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RESEARCH ARTICLE

Stemming the Tide: An Expanded Focus on Employee Turnover

Evolution of professionals' careers upon graduation in STEM and occupational turnover over time: Patterns, diversity characteristics, career success, and self-employment

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Summary

While STEM occupational turnover constitutes a major concern for society given the importance of innovation and technology in today's global economy, it also represents an opportunity to achieve career sustainability for individuals. There is ample research on the reasons why students drop out from STEM education, but evidence on STEM professionals' career patterns and on correlates of occupational turnover after graduation is scarce. Drawing on the sustainable careers framework, the current study examines how STEM graduates' careers evolve over time, revealing diverse patterns of occupational turnover and the relationships of such career patterns with work diversity characteristics in terms of sex and ethnic minority status, career success, and self-employment. Using longitudinal data from 1512 STEM graduates over 10 years, results of an optimal matching analysis demonstrate six career patterns that can be distinguished into three continuity (STEM, part-STEM, non-STEM) and three change (hybrid, boomerang, dropout) sustainable career patterns. We find differences in sex, but not in ethnic minority status, across career patterns. Further, professionals who change from STEM occupations to non-STEM occupations show higher objective career success and are more often self-employed than those following a continuous STEM career pattern. Theoretical and practical implications of these findings are discussed.

KEYWORDS

career patterns, career success, minority, optimal matching analysis, self-employment, sex, STEM leaky pipeline, turnover

1 | INTRODUCTION

With the rising prevalence of innovation and technology in today's global economy, the Science, Technology, Engineering, and Mathematics (STEM) workforce plays a major role for the world's prosperity. However, a significant number of these workers are leaving STEM occupations—a phenomenon that has been referred to as the "STEM leaky pipeline" (Metcalf, 2010). Notably, in the United States, 74% of professionals with a STEM bachelor's degree are not employed in STEM occupations (U.S. Census Bureau, 2014). Such occupational turnover results in significant labor shortages of STEM professionals, especially in the government and private industry sectors, both in the

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United States (U.S. Bureau of Labor Statistics, 2015) and in the European Union (Shapiro et al., 2015). Nonetheless, despite the wide recognition of such a leaky pipeline challenge for societies and labor markets, and its increasing relevance to the field of organizational behavior, scholars' theoretical and empirical understanding of the evolution of STEM graduates' careers over time, as well as the indicators of why leaking occurs, and its implications for individuals, remains limited.

Drawing on the sustainable careers framework (De Vos et al., 2020; De Vos & Van der Heijden, 2015), we examine how careers of professionals who completed studies in a STEM major evolve over time starting with their first job upon graduation, as well as the factors associated with different career patterns. The sustainable careers framework is particularly relevant to address the challenge of the STEM leaky pipeline, given that it conceptualizes individuals' careers as a variety of possible sequences of positions that evolve or remain stable over time, and that it emphasizes a long-term focus on careers. Specifically, based on a systemic (i.e., multiple stakeholder) perspective, the concept of sustainable careers refers to "a sequence of career experiences reflected through a variety of patterns of continuity over time, thereby crossing several social spaces, characterized by individual agency, herewith providing meaning to the individual" (Van der Heijden & De Vos, 2015, p. 7). In the volatile and uncertain labor market characterizing our global economy, individuals are likely to engage in career transitions, thus aiming to maintain and/or enhance their career sustainability (Castro et al., 2020). In other words, according to this perspective, individuals' ongoing aim is to design a sustainable career in which they can work longer because it makes them happy, healthy, and successful (De Vos et al., 2020).

The purpose of the current study is threefold. First, we examine how STEM graduates' careers evolve over time in terms of continuity and change patterns as characterized by occupational turnover timing. Second, we consider how STEM graduates' diversity characteristics—namely, sex and ethnic minority status—may be associated with different career patterns. Third, we examine how career patterns may be related to objective career success in terms of hierarchical advancement and self-employment. Given the dynamic nature of STEM graduates' careers, we apply sequence analysis (e.g., Biemann & Datta, 2014) to derive patterns. We use a sample of 1512 professionals and a longitudinal design over 10 years starting from the first job upon graduation in a STEM major in college.

Our study offers several contributions to the recently introduced sustainable careers theoretical framework, and to the literature on STEM professionals. Overall, we integrate the three key dimensions of sustainable careers (De Vos et al., 2020)—time (career patterns and occupational turnover timing), context (industry, organization changes, hierarchical positions, and types of employment), and person (professionals' diversity characteristics)—to the STEM careers context. Specifically, in line with the notion that sustainable careers represent sequences of career experiences, we address recent calls for studies adopting a sustainable careers perspective using more solid longitudinal designs (De Vos et al., 2020). By doing so, we clarify how sustainable careers concretely unfold over multiple organizations in the STEM context, identifying the timeline of the STEM leaky pipeline and of potential re-entry to STEM, as well as the occupational turnover destinations categorized according to Holland's (1987) typology of Realistic, Investigative, Artistic, Social, Enterprising, and Conventional (RIASEC) occupations. Further, we address limitations in existing STEM scholarship, as most prior studies have taken a static approach to study STEM professionals' careers (e.g., Cardador & Hill, 2018; Fouad et al., 2020; Tremblay et al., 2002). While there is ample research on STEM pipeline leakage among STEM students (van den Hurk et al., 2019), scholarship on professionals' career patterns upon graduation in STEM is scarce. Limited evidence suggests the existence of diverse career patterns followed by STEM graduates, such as technical versus managerial career patterns (Bailyn & Lynch, 1983; Joseph et al., 2012; Tremblay et al., 2002) and career patterns in non-STEM occupations (Smith & White, 2019), but no systematic exploration exists. Further, the sustainable careers perspective on STEM careers is still nascent. Recently, in a qualitative study, Castro et al. (2020) explored the transition of 28 academic researchers in the STEM field into sustainable careers in data science, offering initial evidence for a sustainable careers perspective on STEM careers. In the current study, we provide a more comprehensive and systematic investigation of career patterns of STEM graduates over a 10-year period, thus expanding current knowledge on how their careers evolve over time.

Second, we contribute to expanding the nascent diversity perspective within the sustainable careers framework (see, for instance, Baldridge & Kulkarni, 2017, on workers with a hearing loss disability), thus addressing recent calls for studies examining career sustainability of employees with a different set of sociodemographic characteristics within a diversity perspective (Castro et al., 2020; De Vos et al., 2020). Specifically, our study seeks to further understand whether and how professionals' diversity characteristics (i.e., sex and ethnic minority status) may be associated with sustainable career patterns in the STEM context over time. By doing so, we also address limitations in existing STEM scholarship, as few studies have examined the role of diversity characteristics in the career patterns of STEM graduates. Notably, while previous literature has mostly focused on how gender and racial minority status either affect individuals' major of interest or study attrition (e.g., Hall et al., 2017; Saw et al., 2018; van den Hurk et al., 2019) or the occurrence of their occupational turnover (e.g., Cech & Blair-Loy, 2019; Jelks & Crain, 2020; Makarem & Wang, 2020), our study provides clarification as to which career patterns members of minorities in STEM may follow.

Third, we contribute to the sustainable careers framework by exploring whether and how different sustainable career patterns may be related to career success in terms of career advancement (i.e., reaching higher hierarchical positions) and to self-employment. Further, by using a 10-year longitudinal design, we empirically investigate the theoretical proposition that career success (i.e., reaching higher hierarchical positions) may reflect sustainable careers in a long-term perspective only, as career advancement may be accompanied by greater strain in the short term (De Vos et al., 2020). Expanding burgeoning work incorporating objective career success as an indicator of sustainable careers (Straub et al., 2020), and prior work focusing mostly on organizational mobility outcomes (e.g., Li et al., 2021), our study is the first to link sustainable occupational career patterns to objective career success and self-employment, hence increasing our knowledge of occupational mobility outcomes.

2 | THEORETICAL BACKGROUND AND HYPOTHESIS DEVELOPMENT

2.1 | STEM careers and the sustainable careers framework

In line with prior work (Siekmann & Korbel, 2016; Xue & Larson, 2015), we define STEM occupations as including not only those in science, technology, engineering, and mathematics but also those in architecture, information technology, and pharmacy. An important limitation of prior literature, however, is that managerial, sales, and teaching occupations that require STEM knowledge are usually defined as either STEM or non-STEM occupations. In contrast, we use the term "part-STEM occupations" to refer to those occupations that require a STEM degree but whose key tasks are not STEM-specific (e.g., STEM-related sales or teaching).

