Opening the Black Box of Vertical Transfer Admission: The Experiences of Community College Students in STEM Majors

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Better understanding of how students achieve vertical transfer is vital for advancing equity in science, technology, engineering and mathematics (STEM) majors. Among the many sources of barriers, delays, and complexities demonstrated in previous research as influencing vertical transfer outcomes, the transfer admission process has been generally neglected. Using a longitudinal, qualitative design, and drawing on transfer capital and field theories, this study investigated how community college students who are underrepresented in STEM fields successfully navigated admission to a four-year institution in a STEM major. Results indicated that students experienced transfer admission as risky and uncertain. They accrued transfer capital over time, in the form of knowledge about transfer admission and strategies to bolster their competitiveness, including regulating their coursework intensity and actively managing their GPAs. Although these forms of transfer capital helped students succeed in transferring, some strategies could backfire, causing unintended negative consequences, such as time-to-completion delays, excess credit accumulation, or disadvantages in securing admission. Results supported the contention that the transfer admission process is a pivotal, yet largely neglected aspect of student experience in STEM vertical pathways. Conclusions provide suggestions for further research and implications for institutional practice.

Keywords: community college, vertical transfer admission, STEM, equity, qualitative

Plain language summary: [see above abstract]

Community colleges, with their open access enrollment policies and relative affordability, serve as critical entryways into higher education for students who might not otherwise have the

opportunity. This includes low-income and first-generation college students who may seek the lower costs and geographic accessibility of community colleges as well as students who may have faced academic or personal uncertainties or constraints in accessing four-year institutions directly (Dowd, 2007; Hagedorn, 2010; Schudde & Goldrick-Rab, 2014). At the same time, although a majority of community college students aspire to transfer to a four-year institution, only a third succeed, and of these, only 13 percent complete their bachelor's degree in six years (Jenkins & Fink, 2016; Shapiro et al., 2018). More troubling from an equity vantage point, recent estimates show that bachelor's degree completion rates for Black and Latinx students who begin higher education in community colleges are 6.7% and 8.6% respectively, with completion rates for low-income students less than half that of their more privileged peers (Institute of Education Sciences, 2020). Better understanding of what leads to successful vertical transfer in major-specific pathways is therefore vital to informing improved interventions, policies, and practices that address the real challenges that diverse students actually encounter (Bahr, 2013; Witham, Malcom-Piqueux, Dowd, & Benismon, 2015), including what Handel (2013) refers to as the academic gauntlet of transfer admission.

Purpose of Study

This longitudinal, qualitative study examines the research question of how community college students in science, technology, engineering, and mathematics (STEM) majors successfully secured admission to a four-year institution in STEM as part of their overall vertical transfer pathway experiences. Although there is an expanding literature on the transfer function of community colleges, little of this work addresses how student experiences differ by major field of study (Bailey, Smith Jaggars, & Jenkins, 2015; Taylor & Jain, 2017). Yet, there is ample reason to suspect that STEM majors pose special challenges for transfer success (Bahr, Jackson,

McNaughtan, Oster, & Gross, 2017; Malcom & Feder, 2016; Wang, 2013). This includes gaining admission to a four-year institution in STEM majors, which tend to be constrained by enrollment limits and to involve competitive entry requirements (Dowd, 2012; Grote, Knight, Lee, & Watford, 2020). Prevailing instructional norms in STEM support a culture of attrition (Rodriguez et al., 2012), which heightens the competitive dynamics that have been found to disproportionately affect Black and Latinx students as well as students from low-income backgrounds, who are more likely to switch out of STEM majors and to stop out of higher education altogether (Riegle-Crumb, King, & Irizarry, 2019; Seymour & Hunter, 2019). High levels of curricular complexity in engineering and other technical STEM majors constitute maze-like chains of pre- and corequisite courses, the navigation of which has been found to confound both the students aspiring to transfer and the advisors and faculty who seek to support them (Grote, Lee, Knight, Erwin, & Watford, 2019; Grote, Knight, Lee & Watford, 2021; Reeping & Grote, 2021). Grading practices in STEM courses are harsher than most non-STEM courses, creating a STEM-grading penalty for students, making course failures and withdrawals more commonplace, and contributing to departures from STEM majors (King, 2015; Weston, Seymour, Koch, & Drake, 2019; Witteveen & Attewell, 2020). The cumulative effect of these STEM-specific challenges appears to reproduce and perpetuate disparities in access to STEM majors and careers, which are associated with high levels of prestige and economic value for graduates (Hershbein & Kearney, 2014; Xie & Killewald, 2012).

