.07	−0.22	< .001
Gender	0.14	0.07	0.06	.034	0.04	0.07	0.02	.532
Racially minoritized status	0.01	0.08	0.00	.882	−0.02	0.09	−0.01	.816
First-generation status	0.03	0.07	0.01	.681	−0.06	0.08	−0.02	.444
Year in school								
Second versus first	0.03	0.07	0.01	.668	0.28	0.08	0.10	< .001
Third versus first	0.21	0.08	0.07	.008	0.52	0.08	0.16	< .001
Fourth vs. first	0.53	0.11	0.12	< .001	0.79	0.12	0.17	< .001
Other vs. first	0.43	0.21	0.05	.044	0.43	0.22	0.05	.053
Field of study								
C.S.-related vs. Bio.-related	−0.11	0.11	−0.03	.307	-0.03	0.11	−0.01	.780
Eng.-related vs. Bio.-related	0.10	0.09	0.03	.274	-0.09	0.10	−0.02	.382
Other fields vs. Bio.-related	0.19	0.06	0.08	.003	0.13	0.07	0.05	.059
College GPA	0.06	0.03	0.05	.057	0.07	0.03	0.05	.048

Plans Changing: Yes = 1, No = 0. Gender: Woman = 1, Man = 0. Racially Minoritized Status: Historically marginalized with respect to racial/ethnic identity in STEM = 1, Non-historically marginalized = 0. First-generation status: first-generation student = 1; non-first-generation student = 0. Year in School: Dummy codes representing each year versus the first year (focal year coded as 1, all other groups coded as 0, with first year as the reference group). Field of Study: Dummy codes representing each field of study versus biology-related fields of study (focal field of study coded as 1, all other fields of study coded as 0, with biology-related fields of study as the reference group). College GPA is standardized for analysis

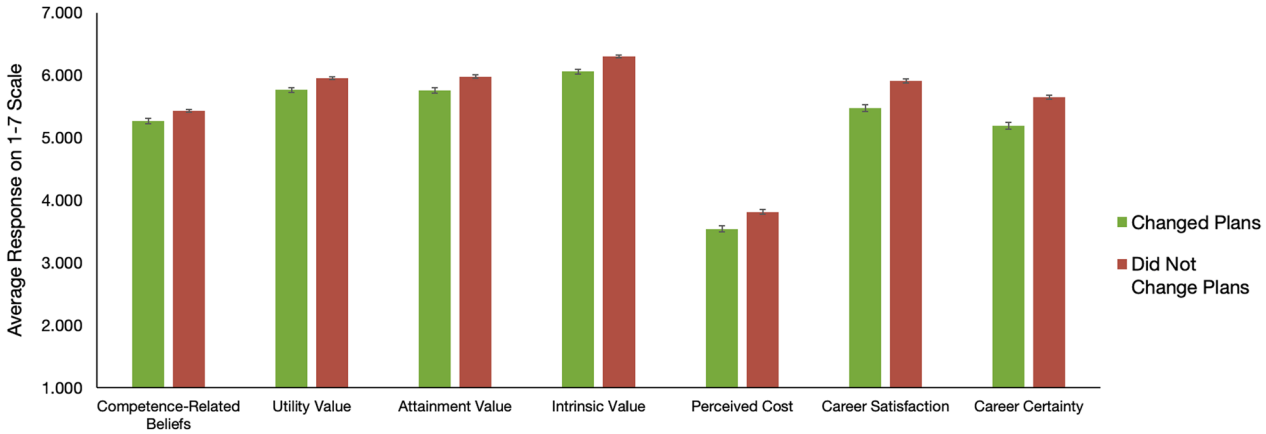

Fig. 1 Comparing students who changed career plans within STEM fields to students who retained consistent STEM career plans on indicators of their current career motivation, satisfaction, and certainty of persisting. Unadjusted mean scores shown here; error bars represent + −1 SE of the mean. In regressions adjusting for student-level characteristics, all mean differences between groups are significant at $p < .001$

Table 7 Logistic regression analyses predicting likelihood of changing career plans within STEM