Sustainable careers (De Vos et al., 2020; De Vos & Van der Heijden, 2015) represent a useful framework for exploring how STEM graduates' careers evolve over time, as well as the extent to which different career patterns may reflect occupational turnover timing and be associated with professionals' diversity characteristics and career outcomes. The first key tenet of this framework is that sustainable careers are dynamic and evolve over time. Specifically, as explained by De Vos et al. (2020, p. 2), sustainable careers represent:

> a cyclical, self-regulatory process … in which (positive and negative) experiences and events, and how these are perceived and interpreted by the individual and the different parties involved, provide opportunities for "dynamic learning." The latter, in turn, enables individuals to adapt to and to influence their environment, as their career evolves, by sharpening their understanding of themselves, their personal and organizational context, and the broader labor market. Ultimately, this allows them to continuously refine perceptions regarding their person–career fit over time.

As such, as STEM graduates progress in their careers, various events and positive or negative experiences are likely to affect their perceptions of fit with their careers, thus resulting in different career patterns characterized by either continuity in STEM occupations and/or transitions to different occupations or organizations. In sum, professionals' increased understanding of themselves, their occupations, and their organizations over time is likely to affect both the timing and the destinations of their turnover decisions.

The second key tenet of this framework is that dynamic processes impacting career sustainability are likely to differ across types of worker groups, as individuals' sociodemographic characteristics may reflect a unique context in which their careers evolve (De Vos et al., 2020). Indeed, the sustainable careers framework emphasizes the role of context, such as society's gendered norms (Straub et al., 2020), in shaping individuals' career experiences. Such cultural norms may also result in inequalities at work, which have been suggested to represent one of the major factors challenging career sustainability in the 21st century (McDonald & Hite, 2018). Concretely, such inequalities may imply more limited opportunities for some workers, making them more vulnerable in their career development (Urbanaviciute et al., 2019). Such vulnerability may imply a lack of freedom in making career choices (e.g., fewer options) or having access to a more limited set of career development resources. In sum, as not all STEM professionals may benefit from the same career opportunities, the proportion of some types of professionals may be higher among certain career patterns compared with others.

The third key tenet of the sustainable careers framework is its emphasis on workers' objective career success (De Vos et al., 2020; Straub et al., 2020) as a core indicator of career sustainability. Specifically, the sustainable careers perspective emphasizes long-term career success (i.e., career advancement), given that short-term intense success may lead to burnout, hence putting the career's long-term success at risk and resulting in career unsustainability (Van der Heijden & De Vos, 2015). Furthermore, the sustainable careers framework recognizes self-employment as a particular category of work that may contribute to career longevity, potentially explaining the rise of such a work arrangement in the current economy (De Vos et al., 2020). Accordingly, we argue that long-term objective career success and self-employment represent important indicators of sustainable careers for STEM professionals.

2.2 | Careers as a dynamic phenomenon

The sustainable careers framework highlights the dynamic nature of careers (Van der Heijden & De Vos, 2015), emphasizing the existence of different patterns of continuity in terms of a sequence of different career experiences. Such experiences result from a cycle of events and personal decisions, illustrating the interplay between agency and context over time (De Vos et al., 2020), and determine professionals' career changes between different occupations and organizations. While prior work has offered supportive evidence for career sustainability achievement within a single organization (e.g., Straub et al., 2020), in the current study, we anticipate the existence of different occupational career patterns, revealing various turnover timings and destinations over time across organizations. Specifically, the sustainable careers framework highlights the occurrence of two main career movements over time: career continuity and career change. To achieve career sustainability in terms of mutually beneficial consequences for both the person (i.e., being happy, healthy, and successful) and their context (De Vos et al., 2020), individuals consistently engage in either career change or continuity. Indeed, both movements reflect accumulated work and career experiences, providing workers with opportunities for dynamic learning, and allowing them, in turn, to influence their environment and/or adapt to their environment (De Vos et al., 2020).

A key challenge of dynamic careers (e.g., turnover in STEM careers) lies in identifying individuals' turnover destinations. According to Holland's (1987) RIASEC typology of occupational interests, individuals choose occupations that fit with their interests, occupations being also classified using this typology. Table 1 defines and provides examples of occupations for each of the six RIASEC occupational interests identified by Holland (1987). We suggest that the RIASEC typology allows to explore non-STEM occupations as turnover destinations, as individuals may perceive their careers as being more sustainable if their current job fits their occupational interests better. As recent work indicates that investigative and realistic interests are those that are the most closely related to a general interest in STEM (Babarović et al., 2019), it is possible that individuals pursuing more sustainable careers in non-STEM fields may possess other occupational interests (i.e., artistic, conventional, enterprising, or social). Put differently, turnover from STEM occupations may promote greater career sustainability due to a greater fit with one's occupational interests.

2.2.1 | Sustainable career patterns characterized by continuity over time

A first set of career patterns may involve continuity and stability over time, as STEM graduates might not be willing to engage in career transitions when they are satisfied with their careers. Such a career pattern might be characterized by continuity in a STEM, part-STEM, or non-STEM occupation. First, a continuity pattern may reflect the traditional expectation that STEM graduates would start a career in the STEM workforce and work in STEM occupations for their entire career. Prior evidence supports the existence of such a pattern, such as Bailyn and Lynch's (1983) qualitative study among U.S. engineers who graduated in the 1950s, which reported that about three quarters were still staff engineers 20 years after graduation. More recently, relying on a U.S. panel study, Joseph et al. (2012) found that most individuals who graduated in IT-related majors followed a career path within the IT field.

A second continuity pattern may be followed by individuals who start working in part-STEM occupations (i.e., requiring a STEM degree but whose key tasks are not STEM-specific, such as STEM-related sales or consulting) after graduation and continue to do so. Prior work has mostly focused on the distinction between individuals who work in STEM occupations versus those who drop out of STEM

TABLE 1 Summary of Holland's (1987) RIASEC typology

Occupational interest	Acronym	Definition	Examples of occupations
Realistic	R	Preference for working with things rather than people; working with hands on, practical problems.	• Auto mechanic • Computer technician • Architect • Medical technician
Investigative	I	Preference for working with ideas rather than people/things; searching for facts, figuring out problems mentally.	• Statistician • Researcher • Industrial engineer • Business analyst
Artistic	A	Preference for working with ideas rather than people/things; working with forms, designs, and patterns.	• Brand manager • Visual manager • Graphic designer • Actor
Social	S	Preference for working with people rather than things; working with and helping or teaching others.	• Coach • Registered nurse • Teacher
Enterprising	E	Preference for working with people and ideas (projects) rather than things; starting and carrying out projects, often business-related, by taking risks.	• Sales representative • Banker • Manager • Politician
Conventional	C	Preference for working with papers and numbers; working with data and details, following procedures.	• Accountant • Financial analyst • Travel agent • Insurance specialist

Note: Definitions and examples have been taken from O'NET (2021).

occupations, thus disregarding individuals who may follow a continuous career pattern in part-STEM occupations. However, supporting the existence of such a pattern, a recent longitudinal study among U.K. STEM graduates showed that many STEM graduates start to work and remain in "associate professional and technical" occupations (Smith & White, 2019).

A third continuity pattern may illustrate the case of STEM graduates who left STEM occupations directly upon graduation to work in non-STEM occupations (i.e., occupations that do not require a STEM degree), thus immediately starting their careers in a non-STEM field and pursuing them over time. In support of such a non-STEM pattern, prior evidence showed that 54% of STEM graduates did not work in STEM jobs (Smith & White, 2019). We argue that changes to non-STEM occupations before even starting one's first job upon graduation may enable a more sustainable career by increasing STEM graduates' fit with their occupational interests. Providing preliminary empirical support for this proposition, Kim and Beier (2020) showed that greater major-occupational fit during college was positively related to starting a STEM job upon graduation.

2.2.2 | Sustainable career patterns characterized by change over time

A second set of career patterns is likely to involve change over time, as STEM graduates might be willing to engage in career transitions because they are unsatisfied with their current careers. Such transitions make it possible to solve career tensions and achieve more sustainable careers in a new organization or with a new job position within the organization (Castro et al., 2020). Concretely, such changes may differ with regard to both time and destination. Indeed, change (i.e., turnover) may take place earlier or later in professionals' careers, and it may only happen once to one destination or involve several changes to different destinations. Such destinations may involve changing to occupations relatively close to STEM (i.e., part-STEM occupations with an enterprising or a social interest, such as STEM-specific consulting, management, sales, and teaching) or to non-STEM occupations associated with conventional or artistic interests.