Qualitative evidence is growing about how community college students in STEM experience vertical transfer pathways, including supports and barriers to transfer and completion of STEM undergraduate degrees (Grote, Richardson, Glisson, Knight, Lee, & Watford, 2022; Packard, Gagnon, Senas, 2012; Reyes, 2011; Wang, 2020; Wang et al., 2020; Wickersham,

2020). This longitudinal, qualitative study contributes fundamental insight to this research base by revealing how the process of securing admission to a four-year institution and STEM major as a community college student unfolds in real time, from students' points of view. In addition, labeling the investigation (as the title does) as "opening a black box" highlights the study's purpose in unpacking admission as a mechanism that has largely hidden and unobserved influence on vertical transfer outcomes. As the results show, framing the problem of transfer in terms of securing admission to transfer, more accurately corresponds to many students' experiences on STEM vertical transfer pathways. This study posits that the transfer admission process is a pivotal, yet largely neglected aspect of community college students' transfer pathway progression that points to similarly underdeveloped areas of policy, research, and programming for improving equity in transfer student attainment and outcomes in STEM fields.

Literature review

Securing vertical transfer admission

Among the many roles of community colleges, vertical or upward transfer has long been associated with advancing equity by providing access for students who might not otherwise pursue postsecondary education (Malcom & Feder, 2016; Taylor & Jain, 2017). At the same time, the strengths of community colleges--their open enrollment policies, flexibility to attend full or part-time, and comprehensive offerings--have been argued to be sources of complexity and confusion for students that undermines their transfer success (Deil-Amen & Rosenbaum, 2003; Scott-Clayton, 2011). One possible facet of the complexity of vertical transfer that has attracted little previous research attention is how community college students secure admission to a four-year institution and STEM major.

Scholarship on college admission has largely focused on traditional students entering higher education from high school (e.g., Black, Cortes, & Lincove, 2015; National Association for College Admission Counseling, 2010). Seldom has the process of gaining admission to a four-year institution been considered in studies of vertical transfer from community colleges. Yet, Monaghan and Attewell (2015) hypothesized that the admission process may explain results from their national survey study that showed 40% of students who accumulated 60 or more credits in community college (equivalent to an associate degree) did not transfer. They conjectured that the students may have failed to apply to a four-year institution, applied to too few four-year institutions, or have been discriminated against by institutional representatives involved in admissions, but provided no findings to advance resolution of the question.

Along similar lines, few previous studies have generated evidence about what happens when community college students do not gain admission to their chosen undergraduate major or transfer destination (Deil-Amen & Goldrick-Rab, 2009). One exception is Musoba, Jones, and Nicholas (2018) who investigated the experiences of transfer students who were admitted to a four-year institution but not into their chosen limited access major, which are majors that constrain enrollment by imposing admission criteria beyond those required for general transfer student admission. They found that career knowledge was key in students' ability to consider other options and to negotiate ensuing obstacles. These findings align with additional research showing that community college students' choices to major in STEM are closely tied to the career and lifetime goals that they hold for themselves (Wickersham, 2020).

Competing for access to STEM majors

Transfer admission into a specific four-year institution and major is seldom guaranteed for community college students, which can mean that students must navigate admission

requirements for multiple four-year institutions to increase their chances of securing access (Handel, 2013; Morris & Cox, 2016). In addition, in STEM fields the transfer admission process can involve heightened challenges due to major-specific admission criteria and poor systems for identifying talented students entering from community colleges (Dowd, 2012). Numerous studies have focused on competition and disparities in student access to selective institutions (e.g., Dowd, Cheslock, & Melguizo, 2008). However, competition for access to undergraduate education is increasing more broadly in some locations and fields, and there is little understanding of how this might be affecting transfer aspiring community college students. Some states have experienced capacity constraints that limit the likelihood that community college students can transfer to a four-year institution (Townsend & Wilson, 2006). This includes California where higher education has faced increases in demand without corresponding increases in enrollment capacity or commitment to accept transfer students, with the result that students must meet higher admission standards (Neault & Piland, 2014; Piland & Neault, 2014).