Variable	B	S.E.	Wald	*p*	Odds Ratio
Intercept	−1.61	0.23			
Gender	0.31	0.14	5.35	.021	1.37
Racially minoritized status	−0.24	0.17	1.98	.159	0.79
First-generation status	−0.12	0.15	0.68	.409	0.89
Year in school					
Second vs. first	0.87	0.14	37.68	< .001	2.38
Third vs. first	1.12	0.15	56.66	< .001	3.07
Fourth vs. first	1.61	0.20	64.42	< .001	5.01
Other vs. first	2.62	0.43	36.85	< .001	13.69
Field of study					
C.S.-related vs. Bio.-related	0.06	0.22	0.07	.793	1.06
Eng.-related vs. Bio.-related	0.38	0.18	4.35	.037	1.47
Other fields vs. Bio.-related	0.33	0.13	6.64	.010	1.39
College GPA	−0.07	0.06	1.38	.240	0.93

Plans Changing: Yes = 1, No = 0. Gender: Woman = 1, Man = 0. Racially Minoritized Status: Historically marginalized with respect to racial/ethnic identity in STEM = 1, Non-historically marginalized = 0. First-generation status: first-generation student = 1; non-first-generation student = 0. Year in School: Dummy codes representing each year versus the first year (focal year coded as 1, all other groups coded as 0, with first year as the reference group). Field of Study: Dummy codes representing each field of study versus biology-related fields of study (focal field of study coded as 1, all other fields of study coded as 0, with biology-related fields of study as the reference group). College GPA is standardized for analysis

of this study should not be taken to imply that we should prevent students from changing career plans within STEM fields. However, these results do show that not all students who retain an STEM career plan across college are equally motivated to succeed their chosen careers.

As was discussed in the Introduction, much prior research shows that competence-related beliefs and intrinsic, attainment, and utility value each are predictive of individuals' satisfaction with their achievement activities, performance in them, engagement with them over time, and likelihood of persisting in them (e.g., Guo et al., 2015a, 2015b; Lauermann et al., 2017; Perez et al., 2014). There are particularly strong links reported in the literature between each of these motivational beliefs and certain career-related outcomes (e.g., competence-related beliefs most strongly predict performance, utility and attainment value most strongly predict persistence, and intrinsic value most strongly predicts satisfaction), but there are also likely to be multifaceted links of each construct to a variety of career-related outcomes. Given these prior findings, it would be expected that individuals with lower self-reported scores on each indicator of career motivation as defined by situated expectancy-value theory (or higher cost) would also report lower career satisfaction and certainty of persisting at their careers, and indeed in this study we also found that students who changed career plans within STEM reported lower scores on these two indicators of career readiness.

Findings have important implications for existing research and policy efforts, which focus predominantly on understanding why students leave STEM careers for non-STEM fields (particularly in the motivational research field). If we want a qualified and successful STEM workforce where employees are satisfied and put forth effort, especially in specific STEM career paths where there is a high need for additional employees, students who change career plans within STEM fields comprise a group that may block such goals. It may not be

sufficient to focus research and policy on trying to prevent students from leaving STEM altogether. Instead, it is important to identify students who are likely to or who actually do change plans within STEM fields, study them further to understand their experiences, and consider how we can provide students like these with additional supports throughout college to help them feel more motivated for, satisfied with, and certain of persisting in their chosen STEM career paths.

There are two explanations for why individuals who changed plans within STEM fields may have reported lower career motivation than individuals who retained consistent career plans. First, as was discussed in the Introduction, there may have been *pre-existing differences* in motivation to engage with a particular STEM field between students who changed career plans within STEM compared to those who did not. According to this explanation, changing plans would not *cause* lower motivation among students who change plans within STEM, but instead changing career plans within STEM would be an indicator of which students started off with relatively lower motivation for their STEM fields of interest. Having lower perceived competence or intrinsic, utility, and attainment value for a particular STEM field of study could lead these students to change plans more often, and it could lead these students to report lower corresponding levels of motivational beliefs for any careers within that field, compared to individuals who had not changed plans. Even if students who change career plans within STEM fields are more motivated for their new STEM careers than they were for their original STEM careers, that does not mean they are as highly motivated for their new careers as students are who have always been motivated to pursue a particular STEM career are for their long-term desired career paths. For example, a student who has always loved zoology and wants to be a veterinarian might be more strongly motivated for that career path compared to a student who feels moderately about zoology and decides to become a veterinarian instead of a doctor halfway through college.