Accordingly, first, a moderate change pattern may involve turnover from STEM to part-STEM occupations, with professionals retaining their focus on STEM skills and knowledge while developing others. Such a career pattern would be in line with the "hybrid" career path proposed in earlier studies (i.e., combining technical and managerial paths; Cardador & Hill, 2018). Indeed, prior work found that engineers who left the standard engineering career path did so mostly to shift away from specialized technical projects and towards more complex responsibilities (i.e., part-STEM occupations; Bailyn & Lynch, 1983) and that movement out of STEM jobs was mostly into managerial roles (Smith & White, 2019).

A second change pattern may result in early or late turnover to non-STEM occupations (i.e., dropping out from STEM careers altogether). Prior work supporting the existence of such a pattern showed that some STEM graduates first explored STEM jobs early in their work histories before changing to non-STEM professional and managerial jobs (Joseph et al., 2012; Smith & White, 2019). Further, as Kim and Beier (2020) showed that STEM graduates experienced increasing job fit in terms of their occupational interests over time, it is possible that a late turnover to non-STEM occupations may foster a more sustainable career by increasing STEM graduates' fit with their occupational interests.

Finally, a third change pattern may involve early or late boomerang career moves (Shipp et al., 2014), reflecting the case of those professionals who quit STEM occupations to work in non-STEM occupations but later return to STEM occupations. In line with prior research reporting that, compared with workers who do not return, boomerang workers may leave earlier in their tenure before coming back in the future (Shipp et al., 2014), we expect a similar effect in the STEM context. Furthermore, we also expect that compared with the STEM graduates dropping out from STEM altogether, those following a boomerang trajectory may possess less additional occupational interests than the traditional STEM-related interests (i.e., realistic and investigative), which may explain why they would ultimately come back to a STEM career. While we could not find prior studies supporting the existence of a boomerang pattern in STEM careers, earlier work suggests that some STEM graduates enter the STEM field several years after finishing their degree (Smith & White, 2019). Considering these various possible patterns, we thus propose the following research question:

> **Research Question 1.** What are the general patterns of career continuity and change in professionals with a STEM degree?

2.3 | Career patterns and professionals' diversity characteristics

Inequalities represent one of the major factors challenging career sustainability in the 21st century (McDonald & Hite, 2018). Specifically, the sustainable careers framework emphasizes the role of individuals' sociodemographic characteristics in shaping a unique context in which their careers evolve (De Vos et al., 2020). In the context of STEM careers, the two major sociodemographic characteristics of sex and ethnic minority status may affect individuals' career experiences in terms of facing additional obstacles to pursuing their desired career. Such disadvantages or vulnerability (Urbanaviciute et al., 2019) may in turn affect these professionals' turnover and pursuit of (non-)STEM careers.

2.3.1 | Sex

Women remain underrepresented in the STEM workforce in the United States (i.e., 27%; U.S. Census Bureau, 2021) and in Europe (i.e., 41%; Eurostat, 2021). Prior empirical evidence reported the existence of gendered career patterns among industry engineers in the United States (Cardador, 2017) and found that women in STEM occupations were significantly more likely to leave this occupational field, especially early in their careers, than women in other professions (Glass et al., 2013). Moreover, women who graduated from STEM majors were less likely to have jobs related to their major than men 10 years after graduation (Xu, 2013). This may be explained by findings suggesting that female STEM students (Leaper & Starr, 2019) and female STEM workers (Makarem & Wang, 2020) may be more likely to face gender bias and hostile male-dominated work environments. Taken together, prior evidence seems to suggest that female workers may have a harder time than male workers entering and persisting in STEM occupations after graduation. Thus, as females might be more likely to anticipate, or actually experience, an unsustainable career in STEM occupations than males, they might also be more likely to transition to occupations out of STEM in which they expect to experience more sustainable careers. Hence, they may be less likely to follow a traditional, lifelong STEM career pattern (i.e., characterized by continuously working in STEM occupations after graduation in a STEM major without further transitions). We thus hypothesize that:

> **Hypothesis 1.** Female professionals will be more likely to follow career patterns characterized by (a) never working in STEM occupations and (b) dropping out of STEM occupations than the traditional STEM career pattern.

2.3.2 | Ethnic minority status

Ethnic minorities are underrepresented in the STEM workforce. In the United States, African and Hispanic Americans, who characterize 11% and 16% of the workforce, represent only 9% and 7% of all STEM workers, respectively (Pew Research Center, 2018). In Europe, it is individuals from an immigration background who represent ethnic minorities. For instance, prior work showed that despite being dual citizens and holding Swiss degrees, children of first-generation immigrant parents in Switzerland needed to send 30% more applications than children of native Swiss parents to be called back for an apprenticeship interview, which may be explained by the non-Swiss-sounding names on their resumes (Zschirnt & Fibbi, 2019/2020). Applied to the STEM context, in Germany, individuals with a migration background (26% of the workforce; Destatis, 2020a) represent only 20% of all STEM workers (Anger et al., 2020). Prior work has suggested potential reasons explaining such underrepresentation of ethnic minorities in STEM, namely stereotypes (Eaton et al., 2020) and workplace discrimination (e.g., Hall et al., 2017; Saw et al., 2018), as well as cultural isolation, a low sense of belonging, and self-doubt (Byars-Winston, 2014). Therefore, not entering STEM occupations or leaving STEM occupations might be a career choice aiming to preserve or enhance career sustainability for professionals from an ethnic minority background. We thus hypothesize that:

> **Hypothesis 2.** Ethnic minority professionals will be more likely to follow career patterns characterized by (a) never working in STEM occupations and (b) dropping out of STEM occupations than the traditional STEM career pattern.

2.4 | Career patterns, career success, and self-employment

According to the sustainable careers framework (De Vos et al., 2020), career sustainability over time depends on individuals' perceptions of being successful at work, in terms of an adequate and dynamic fit between their values and career goals (person-career fit). Such a fit results from a cyclical process in which positive and negative experiences at work are interpreted by individuals and provide them with opportunities for dynamic learning. Specifically, workers improve their understanding of themselves, and of their organizational and labor market contexts, allowing them to refine their person-career fit over time to achieve more sustainable careers. In the STEM context, negative experiences of a misfit are likely to take place between individuals' (prospective) career in STEM and their career expectations in terms of career advancement and/or innovation-seeking opportunities. As STEM graduates achieve a greater understanding of themselves (i.e., having a strong need for career advancement or to contribute to innovation) through a dynamic learning process, they may start to look for better opportunities and engage in deeper exploration of their labor market context to ultimately achieve greater career sustainability.

2.4.1 | Career success

Career advancement, or reaching higher hierarchical positions, is a specific form of career success (Seibert et al., 2001), which, in its long-term form, has been argued to represent a core indicator of career sustainability (De Vos et al., 2020; Straub et al., 2020). As STEM graduates perceiving a misfit between their careers and advancement expectations explore the labor market, they may realize that the STEM field rapidly evolves due to the fast-paced development of new technologies. Indeed, STEM graduates' skills and knowledge become more rapidly outdated compared with those of non-STEM graduates (Deming & Noray, 2018), which may lead to lower employability, and thus lower career sustainability (De Vos et al., 2020). Accordingly, a continuous career pattern in part-STEM occupations (e.g., consulting, management, sales), or dropping out of STEM occupations, might offer better career advancement opportunities. This suggestion is supported by prior research highlighting an exit from STEM occupations after the first decade of STEM graduates' careers for non-STEM occupations (Deming & Noray, 2018) or for managerial occupations that promise better long-term career success in terms of hierarchical position (Bailyn & Lynch, 1983). Accordingly, career patterns characterized by either part-STEM occupations or dropout from STEM occupations may allow STEM graduates who experience a person-career misfit in terms of career advancement expectations to solve such a career tension through transitioning to more rewarding occupations (Castro et al., 2020), hence allowing for more sustainable careers. Thus, we hypothesize:

> **Hypothesis 3.** Professionals following career patterns characterized by (a) part-STEM occupations and (b) dropping out from STEM occupations will have higher objective career success than those following the traditional STEM career pattern.