A few studies provide context for understanding how admission processes may intersect with factors influencing transfer destination selection and enrollment decisions, and thereby perpetuate inequities in access to STEM majors. Ethnically and racially minoritized students in STEM have been found to prioritize attending institutions that they view as having a good reputation but are not among the most exclusive or selective because students view these institutions as having less competitive institutional climates (Chang, Cerna, Han, & Saenz, 2008). Students from low-income family backgrounds, who compose a substantial proportion of vertical transfer aspirants (Dowd, 2010), have been perpetually disadvantaged in higher education as access becomes more competitive, according to Bastedo and Jaquette (2011). Drawing on national data from 1972-2004, they found that although financially disadvantaged

students made substantial academic achievement progress, wealthier students made even stronger gains in admission test scores and course grades, thereby ensuring their continued competitive advantage in the market for college admission. In addition, research has demonstrated that low-income and ethnically and racially minoritized students prioritized transfer destination institutions that are close to their home communities and in geographical proximity to family (Jabbar, Sánchez, & Epstein, 2017). Still, not enough is known about how students manage transfer destination decision-making and admission processes in conjunction with personal priorities and constraints (Deil-Amen & Goldrick-Rab, 2009) and how this plays out in competitive and limited access fields, such as STEM majors.

Further, how the vertical transfer admission process itself is perceived and experienced by community college students is not well understood. Gaining admission to a four-year institution is criteria based, yet the process remains complicated and success is difficult for students and their families to predict (Selingo, 2020). Recent research indicates that the only transfer admission criteria rated highly important by a substantial proportion of four-year institutions that were surveyed consisted of applicants' overall grade point average (GPA) and their average grades in transferrable courses (Clinedinst & Patel, 2018). Among community college students in STEM, Wang et al. (2020) found that students' community college GPA significantly predicted their eventual transfer. Further, their qualitative findings indicated that transfer-aspiring students felt defined by their grades, with grades validating student decisions to remain in STEM transfer pathways. Studies have consistently shown that, despite a preponderance of access and implementation problems, pre-transfer advising plays a crucial role in supporting students' timely progress in STEM transfer pathways (Harper & Thiry, 2022; Packard, Gagnon, & Senas, 2012; Queen, 2022), with particular benefits demonstrated from

adoption of tailored and intrusive pre-transfer advising models (Grote, Richardson, Glisson, Knight, Lee, & Watford, 2022). Transfer admission is also likely to be influenced by students' engagement with co-curricular opportunities, which studies have shown are less available to students from low-income backgrounds in comparison to their more privileged peers (Snellman, Silva, Frederick, & Putnam, 2015).

Conceptual framework

This study uses transfer capital and field theories as a framework for understanding how community college students navigate their way to securing admission to a four-year institution in a STEM major. Transfer capital refers to the process through which community college students acquire knowledge and skills necessary to navigate vertical transfer (Laanan, 2004). Relevant to the current study, transfer capital has been shown to include student knowledge of information about specific transfer destination institutions and careers as well as student practices indicative of seeking out information and interactions with institutional agents about transfer (Laanan, Starobin, & Eggleston, 2010). Studies incorporating transfer capital have focused on equity in STEM pathways, involving first-year community college students (Wang, Wickersham, Lee, Lor, Gaskew, & Prevost, 2020), Latinx students (Johnson, Starobin, & Santos Laanan, 2016) and female students (Starobin, Smith, & Santos Laanan, 2016). Recent research has also expanded the transfer capital construct to incorporate the positive effects of pre-transfer academic performance (Moser, 2013), advising and information (Grote et al., 2019; Grote et al., 2020; Hayes, Lindeman, & Lukszo, 2020), and mentoring and faculty support (Moser, 2013; Starobin, Smith, Laanan, 2016) on students' adjustment and success in transfer pathways. Access to informal, insider knowledge and connections with university faculty while still a community college student have also been found to be crucial but rarely accessed contributors to transfer

capital formation and adjustment (Grote, et al., 2020; Wang, Lee, Nachman, & Zhu, 2021). Still, how transfer capital figures into community college students' success in the field of transfer admission in STEM majors remains a gap in the literature. To address this gap, the current study applies transfer capital to STEM transfer admission with the goal of describing and understanding how community college students develop capital and deploy it as knowledge and strategies to secure transfer access.