The second possible explanation is that changing career plans may have *caused* students to report lower career motivation. That is, the process of changing career plans may harm students' motivation for their new career pursuits by interfering with students' opportunities to develop competence-related beliefs and intrinsic, attainment, and utility value. As was noted in the Introduction, interest develops over time via repeated engaging experiences in relevant contexts, followed by opportunities to connect in a meaningful personal way with a particular activity/career path (Hidi & Renninger, 2006). In turn, experiences where students make relevance connections are what can develop over time into more long-term perceptions of value like attainment and utility value (Priniski et al., 2018). Students who change to a new career path may have emerging interest but they may not have as many opportunities to experience relevant activities within it (e.g., job shadowing, internship activities) or as many chances to engage in a personal way with course material (e.g., by choosing paper topics that are relevant to their future careers) compared to students who have always had that career interest. This could interfere with the development of intrinsic, attainment, and utility value for one's new career path. Similarly, students who change career plans within college may have fewer experiences with hands-on successes relevant to a career path and fewer opportunities to develop their skills. Hands-on success activities are the strongest predictors of students' competence-related beliefs (Butz & Usher, 2015). Thus students who change career plans within STEM are likely not to have as many opportunities to develop such beliefs as do students who retain consistent career plans.

Our cross-sectional findings cannot shed light on which of these explanations is more likely. We hypothesize that both explanations are likely to be true, given that there is a relevant base of prior literature to support both arguments. This should be confirmed in subsequent research by using a longitudinal study. Longitudinal research also can examine whether the differences in career readiness and certainty that were observed here are likely to persist over time, once students have a chance to engage in more hands-on activities within their new career. It is possible that students who changed plans actually will be more motivated than those who did not change plans once in the workforce, because they are confident that they prefer this career over alternatives and have engaged in meaningful identity exploration (Perez et al., 2014).

Regardless of whether effects persist, findings of the present study suggest that students in college who change career plans within STEM fields can benefit from motivational supports for their chosen career paths at the time when they are enrolled in college, when their motivational beliefs for their careers are lower than their peers' beliefs. Instead of primarily trying to prevent students from leaving STEM careers, or trying to motivate students towards STEM versus non-STEM pursuits, educators and administrators should think more specifically about how to support students who change career plans within STEM. They might identify students who have changed plans within STEM (e.g., through regular advising meetings or surveys) and ensure these students (a) know what coursework and career preparation activities are required for success in their new career path, to help promote their competence-related beliefs (e.g., Butz & Usher, 2015) and (b) have opportunities to engage in career preparation experiences (e.g., job shadowing,

internships), to engage in sustained hands-on activities to build interest and value (e.g., Hidi & Renninger, 2006). More broadly, proactive structural supports for all students' career motivation can be helpful in ensuring that students feel optimally motivated for their chosen paths in STEM and are less likely to switch in the first place. To that end, educators or administrators might consider adapting existing interventions that have helped college students reflect on the utility value or attainment value of what they are learning in a *course* (e.g., Harackiewicz & Prinsiki, 2018; Perez et al., 2022) to focus on *career plans*, or by helping students perceive more belonging in their career paths, for example by providing mentoring opportunities (e.g., Dollinger et al., 2019) or more connections to STEM role models (see Gladstone & Cimpian, 2021, for review). They might also consider providing better infrastructure to support career development within the requirements for STEM majors, for example by providing courses that introduce students to various career pathways in a major, or by requiring an internship.

The recommendations for future research and career development supports just provided are all the more important given the large proportion of students who changed career plans within STEM fields in this study. Despite a sample of mostly first- and second-year students, more than 30% of students in our study reported having changed career plans when surveyed, and among fourth-year students, a *majority* reported having changed career plans within STEM fields. This study provides an initial estimate of the magnitude of within-STEM career shifts happening during college at a 4-year state research university, with findings suggesting that such shifts are likely to be equally if not more common than attrition out of STEM majors (i.e., up to about half of students are estimated to leave STEM fields during college; Chen, 2012). By revealing a large number of students who do not leave STEM yet risk lower career readiness, results underscore the consequences of ignoring students who change career plans within STEM fields in workforce education efforts and interventions.

The only result that did not follow the trends noted above was the finding that students who changed career plans within STEM fields reported *lower* perceptions of cost compared to students retaining consistent career plans. Our initial hypotheses predicted the opposite pattern, which is that perceptions of cost would be higher among students who changed plans (either because they had higher initial perceptions of cost or because the process of changing plans made students perceive more cost). Relative to the other motivational beliefs in situated expectancy-value theory, perceived cost has been studied much less and its developmental antecedents are less well-understood (Eccles & Wigfield, 2020; Flake et al., 2015; Wigfield et al., 2017). It is possible, conceptually, that changing career plans could help students reappraise the challenges of a new career in a more positive light, which made those challenges seem less costly than original career challenges (Rosenzweig et al., 2020). This would imply that one motivational *benefit* of changing career plans within STEM is perceiving that the new plan does not require one to "give up" as much to persist at it. However, more research is needed on cost and career planning to understand this particular effect most fully.