2.4.2 | Self-employment

As self-employment has been identified as an alternative work arrangement that may allow workers to attain more sustainable careers (De Vos et al., 2020), self-employment may represent a path towards greater career sustainability for professionals following career patterns characterized by working in non-STEM occupations (either continuously or after dropping out), compared with those following a traditional STEM career pattern. Indeed, STEM graduates who dropped out of STEM occupations or who never worked in STEM occupations may be more likely to interpret the self-employment work arrangement as a positive experience leading to greater person-career fit because it may better meet their expectations for innovation-seeking opportunities. While a non-STEM career context may provide less opportunities for innovation than a STEM context that allows being involved in actively developing or engineering the latest technological innovation, transitioning to self-employment may be motivated by the prospect of greater innovation opportunities (hence greater career sustainability) for STEM graduates who never worked in STEM occupations or who dropped out from STEM occupations—compared with those who follow a traditional STEM career pattern. Indeed, prior work has shown that individuals experiencing an educational mismatch (i.e., who were trained as scientists and engineers but whose jobs did not utilize the skills acquired during education) were more likely to transition into entrepreneurship (Stenard & Sauermann, 2016). Further, working in an occupation unrelated to one's highest degree was found to be associated with higher job satisfaction among self-employed compared with employed STEM graduates (Bender & Roche, 2013). Thus, we hypothesize that:

> **Hypothesis 4.** Professionals following career patterns characterized by (a) never working in STEM occupations and (b) dropping out from STEM occupations will have higher levels of self-employment than those following the traditional STEM career pattern.

3 | METHOD

3.1 | The Xing database

We derived career data of professionals who graduated in STEM from Xing, the leading social network for German-speaking business professionals (similar to, e.g., the LinkedIn platform) with more than 18 million profiles mainly in Germany, Austria, and Switzerland (Xing, 2020). Public profiles from this and similar platforms have been used in career research (e.g., Flöthmann & Hoberg, 2017), as they provide a reliable and representative data source. Users of these platforms keep their profiles up to date for representation purposes in their professional environment and per their agreement with the social network's terms to provide correct and up-to-date information. Specifically, profiles consist of a full curriculum vitae, including information on users' occupation (e.g., senior software engineer) with each position's specific dates and employer name, educational background (e.g., a master's degree in computer science with the university's name), skills (e.g., big data analytics), languages (e.g., basic language skills in Italian), and personal interests.

3.2 | Sample and procedure

From this database, we searched for individuals who had completed a STEM degree (Destatis, 2020b) from one of the 24 technical universities in Germany (19 universities), Austria (3 universities), and Switzerland (2 universities). We first randomly selected 200 individuals per university who indicated having earned their degree there, thus obtaining a total of 4800 individuals. We then extracted their online information using the Python software's (Van Rossum & Drake, 1995) libraries *requests* and *BeautifulSoup*. Of those randomly selected, we excluded 2407 individuals who had not graduated in STEM but in other majors (e.g., business administration, psychology). We also excluded 62 individuals whose information regarding their occupational position was missing for more than 1 year across the examined career years, as well as 25 individuals whose study major and university degree information was missing or unclear.

Individuals' occupational career sequences began in the month they started their job upon graduation. To obtain sequences of comparable length (Dlouhy & Biemann, 2015), we set career length to 120 months (i.e., 10 years); that is, we examined the first 10 years in individuals' careers upon graduation with a 1-month interval, irrespective of their actual career tenure.[1] Accordingly, we excluded 794 individuals whose career since graduation had a duration of less than 10 years. The final sample for this study is thus 1512. Individuals in our sample had an average career duration of 20.7 years ($SD = 6.84$) and had been members of the Xing social network for an average of 10.1 years ($SD = 3.79$). Women made up 16.7%[2] of our sample. Regarding country of residence, 79.3% lived in Germany, 11.2% in Switzerland, 8.3% in Austria, and 1.2% in another country. Consistent with the mainly German context (Destatis, 2020b), 3.8% of our sample held a Bachelor's degree as their highest degree, 66.7% a Master's degree, and 29.5% a doctoral degree. Finally, 4.6% additionally held an MBA degree.

3.3 | Measures

3.3.1 | Career characteristics

Occupation

The Xing database provides information on users' occupations using the prompt "job title" with required open answers (e.g., "senior software engineer") and the prompt "job details" with optional open answers (e.g., "design software using collected data" or "systems analysis and bug reports"). Start and end dates (by month) are provided. For this study, two native German-speaking research assistants independently coded a total of 8678 different job titles. Coding was *1* for STEM occupations (45.1% of occupations coded; i.e., science, technology, engineering, and mathematics occupations), *2* for part-STEM occupations that usually require a STEM degree but whose key tasks are not STEM-specific (33.8% of occupations coded; i.e., STEM-specific consulting, management, sales, and teaching occupations), *3* for non-STEM occupations that do not require a STEM degree, which were further subcoded according to Holland's (1987) RIASEC typology (16.5% of occupations coded; see Table 1), and *4* for holding a non-paid primary activity (4.6% of occupations coded; i.e., parental leave or care, career break, volunteering activities, and full-time studies). The number of occupations coded by both raters that is required to calculate Cohen's κ was determined to be 157 with the *kappaSize* package for R (Rotondi & Donner, 2012). Overall agreement between coders was supported by a Cohen's κ of .76, indicating substantial agreement above the threshold of .70 (Fleiss & Cohen, 1973).

Career start

Career start was the year individuals started their first job upon graduation.

Industry

The prompt "industry" that was required for each job position provided a choice from various fixed answers, such as "IT and telecommunication" or "financial and legal services." Additionally, in line with prior work (Adams & Kirchmaier, 2016), we classified an industry as a STEM industry (*1* = yes, *0* = no) when more than 50% of people in these industries usually held a STEM degree, based mainly on data from the German Economic Institute (Anger et al., 2020). We relied on the German industry given that most (79.3%) of our sample was from that country. For example, the IT and telecommunication industry was classified as STEM, while the financial and legal services industry was not. Table 2 lists all the industries present in our sample, indicating whether an industry would be considered a STEM industry and what percentage of job positions in our sample was in this industry (58.3% of job positions in our sample were in STEM industries, while 41.7% were not).

TABLE 2 Industry classifications of occupations

Industry	STEM industry	% job positions in study
1. Academia and education	No	5.3%
2. Architecture and construction	Yes	6.8%
3. Art, culture, and sports	No	1.2%
4. Consulting	No	5.5%
5. Consumer goods and trade	No	13.5%
6. Energy and environment	Yes	5.1%
7. Engineering	Yes	16.2%
8. Financial and legal services	No	2.6%
9. IT and telecommunication	Yes	15.2%
10. Marketing, PR, and design	No	1.2%
11. Other	No	8.8%
12. Pharmaceutical and medical	Yes	5.0%
13. Public and non-profit	No	2.8%
14. Social work, care, and health	No	1.2%
15. Tourism and gastronomy	No	1.2%
16. Vehicle construction	Yes	10.0%

Occupation changes

We derived the number of occupation changes between STEM, part-STEM, non-STEM, and non-paid occupations in the first 10 years of individuals' careers.

Organization changes

The Xing database provides information on users' organizations with required open answers (e.g., "SAP SE"). We were thus able to derive the number of organization changes in the first 10 years of individuals' careers.

3.3.2 | Professionals' diversity characteristics

Sex

While the Xing database does not provide direct information on a person's sex, the person's name and an optional photo are available. Sex was obtained using the application programming interface NamSor (2020), which infers sex based on a person's name with an accuracy of 98.6% (Santamaría & Mihaljević, 2018). *NamSor* recognizes the country of origin of names in any alphabet or language, thus allowing it to infer sex. For instance, "Artur Schmidt" would be classified as male. A likelihood value for correctness of classification is given. We checked individuals' profile photos for cases with low values (i.e., lower than 15.0%), but no adjustment was necessary, as the photos confirmed *NamSor*'s attribution. Sex was coded as *0* for female and *1* for male.

Ethnic minority status

In contrast to the United States, which differentiates Americans' immigration country of origin in terms of race and ethnicity, because we relied on a European dataset, a measure of race or ethnicity as defined in the U.S. context was not meaningful as an indicator of minority status. In Germany, Switzerland, and Austria, ethnic minority status instead relates to immigration status from another country of origin and/or a different native language than the official one in the focal country (Volodina et al., 2020). Similarly as with sex, we determined *foreign country of origin* using the NamSor (2020) software, based on a person's name as NamSor has processed more than 6 billion names. For instance, "Artur Schmidt's" country of origin would be inferred as Germany (coded as *0*), whereas "Artur Aktas's" would be Turkey. The latter would thus result in a label of ethnic minority status (coded as *1*). We randomly checked NamSor's determination of foreign country of origin, but no adjustment was necessary. Further, the Xing database provides information about *non-native speaker status* through an optional indication of language skills (possible answers: native, fluent, good, basic, none). For Germany and Austria, ethnic minority status was coded as *1* for non-native German speakers, with German being the official language; because Switzerland has four official languages, individuals in this country were considered to have an ethnic minority status when their native language was not German, French, Italian, or Romansh.