In conjunction with transfer capital, the study draws on the construct *field*. Foundational social theory views any form of capital as deriving its meaning and utility from a field (Bourdieu, 1977; 1986). As a construct, fields are spaces of common purpose as well as arenas of competition, such as the field of professional electrical engineers or the field of undergraduate education admission in a particular state (Emirbayer & Johnson, 2008). In a recent application of field theory, Schudde, Jabbar, and Hartman (2021) used strategic action field analysis to understand the role of political-ecological contexts on vertical transfer from community colleges to universities. They found that university administrators, faculty, and staff held dominant positions in the transfer field, by setting the rules and norms for accepting transfer credits and applying those credits to undergraduate requirements. Transfer aspiring students, who they found to hold the least privilege in the transfer field, had to invest considerable time and energy to gather information about constantly shifting transfer requirements and policies. Using transfer capital theory, the current study extends this line of inquiry to community college students' development and enactment of knowledge and strategies that help them secure transfer admission in STEM.

As noted, the admission process has been a largely implicit aspect of research and policy focused on vertical transfer pathways. However, in positing whether something about the

admission process might account for the fact that so many community college students who have accumulated 60 or more credits do not transfer, Monaghan and Attewell (2015) raised a related issue that also tends to be absent in the transfer literature but is incorporated into the current study: *competition for access*. Phenomenologically, this study assumes that vertical transfer admission is not secured through volition, as a rational choice, but is instead achieved through competitive demonstration in the admission field of having met or exceeded the specific evaluative criteria established by a four-year institution for a STEM major (Schudde et al., 2021). Even outside of selective institutions, on average across U.S. universities, only 61% of transfer applicants were accepted in 2018 (Clinedinst, 2019). Among those who apply, many apparently accomplished transfer applicants therefore do not succeed for reasons that remain unclear. By drawing on transfer capital and field theories, this study sheds light on these issues and reveals how STEM students perceive and navigate competitive transfer admission processes during their time in community college.

Methods

Research design and site selection

This study is part of a five-year, mixed-methods investigation of STEM student experiences and institutional practices in two- to four-year institution transfer pathways. The overall study includes surveys and interviews with former transfer and non-transfer seniors who are close to graduating from their four-year institution; in-depth interviews with institutional agents in the participating institutions; state and institution level policy and program review; and longitudinal, qualitative interviewing with STEM students beginning when students were anticipated to be near the point of transfer to a four-year institution. The study reported here draws on these latter,

longitudinal, qualitative interviews that tracked STEM students' navigational experiences as they progressed in real time during and beyond their community college studies.

The larger study includes five institutions in three states: two pairs of a community college and a four-year comprehensive public university and one stand-alone university (in which the recruited community college dropped out of the study and was not replaced before data collection began). The four-year institutions in the larger study were selected first, through a process using IPEDs data to identify institutions that surpass their peers in eliminating attainment gaps by graduating high numbers of diverse students in terms of ethnicity, race, and socioeconomic status, using Pell-eligibility as a proxy. The two community colleges were selected based on geographic proximity to the two participating four-year institutions. Both community colleges had articulation agreements in place with their partner four-year institution. At the beginning of the study (2018), Pacific Community College (PCC, a pseudonym) had a three-year graduation rate of 22% and a transfer out rate of 11%. It is a Hispanic-serving institution, where 58% of students received needs-based financial aid. Atlantic Community College (ACC, a pseudonym) had a graduation rate of 35% and a transfer rate of 24%. Nearly a third of its students at the time were African American and half received need-based aid.