Student characteristic differences in career plan changes within STEM fields

We had only exploratory hypotheses about student-level characteristics that might shape students' experiences in a way that would affect the relations we observed in this study, and in general we found few effects suggesting that the trends just discussed differed as a function of any of the characteristics we examined. Results broadly speaking point to the robustness of key findings across different types of students.

The only major finding that does not fit that description was that women were more likely to change career plans within STEM fields than men were. This finding extends prior research showing the same gender difference in biomedical fields with a different sample (Rosenzweig et al., 2021a). Although women are not underrepresented in all STEM fields, they are underrepresented in many specific STEM sub-fields, particularly computer science and engineering. In thinking about how to address these issues, researchers often examine why women leave STEM altogether; however, there also seem to be systematic differences in how women negotiate career options *within* STEM fields that lead to them changing career plans more readily during college compared to men. These findings can be due to a variety of explanations, including (but not limited to) the idea that women may be more attuned to careers that afford communal opportunities due to their past socialization about this topic and change plans more readily to seek out careers that afford such opportunities and align with their values. To understand the precise mechanism of the effect observed requires more research, but this finding does point to the possibility that women might be more likely to have lower motivation for their chosen STEM career paths, either because they began college less motivated for their STEM field of choice due to past experiences and socialization that shaped their perception of career value affordances, or because their shift in plans may make them more likely to lose career motivation. Gendered within-STEM career shifts may explain some of the disproportionate patterns of participation as a function of gender in particular career areas within STEM, such as the life sciences versus

engineering fields. At the same time, within-STEM career shifting also can occur even in STEM sub-fields where women are not underrepresented overall (e.g., biological sciences), leading to women leaving certain types of specific career paths within those sub-fields at a higher rate than men (e.g., women may leave the career path of doctor more often than men, despite still pursuing some kind of biomedical career path; Rosenzweig et al., 2021a). Such patterns may shed new light on particular types of career shortages and whether there is equity in who pursues versus leaves specific career paths in different areas of STEM. These findings suggest that examining changes in career plans within STEM is an essential complement to work on STEM attrition, if educators or administrators want to ensure they provide equitable supports for students to succeed in STEM career paths.

Besides the gender difference in how many students reported changing plans, there were few other student-level factors that predicted students changing career plans besides year in school (which is not surprising, because this is a cross-sectional dataset and each year more students have an opportunity to change plans) and in some of the analyses, field of study. There were also few differences suggesting that the relation between changing career plans and STEM career motivation or certainty differed as a function of any student-level variables. As was discussed in the Introduction, much research suggests that these individual characteristics can impact students' experiences in and attitudes about STEM careers, which in turn can affect students' STEM career participation. However, our results suggest that the *processes* by which changes in career plans were associated with motivation may be somewhat robust across different types of student characteristics. This is a preliminary exploration of student characteristics, and future research should build on these findings (e.g., by examining the intersections of different student identities, by exploring different types of student characteristics, or by using methods that allow students to articulate how their identities shape their STEM career decision-making).

Limitations and conclusions

This study provides only a first examination of the experience of changing career plans within STEM fields, and future studies should build on the limitations of the present analysis. In particular, this analysis is cross-sectional and it is not possible to know whether having lower career motivation causes students to change plans within STEM fields, whether changing plans within STEM fields causes students to have lower career motivation, or both. We believe that theory supports a bidirectional relationship whereby students have lower motivation and career readiness both before and because of career transitions within STEM fields, but future research should examine this possibility empirically. Only by doing so can researchers understand the best avenues for intervention for these students. Similarly, a longitudinal data analysis examining motivation at the point when students change career plans across college, rather than cross-sectional data that does not address career plan change timing directly, is a better way to examine the processes by which students make career transitions.