3.3.3 | Career success and self-employment

Career success

In line with prior literature (Seibert et al., 2001), we considered individuals' hierarchical level (i.e., career advancement) to reflect their objective career success. Specifically, we measured participants' hierarchical level in employed labor 10 years after starting their career (i.e., in month 120 of their career), based on answers to the prompts "job title" and "job details" in Xing. Hierarchical level was coded as *1* for non-managerial positions, *2* for managerial positions, *3* for director or vice president positions, and *4* for chief functional officer, president, or partner positions. For instance, "senior software engineer" would be coded as *1*. Overall agreement between the coders was supported by a Cohen's κ of .95, representing an extremely high level of agreement (Fleiss & Cohen, 1973).

Self-employment

We considered individuals' self-employment status 10 years after starting their career (i.e., in month 120 of their career). The prompt "type of employment" in Xing required a choice from various fixed answers for each job position, such as "full-time employed," "intern," or "self-employed." Self-employment was coded as *1* if individuals were self-employed and as *0* otherwise.

3.4 | Analytical strategy

We used optimal matching analysis (e.g., Biemann & Datta, 2014) to calculate the dissimilarities in individuals' occupational careers and to derive career patterns. Given that we had monthly information on individuals' occupations, we created occupational career sequences by appending each monthly occupation status to the preceding one. When individuals' monthly occupation information was missing, a missing value category *X* was appended (Biemann & Datta, 2014). As an example, the occupational career sequence of an individual who worked in a STEM occupation for 6 months (coded as *1*) and then worked in a non-STEM occupation (*3*) for another 6 months would be coded as *1-1-1-1-1-1-3-3-3-3-3-3*. With optimal matching analysis, the dissimilarity between this sequence and another sequence (e.g., *1-1-1-1-1-1-1-1-1-1-1-1* for an individual who worked in a STEM occupation for 12 months) can be computed by counting the number of operations that are necessary to transform one sequence into another.

Possible operations for this purpose are deleting an element, inserting an element, and substituting an element for another element. These operations have specific costs and mirror the extent to which sequences have to be altered. Higher costs arise whenever a higher number of operations is necessary to align two sequences, such that higher costs indicate greater dissimilarity between the two sequences. Specifically, insertion and deletion usually have costs of 1, while substitutions need to be based on a theoretical rationale and involve customized costs (Biemann & Datta, 2014). In the current study, we customized substitution costs by setting the substitution costs of the STEM versus part-STEM occupations (and vice versa) to 0.5. Indeed, while a distinction between these occupational positions is substantive, these occupations are still similar to each other, and our overarching aim is to examine turnover out of STEM (or part-STEM) occupations. Substitution costs between all other occupational positions (e.g., *1* vs. *3*, or *1* vs. the missing category *X*) were set to 2, the standard cost setting (Dlouhy & Biemann, 2015).

Applying this reasoning to our two example sequences (*1-1-1-1-1-1-3-3-3-3-3-3* and *1-1-1-1-1-1-1-1-1-1-1-1*) that differ in their seventh to twelfth elements, several operations are required to align these two sequences (i.e., replacing the *3*s in the first sequence with *1*s). This results in total costs, or a dissimilarity, of 12: based on either six substitution operations with a cost of 2 each or 6 deletion and 6 insertion operations with a cost of 1 each. Applied to another set of two sequences, such as *1-1-1-1-1-1-2-2-2-2-2-2* and *1-1-1-1-1-1-1-1-1-1-1-1*, the dissimilarity would be 3, given that we set substitution costs of part-STEM (coded as *2*) with STEM occupations (coded as *1*) to 0.5. In sum, there are various ways to align sequences, and the optimal matching algorithm identifies the one that is the least costly (i.e., optimal).

After conducting an optimal matching analysis for all occupational career sequences in our sample, we obtained a symmetric 1512 × 1512 dissimilarity matrix. Following prior recommendations (Biemann & Datta, 2014; Dlouhy & Biemann, 2015), we then clustered sequences based on dissimilarity using the Ward clustering algorithm. The *TraMineR* package for R (Gabadinho et al., 2011) was used for the analyses. Finally, we tested our hypotheses using variance analyses with contrasts between clusters.

4 | RESULTS

4.1 | Career patterns

Based on recommended measures of the quality of a cluster solution (i.e., Point Biserial Correlation, Hubert's Gamma, Hubert's C, Average Silhouette Width; Studer, 2013), the solutions with six, seven, eight, and nine clusters were equally preferable. In solutions with more than six clusters, some clusters were very small (<5% of sample); hence, we retained six clusters. Each cluster contains individuals with similar occupational career patterns, thereby forming six different career patterns. Cluster tempograms are displayed in Figure 1. The x-axes represent months, while the y-axes represent the percentage of individuals who worked in a specific occupation in a given month. Clusters were derived solely from occupations coded as *STEM*, *part-STEM*, *non-STEM*, and *non-paid*. Descriptive career characteristics of individuals (career start, industries and occupations worked in) by career pattern are displayed in Table 3. Mean values for our variables of interest (occupation and organization changes, professionals' diversity characteristics, career success, and self-employment) by career pattern are displayed in Table 4.

4.1.1 | Pattern 1: STEM career

This career pattern is followed by individuals who started working in a STEM occupation after graduation and mostly continued to do so over time ($n = 531$; see Figure 1). If they changed occupations, they mostly did so from STEM occupations to part-STEM occupations after the first 6 years of their career (see Figure 1). Individuals following this pattern mostly worked in STEM industries (see Table 3) and had on average 0.45 occupation changes and 1.94 organization changes in the first 10 years of their career (see Table 4).

4.1.2 | Pattern 2: Part-STEM career

This career pattern is followed by individuals who started working in a part-STEM occupation after graduation and mostly continued to do so over time ($n = 338$). About 15% also changed from part-STEM occupations to STEM occupations, mostly after the first 5 years of their career. Individuals following this pattern mostly worked in STEM

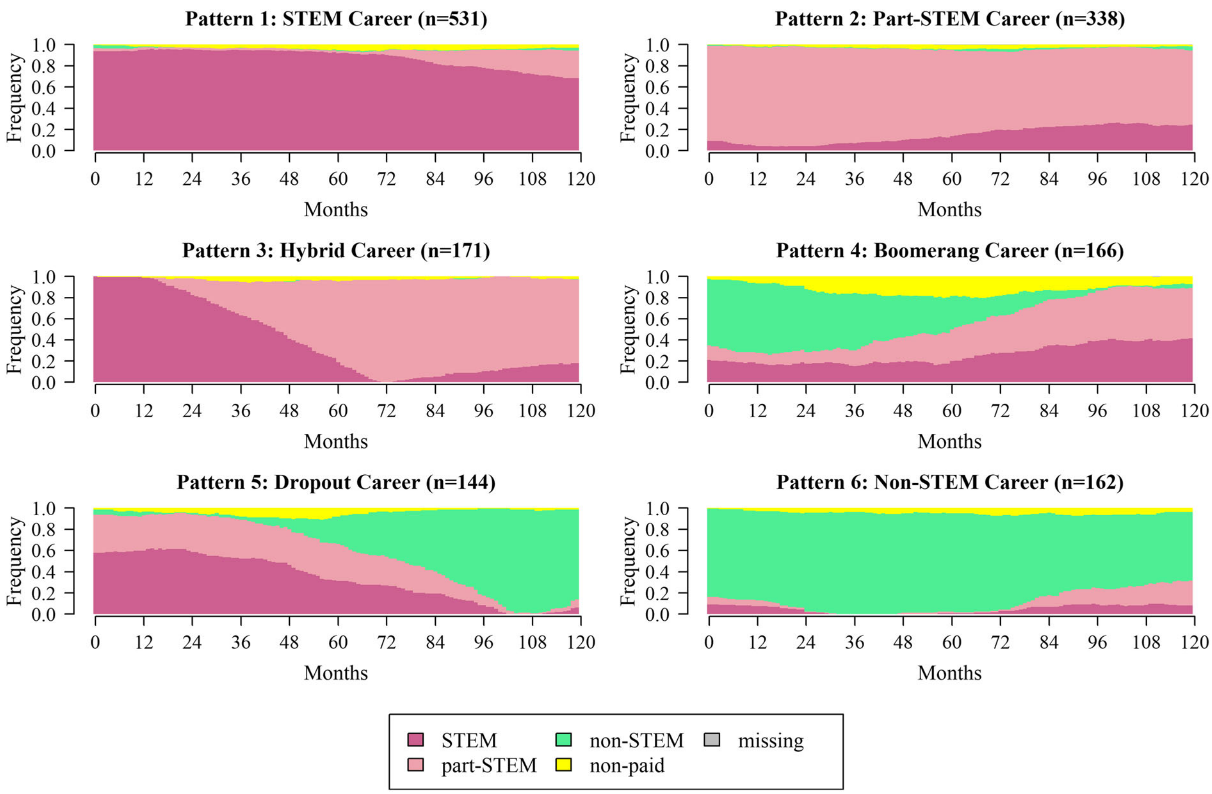

FIGURE 1 Occupational career patterns. *Note*: $N = 1512$

TABLE 3 Characteristics of occupational career patterns

	1. STEM career pattern	2. Part-STEM career pattern	3. Hybrid career pattern	4. Boomerang career pattern	5. Dropout career pattern	6. Non-STEM career pattern
Career start: Year	1999.2 (6.9) [4]	1999.3 (6.6) [4]	1998.7 (6.7) [4]	2001.3 (6.3)[1,2,3,5,6]	1998.7 (7.2) [4]	1999.2 (7.1) [4]
Career start: STEM industry[a]	0.68 (0.47) [4,6]	0.70 (0.46) [4,6]	0.69 (0.46) [4,6]	0.53 (0.50) [1,2,3,5,6]	0.65 (0.48) [4,6]	0.39 (0.48) [1,2,3,4,5]
Entire career: STEM industry[a]	0.71 (0.48) [4,6]	0.69 (0.49) [4,6]	0.71 (0.50) [4,6]	0.60 (0.48) [1,2,3,6]	0.55 (0.49) [6]	0.39 (0.50) [1,2,3,4,5]
Entire career: Main industries	Engineering: 19% IT & tele.: 18% Vehicle con.: 11% Cons. goods: 11% Architecture: 8%	Engineering: 19% IT & tele.: 14% Vehicle con.: 12% Other: 9% Cons. goods: 8%	IT & tele.: 18% Engineering: 17% Vehicle con.: 13% Cons. goods: 10% Architecture: 8%	Engineering: 14% Cons. goods: 12% IT & tele.: 12% Vehicle con.: 9% Other: 9%	Cons. goods: 16% IT & tele.: 16% Consulting: 10% Engineering: 9% Other: 9%	Cons. goods: 15% Other: 12% Consulting: 9% Fin. & legal: 8% IT & tele.: 8%
Entire career: Non-STEM occupations	All < 1%	All < 1%	All < 1%	Investigative: 8% Enterprising: 7% Realistic: 6% Conventional: 4% Social: 3% Artistic: 2%	Enterprising: 16% Investigative: 8% Social: 6% Conventional: 5% Realistic: 3% Artistic: 2%	Enterprising: 32% Conventional: 17% Artistic: 11% Realistic: 11% Investigative: 8% Social: 5%

Note: Numbers in parentheses indicate the standard deviation; superscripted numbers indicate significant (Tukey adjusted *p* values) mean differences with other clusters; entire career are the first 10 years after graduation.
Abbreviations: cons. goods, consumer goods; fin. & legal, finance and legal; tele., telecommunication; vehicle con., vehicle construction.
[a]0 = no, 1 = yes

TABLE 4 Mean differences between occupational career patterns

	1. STEM career pattern	2. Part-STEM career pattern	3. Hybrid career pattern	4. Boomerang career pattern	5. Dropout career pattern	6. Non-STEM career pattern	*F* value ANOVA
Continuity versus change							
Occupation changes	0.45 (0.56)[2,3,4,5,6]	0.67 (0.62)[1,3,4,5]	1.02 (0.15)[1,2,4,5,6]	1.40 (0.49)[1,2,3,6]	1.29 (0.47)[1,2,3,6]	0.61 (0.62)[1,3,4,5]	128.40***
Organization changes	1.94 (1.36)[3,4,5]	1.94 (1.47)[3,4,5]	2.29 (1.31)[1,2,6]	3.11 (1.72)[1,2,6]	2.44 (1.57)[1,2,6]	1.86 (1.54)[3,4,5]	20.29***
Diversity characteristics							
Sex[a]	0.15 (0.35)[6]	0.16 (0.37)[6]	0.13 (0.34)[6]	0.19 (0.39)	0.15 (0.36)[6]	0.28 (0.45)[1,2,3,5]	4.12***
Non-native speaker[b]	0.07 (0.26)	0.07 (0.25)	0.08 (0.27)	0.07 (0.25)	0.06 (0.24)	0.06 (0.23)	0.19
Foreign country of origin[b]	0.20 (0.40)	0.18 (0.39)	0.13 (0.34)	0.13 (0.34)	0.15 (0.35)	0.17 (0.38)	1.71
Career outcomes after 10 years							
Hierarchical position	1.56 (0.82)[2,5]	1.82 (0.93)[1]	1.62 (0.82)	1.64 (0.91)	1.81 (0.96)[1]	1.64 (0.97)	4.21***
Self-employed[b]	0.07 (0.25)[5,6]	0.06 (0.25)[5,6]	0.07 (0.26)[5,6]	0.07 (0.26)[5,6]	0.21 (0.41)[1,2,3,4]	0.17 (0.38)[1,2,3,4]	9.33***

Note: Numbers in parentheses indicate the standard deviation; superscripted numbers indicate significant (Tukey adjusted *p*-values) mean differences with other clusters.
[a]0 = male, 1 = female.
[b]0 = no, 1 = yes.
**p* < .05. ***p* < .01. ****p* < .001.

industries and had on average 0.67 occupation changes and 1.94 organization changes.

4.1.3 | Pattern 3: Hybrid career

This career pattern is followed by individuals who started working in a STEM occupation after graduation and then changed to part-STEM occupations, mostly around 2 to 5 years after starting their career ($n = 171$). Individuals following this pattern mostly worked in STEM industries and had on average 1.02 occupation changes and 2.29 organization changes.

4.1.4 | Pattern 4: Boomerang career

This career pattern is followed by individuals who either (1) started in a non-STEM occupation after graduating from STEM studies and then changed back to STEM or part-STEM occupations or (2) started in STEM or part-STEM occupations, changed to non-STEM or non-paid occupations, and then changed back to STEM or part-STEM occupations ($n = 166$). In general, about 8 years after starting their career, they worked either in a STEM or a part-STEM occupation. During the time spent in non-STEM occupations, as seen in Table 2, individuals most often worked in occupations characterized as investigative (8%), enterprising (7%), or realistic (6%). Individuals following this pattern had on average 1.40 occupation changes and 3.11 organization changes.

4.1.5 | Pattern 5: Dropout career

This career pattern is followed by individuals who started working in STEM or part-STEM occupations and then changed to non-STEM occupations 4 to 8 years after starting their career ($n = 144$). In contrast to those in Pattern 4, they did not come back to STEM. During the time they spent working in non-STEM occupations, they most often worked in occupations characterized as enterprising (16%), investigative (8%), or social (6%). Individuals following this pattern had on average 1.29 occupation changes and 2.44 organization changes.

4.1.6 | Pattern 6: Non-STEM career

This career pattern is followed by individuals who started working in a non-STEM occupation after graduation and mostly continued to do so over time (i.e., never worked in STEM; $n = 162$). Most non-STEM industries included consumer goods and trade, consulting, and financial and legal services. During their career half of the individuals following this pattern worked in occupations characterized as enterprising (32%) or conventional (17%). Individuals following this pattern had on average 0.61 occupation changes and 1.86 organization changes.