Another limitation is that these findings were collected only at one institution. Institutions each have specific norms around how certain departments and fields of study operate (e.g., how much faculty care about equitable education, how much career preparation is required in different programs, how difficult or easy it is to obtain career training within different fields), and different types of supports for students in different years of their education (e.g., mentorship opportunities, social support, advising). Because of this, it is not possible to tease apart the role of student characteristics versus institutional norms fully in this study. We believe that given the breadth and scope of our sample and the variety of courses measured, findings are likely to be generalizable to other 4-year research-intensive U.S. universities with similar student demographics, but this would need to be confirmed at other institutions. Additionally, the same trends may not apply to all types of universities (e.g., liberal arts colleges, institutions in other countries, minority-serving institutions). Future research should explore these trends in more varied samples and explicitly measure the institutional norms and practices that might coincide with higher levels of career motivation and/or satisfaction. Going along with this aim, in more diverse samples it will be more possible to test a wider array of student-level variables that might be influential in particular learning contexts and institutions that are not the one where the present study was conducted (e.g., first-generation student status).

A final limitation is in our operationalization of some constructs. In terms of motivational beliefs, we used the major constructs of situated expectancy-value theory as the lens through which we examined career motivation, but there are many other potential motivational beliefs that could be important to consider with respect to STEM career participation (e.g., autonomy, competence, and relatedness needs, intrinsic motivation, or mindset, see Miele & Wentzel, 2016, for discussion). Future research can complement this study by examining additional constructs to complement this work. We also measured career plan changes using students' self-reports of whether they perceived themselves to have changed career plans. Although this approach helped capture a breadth of different career changes that were perceived

by students to represent a different future career, such questions are subjectively interpreted by students and we did not assess what types of different changes students made or whether all students defined career plan changes in the same ways. These avenues of investigation would provide additional nuance to the findings reported here and suggest specific types of career change pathways that might be most in need of additional supports.

Acknowledging the importance of these next steps, we nonetheless believe that findings of this study contribute several novel and critical contributions to the field of STEM career education research in higher education. Most critically, results point to a critical, underexamined group of students whose experiences in college could be improved to enhance STEM workforce participation and success: those who change career plans within STEM fields. There are large numbers of students who make these shifts and thus could benefit from more precise and targeted supports to ensure that they do not ultimately experience lower career readiness than their peers. Although much research has examined STEM career participation, it often focuses heavily on STEM attrition and thus neglects to consider experiences of students who remain in STEM fields of study but shift in their career plans. Second, the gender differences observed in the frequency of shifting career plans within STEM fields points to the importance of addressing this phenomenon to ensure that women are not disproportionately undermotivated or under-prepared for success in the STEM workforce. With more attention to the experiences of students who change career plans within STEM fields, alongside attention to STEM attrition, researchers can address STEM workforce shortages and inequities more completely and comprehensively.

Supplementary Information

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Additional file 1: Table S1. Items in Career Expectancy-Value Motivational Measure. **Table S2.** Results of Regressions Predicting Competence-Related Beliefs for Expected STEM Career Plans with Interactions by Gender and Racially Minoritized Status. **Table S3.** Results of Regressions Predicting Task Values for Expected STEM Career Plans with Interactions by Gender and Racially Minoritized Status. **Table S4.** Results of Regressions Predicting Career Satisfaction and Certainty with Interactions by Gender and Racially Minoritized Status. **Table S5.** Results of Regressions Predicting Competence-Related Beliefs for Expected STEM Career Plans with Interactions by Field of Study and Year in School. **Table S6.** Results of Regressions Predicting Task Values for Expected STEM Career Plans with Interactions by Field of Study and Year in School. **Table S7.** Results of Regressions Predicting Career Satisfaction and Certainty with Interactions by Field of Study and Year in School. **Figure S1.** Visual depiction of interactions between changing plans and year in college in predicting self-reported motivational beliefs. **Figure S2.** Visual depiction of interactions between changing plans and field of study in predicting self-reported career satisfaction and career certainty

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Author contributions
ER: conceptualization, data curation, formal analysis, investigation, methodology, project administration, resources, supervision, writing—original draft, writing—review and editing, visualization. XYC: project administration, data curation, formal analysis, investigation, methodology, validation, writing—review and editing. YS: data curation, formal analysis, validation. Writing—review and editing. AB, MB, MC, JD, AI, NW, JW, CW: conceptualization, investigation methodology, writing—review and editing. PPL: conceptualization, investigation, data curation methodology, supervision, writing—review and editing.

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Availability of data and materials
The data and code from this project are available upon request to the corresponding author; data are not publicly available at present due to other ongoing work with the broader project from which this data is drawn. All study questionnaires and materials analyzed in the present paper are listed in the manuscript and/or in the Additional file 1.

Declarations

Competing interests
The authors declare that they have no competing interests.

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