4.2 | Continuity versus change in career patterns

We were able to show that professionals with a STEM degree exhibit distinct career patterns, varying in the content of their occupations, the pattern of their occupations over time, and the industries in which they started or spent their careers. Tukey post-hoc analyses with adjusted p-values revealed further important differences between individuals following these career patterns. As can be seen in Table 4, individuals following the STEM, part-STEM, and non-STEM career patterns had significantly fewer occupational and organizational changes than individuals following the hybrid, boomerang, and dropout career patterns. The career patterns can thus be distinguished into continuity (STEM, part-STEM, and non-STEM; 68.2% of our sample) and change (hybrid, boomerang, and dropout; 31.8%) patterns based on these characteristics, thus answering our Research Question 1.[3]

4.3 | Professionals' diversity characteristics

In terms of sex, we found significant differences between career patterns ($F = 4.12$, $p < .001$). The share of females was significantly higher among those individuals who followed the non-STEM career pattern (28%) than the STEM career pattern, 15%, $t(1506) = 4.17$, $p < .001$, supporting Hypothesis 1a. However, as the share of females was the same among those individuals who followed the dropout career pattern (15%) and the STEM career pattern, 15%, $t(1506) = 0.22$, *n.s.*, Hypothesis 1b was not supported.[4] The F values from the analyses of variance for ethnic minority status, in terms of non-native speaker ($F = 0.19$, *n.s.*) and foreign country of origin ($F = 1.71$, *n.s.*), were not significant, and variable means across career patterns did not vary significantly. Thus, Hypotheses 2a and 2b were not supported.

4.4 | Career success and self-employment

Hypothesis 3a predicted that individuals following a career pattern characterized by part-STEM occupations would have higher objective career success than those following the traditional STEM career pattern. As aforementioned, two career patterns were indeed characterized by part-STEM occupations: the part-STEM and the hybrid career pattern. Our findings demonstrate that 10 years after university graduation, individuals following the part-STEM career pattern did indeed have a significantly higher hierarchical position, $M = 1.82$; $t(1506) = 4.17$, $p < .001$, than those following the STEM career pattern ($M = 1.56$), while the same was not true of those following the hybrid career pattern, $M = 1.62$; $t(1506) = 0.73$, *n.s.* Thus, there was only partial support for Hypothesis 3a. Further, individuals following the dropout career pattern reached on average a higher hierarchical position, $M = 1.81$, $t(1506) = 2.72$, $p < .05$, than those following the STEM career pattern ($M = 1.56$), thus supporting Hypothesis 3b. Finally, in terms of self-employment, 17% of individuals who followed the non-STEM career pattern and 21% of individuals who followed the dropout career pattern were self-employed 10 years after their career start, representing a significantly higher share than among individuals following the STEM career pattern, 7%; $t(1506) = 4.09$, $p < .001$; $t(1506) = 5.22$, $p < .001$, thus supporting Hypotheses 4a and 4b.[55]

5 | DISCUSSION

This study breaks new ground by investigating the STEM leaky pipeline as a salient societal challenge and looking into different career patterns among individuals who graduated in STEM over a 10-year time span. We found six career patterns, which could be distinguished into three continuity (STEM, part-STEM, and non-STEM) and three change (hybrid, boomerang, dropout) career patterns. We further found that female professionals more frequently followed a non-STEM career pattern than a STEM career pattern. However, we did not find any differences between career patterns for professionals from an ethnic minority (i.e., immigration) background. Moreover, we demonstrated that professionals following a part-STEM or dropout career pattern were more successful in their careers in terms of career advancement, than were those following a traditional STEM career pattern. Finally, we found that professionals following a dropout or non-STEM career pattern were more often self-employed than were those following a STEM career pattern (as well as all other career patterns).

5.1 | Theoretical implications

Our findings offer several important theoretical implications for the sustainable careers framework (De Vos et al., 2020; De Vos & Van der Heijden, 2015). First, we clarify how sequences of career experiences unfold in the STEM context. Specifically, our study has the potential to define a new conversation regarding the extent to which variability and movement within and out of organizations and occupations unfold for STEM graduates as they strive to achieve career sustainability. Indeed, while limited evidence suggests the existence of career patterns over time for STEM graduates, and the existing evidence relies mostly on conceptual rather than empirical work (e.g., Tremblay et al., 2002), we proposed that STEM graduates' career patterns may involve either continuity or change over time. Specifically, in a first systematic exploration of career patterns, the current study demonstrates the existence of three continuity (STEM, part-STEM, non-STEM; 68.2% of the sample) and three change (hybrid, boomerang, dropout; 31.8%) career patterns. Thus, continuity patterns clearly dominated among STEM graduates.

Second, our study represents one of the first empirical confirmations that career sustainability should only be evaluated using a long-term perspective. Within the STEM context, we find, notably, change career patterns for 31.8% of our sample, which further highlights the importance of considering how STEM careers evolve over time. It is possible that past studies reported, for example, individuals following the boomerang career pattern as dropouts, while our analyses over 10 years revealed that a significant proportion of professionals returned to STEM occupations. Our paper further contributes to the identification of the timeline of such a re-entry into STEM, as we found that occupational turnover from STEM to non-STEM occupations happened earlier in the boomerang career pattern than in the dropout career pattern. This is in line with literature reporting that boomerang workers may leave earlier in their career before coming back, compared with those who leave for good (Shipp et al., 2014).

In addition, we empirically demonstrate that a long-term perspective is needed to evaluate career success as an indicator of sustainable careers (De Vos et al., 2020), by nuancing the conditions and timing under which part-STEM occupations may be associated with greater career success. We find that individuals starting their careers upon graduation in a part-STEM occupation were more successful (i.e., experienced more career advancement) than those following the STEM career pattern in the long term. However, this was not the case for individuals following the hybrid career pattern who had transitioned from a STEM to a part-STEM occupation a few years after starting their career.[6] The part-STEM career pattern seems more sustainable in terms of long-term success than the hybrid career pattern, which may be explained by the high worth of early career graduates with up-to-date knowledge on the job market, compared with professionals with a longer tenure (Deming & Noray, 2018).

Third, our paper focusing on the STEM leaky pipeline phenomenon demonstrates the complexity of the person-context interactions required for careers to be sustainable. Specifically, while in this paper we adopted an individual (micro) perspective according to which STEM graduates continuously strive to achieve a sustainable career, at the societal and economical (macro) levels, such efforts may result in losses. Indeed, individual career patterns implying leaving STEM occupations for those in which a STEM degree is not required (i.e., the dropout and non-STEM career patterns, representing 20.2% of our sample)[7] may result in a loss of investment from society in individuals' education and subsequently in a possible labor shortage for the economy. By highlighting such possible tensions in person-context interactions, this study thus questions the sustainable careers framework's proposition that "sustainable careers are characterized by mutually beneficial consequences for the person and for their surrounding context" (De Vos et al., 2020, p. 24). Rather, our findings suggest that, in some cases, greater career sustainability for the person may occur at the detriment of the context. Thus, a particularly interesting question arises for the sustainable careers scholarship: Are career patterns sustainable when their sequence of career episodes is no longer characterized by mutually beneficial consequences for both the person and the context?

Fourth, our findings clarify how sustainable careers concretely unfold over multiple occupations in the STEM context, by identifying professionals' turnover destinations in non-STEM occupations in terms of occupational interests (Holland, 1987). Expanding recent STEM literature on career interests (e.g., Babarović et al., 2019; Kim & Beier, 2020), our analysis revealed that when working in non-STEM occupations, future boomerang professionals mainly chose investigative, enterprising, and realistic occupations—hence remaining close to STEM-related career interests (i.e., investigative and realistic; Babarović et al., 2019). In contrast, those following a non-STEM career pattern mostly worked in enterprising and conventional occupations, thus placing them further away from typical STEM career interests. Altogether, these results indicate that individuals seem to perceive their careers as more sustainable if their current job fits their occupational interests better (i.e., STEM graduates with interests mostly for realistic and investigative occupations experience a greater fit more likely to result in boomerang patterns if leaving STEM fields) and suggest that dropping out from STEM fields may lead to greater career sustainability through a better fit with one's occupational interests.

Fifth, we integrate the sustainable career framework with the workforce diversity perspective (Roberson, 2019) in the context of STEM careers, hence contributing to a better understanding of whether and how professionals' diversity characteristics may be associated with sustainable career patterns over time. Specifically, our study examined two underlying stable sociodemographic characteristics (i.e., sex and ethnic minority status) that may be associated with greater vulnerability for some STEM graduates. Expanding prior literature on female workers in STEM (Makarem & Wang, 2020), we observed more female professionals in the non-STEM career pattern but not in the dropout career pattern. This suggests that for female STEM graduates, the pipeline is likely to leak very early, even before getting a first job upon graduation. By doing so, we expand prior work mostly adopting a static approach and showing that nearly one third of women intended to leave STEM jobs within their first year upon graduation (Hewlett et al., 2014). Further expanding prior findings showing an absence of significant differences among racial groups of STEM graduates in their occupational career choices (Xu, 2013), but in contrast with other prior studies (e.g., Hall et al., 2017; Saw et al., 2018), we found no variation across career patterns based on professionals' ethnic minority status. This may be explained by our specific study context, as the German government has actively sought since 2005 to attract foreign STEM professionals to Germany (Maaß & Icks, 2012). This may have provided ethnic minorities in STEM with an official recognition of the necessity of their contribution to the German economy.

Sixth, this study contributes to broadening scholars' current understanding of how sustainable career patterns may relate to long-term career success (Straub et al., 2020) in terms of reaching higher hierarchical positions. Indeed, our findings seem to indicate that career advancement may be related to transitioning out of a STEM occupation (i.e., dropout and part-STEM career patterns), thus shedding light on the possibility that the STEM leaky pipeline may represent a way for some STEM graduates to transition into more sustainable careers (Castro et al., 2020). It is important to note, however, that our investigation of career success was limited by our dataset, allowing us to focus on hierarchical positions only, hence overlooking other objective and subjective indicators of sustainable careers (De Vos et al., 2020). Finally, our results suggest that self-employment may also represent a better opportunity to achieve career sustainability for professionals following the dropout and non-STEM career patterns, compared with those in STEM occupations who may benefit from higher salaries and greater opportunities for innovation that can enable them to more easily achieve career sustainability in their employed positions.

5.2 | Practical implications

Findings of our study have practical implications for organizations' efforts to enhance all their employees' career longevity in a sustainable careers perspective (McDonald & Hite, 2018) through their human resource management practices. In particular, our results can inform managers and organizations about the best time, and on which employees' socio-demographic characteristics to focus such retention efforts. As we found that occupational turnover in the dropout career pattern was taking place 4 to 8 years after individuals' career start, that professionals following the part-STEM or dropout career patterns (mostly in the consumer goods and consulting industries) were the most successful in terms of career advancement, and that female (vs. male) STEM graduates were less often in higher hierarchical positions, we recommend that retention interventions focus on early-career and female employees. Concretely, organizations in the STEM industry should adopt a more sustainable HR management perspective by rethinking their employees' career management and access to higher hierarchical positions to avoid retention issues. Specifically, organizations should provide their employees with regular access to formal education, allowing them to update their skills and knowledge on a regular basis and to advance accordingly in the succession planning to reach higher hierarchical positions. Such efforts are in line with the sustainable careers framework, which highlights career renewability through "re-education" to allow employees to be more engaged and resilient as their careers evolve (Newman, 2011).

Another important finding of our study is that female STEM graduates most frequently followed the non-STEM career pattern, hence never starting a first job in STEM in the first place. This concretely implies that universities should develop programs supporting their female STEM students to increase their odds of actually starting a STEM career. As female graduates are more likely to face gender bias and hostile work environments upon their career start in a STEM occupation (Leaper & Starr, 2019), such programs should provide access to successful female role models (Roemer et al., 2020). Concretely, universities' career development services should develop partnerships with organizations in the STEM industry to allow their female students to be paired with successful STEM female professionals during an internship and/or mentorship program. Having observed their mentor as role models in terms of how STEM occupations may concretely represent a sustainable career choice, female students may ultimately make a more informed decision of whether or not to enter a STEM career upon graduation based on more realistic expectations on how a STEM career may be sustainable for themselves as well.

5.3 | Limitations and avenues for future research

Although the reliance on career data from a large public professional networking platform represents a strength of the current study, it also has several limitations. First, because the Xing data were archival in nature and thus not collected with our research questions in mind, the availability of indicators was limited. Notably, no information was provided on respondents' age, occupational interests (e.g., using the Self-Directed Search assessment tool; Holland, 1994), on whether the reported career changes reflected voluntary or involuntary turnover, or on other subjective (e.g., career or job satisfaction, health) and objective (e.g., salary) measures highlighted by the sustainable careers framework. Thus, we acknowledge the existence of several other factors that are relevant to STEM graduates' career patterns and warrant future research. Furthermore, as is also the case in many other STEM studies, an implicit assumption of our study of professionals' diversity characteristics is that these characteristics are biologically based (Metcalf, 2010). We used limited categories that are mutually exclusive; accordingly, future studies should explore the role of gender (e.g., non-binary) instead of sex and of racial/ethnicity (e.g., Latino/a/x) identities in STEM to further address calls for more research on "the [career] sustainability of employees belonging to minority groups" (De Vos et al., 2020, p. 10).

Second, our sample from the social network Xing might not be representative of the entire STEM workforce. Like LinkedIn, Xing and other similar social network platforms tend to be used more by people in knowledge-intensive sectors and less by individuals with lower education and income (Blank & Lutz, 2017; Hargittai, 2020). While we focused on individuals with a STEM university degree, some professionals (e.g., self-employed professionals or those who work in enterprising occupations) might be more likely than others to use a professional social network like Xing. Of note, the percentage of individuals in our sample that were self-employed after 10 years (9%) corresponds to the proportion of individuals that are self-employed in Germany (Destatis, 2020c). Still, our dataset allows us to avoid limitations of other types of longitudinal data (e.g., from national panel studies), such as a limited share of STEM workers and panel attrition, especially for individuals who work long or odd hours (Uhrig, 2008), and are self-employed or have an enterprising occupation (Ezzedeen & Zikic, 2017). Therefore, we recommend that future studies rely on data from different sources to contribute to a complete picture of STEM careers and occupational turnover.

Third, while we propose that the career patterns of professionals who graduated in STEM identified in our study can be found in other countries as well, the prevalence of STEM graduates who follow these patterns might differ across countries. In our study, there were no country differences between Germany, Austria, and Switzerland. However, cultural or institutional differences that either favor dropout or that tie individuals to STEM occupations might nevertheless exist. Hence, a fruitful avenue for future research may be to examine and compare STEM graduates' career patterns in more distant countries.

6 | CONCLUSION

Overall, the leaky pipeline of STEM careers represents a major challenge at the societal and economical levels, given the important role played by STEM occupations for the prosperity of a world characterized by rapidly evolving innovation and technology. Moreover, it also represents an opportunity to achieve career sustainability for STEM professionals. As such, it is becoming increasingly necessary to understand how STEM graduates' careers evolve over time, as well as correlates of occupational turnover after graduation. The current study offers a sustainable careers perspective that explicitly considers the existence of continuity and change career patterns. Our results suggest three continuity and three change career patterns, as well as associations with sex (but not with ethnic minority background), career success, and self-employment. These findings suggest that organizations should aim to enhance their employees' career longevity in a sustainable careers perspective through their human resource management practices, focusing their retention efforts on early-career and female employees. Moreover, universities should develop programs supporting their female STEM students so that they may ultimately decide whether or not to pursue a STEM career under the best conditions.

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DATA AVAILABILITY STATEMENT

Data available on request from the authors.

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ENDNOTES

[1] In a sensitivity analysis, we conducted optimal matching analyses for sequences with lengths of 15 years ($N = 810$) and 20 years ($N = 407$). These sensitivity analyses yielded essentially the same patterns as the ones we later report in the main text. Interested readers may contact the authors for more details on these findings.

[2] This percentage is representative for STEM graduates in German-speaking countries (German Federal Employment Agency, 2021).

[3] In a sensitivity analysis, we repeated these tests in cluster solutions with seven, eight, and nine clusters. In all solutions, Research Question 1 was answered similarly. Interested readers may contact the authors for more details on these findings.

[4] In a post hoc analysis, we further explored whether female versus male professionals may also be less likely to have reached a higher hierarchical status 10 years after starting their careers. We found that women indeed had a significantly lower hierarchical level after 10 years ($M = 1.43$) than men, $M = 1.71$, $t(1506) = 4.34$, $p < .001$.

[5] There were no significant differences between career patterns with regard to highest degree ($F = 1.43$, *n.s.*), MBA ($F = 0.43$, *n.s.*), or country (Germany vs. other, $F = 1.71$, *n.s.*).

[6] In a sensitivity analysis, we explored whether individuals in the hybrid pattern might simply need some time after their transition to part-STEM occupations to secure higher positions. We found that the results did

not change for careers with lengths of 15 years ($N = 810$) and 20 years ($N = 407$). Interested readers may contact the authors for more details on these findings.

[7] While prior studies reported that up to 75% of STEM graduates might not work in STEM occupations (e.g., U.S. Census Bureau, 2014), this difference may be explained by the fact that only STEM versus non-STEM occupations were considered, hence overlooking part-STEM occupations (with the recent exception of Smith & White, 2019). While Smith and White (2019) found that 17–22% of U.K. STEM graduates worked in associate professional and technical occupations, we found that 22.1–33.7% worked in part-STEM occupations.

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