PCC and ACC are in different states, although both state policy contexts incentivize students to complete associate degrees or the equivalent in credit, and both guarantee that up to 60 qualifying course credits earned in community college will be accepted in many four-year institutions in the state. This means that results from this study might not generalize to state policy settings in which vertical transfer can occur earlier in students' pathways progression or prior to students' earning an associate degree (e.g., Jaeger et al., 2015). In addition, differences in state policy context were evident in the number of credits that students participating in the study

had accrued at the time of that baseline interviews were conducted prior to transfer. At PCC, the median number of credits students had accrued when they entered the study was 84.5 (for 18 students), while at ACC the median was 54 (for 11 students). Indeed, ACC is in a state with stricter excess credit policies in place than PCC. ACC is also in a state where a single, required transfer associate degree is in place, while PCC's state context includes multiple transfer degree pathways. Additionally, multiple inter-institutional (although not necessarily statewide) articulation and transfer agreements exist to support major-specific transfer in both states. Four-year institutions largely control criteria for transfer admission and impose higher admission standards for many STEM majors.

Participant selection and data collection

To identify a sample of advanced transfer-aspiring community college students in STEM at the two participating community colleges, a directory request was placed for a list of students who had taken 30-or-more transferable credits in STEM courses and at least 45 credits overall. The directory data were stratified by gender, race and ethnicity, Pell eligibility (as a proxy for income status) and intended major after transfer. After sending out an email inviting students to participate and receiving responses from volunteers, a sample of STEM students was selected. This sample included a disproportionate number of students from backgrounds that are traditionally underrepresented in STEM fields.

The baseline and follow-up interview protocols were developed by a team of four qualitative researchers. The protocols were based on literature pertaining to influences on underrepresented student persistence in vertical transfer pathways and STEM majors more generally. The baseline protocol included 14 overall questions, each with follow-up probes and prompts. Given the longitudinal design of the study and semi-structured interviewing approach,

follow-up interviews were highly tailored to each student's circumstance and progress in a STEM pathway, focusing on new developments. Topics in the interviews included: choice of major, STEM interest, career goals, advising experiences, co-curricular opportunities, experiences with peers, interactions with faculty, student finances, classroom experiences, sources of academic support, curricular issues, experiences with grades, worries and challenges, and plans for transfer. Interview questions most relevant to the current study were: When do you plan to begin your applications for transfer? Which university(ies) will you apply to, and why? Have there been any changes in your transfer plans? What, if any, challenges to transfer are you now facing? Who or what has helped you stay on track for transfer?

Baseline semi-structured interviews (Bernard, 2000) were conducted in person with the final sample of 29 students at the two participating community colleges during the spring and fall 2019. These interviews lasted 60-90 minutes. After baseline interviews were conducted, students were contacted by email every six months and invited to participate in a follow-up interview by Zoom. Follow-up interviews were typically shorter. A modest incentive in the form of a gift certificate was offered to students for each round of participation in the study. From the initial sample of 29 students, 23 participated in at least one follow-up interview. Many participating students actively looked forward to follow-up interviews, appreciating the opportunity to share and reflect (and sometimes vent) about their experiences, and often coming to the interview appointment ready with updates, ranging from achievements and triumphs to bureaucratic struggles, academic failures, and personal traumas.

Study participants

Study participants were evenly divided by gender and were pursuing a variety of intended majors: 31% biology, 24% computer science, 24% engineering, 14% chemistry, and 10% math.

Students were racially diverse, with 55% Latinx, 34% White, 17% Asian/Pacific Islander, and 7% African American students. Over half, 52%, spoke a language other than English at home, mostly Spanish. Over two-thirds, 69%, received the Pell grant or a comparable needs-based grant, and several received dependent benefits grants through the Veterans Administration. Consistent with national estimates (Community College Research Center, n.d.), 76% of the students in the baseline sample worked during their community college attendance. Five participating students (17%) had a disability for which they received accommodations. Many were first-generation college students, with 41% from families in which neither parent had completed an associate degree or higher. Appendix A provides a table that lists each participating student according to pseudonyms that are used in the results, as well as students' background characteristics and status in the STEM transfer pathway.

Data, analysis, and trustworthiness of results

The aim of data analysis for this study was to identify patterns and variations in participants' understanding of and responses to the conditions and challenges involved in securing vertical transfer admission in a STEM major (Emerson, 2011). Interviews were digitally recorded and transcribed verbatim, with transcribed interview content constituting the data for the study. Based on the larger study's research questions and existing literature, a team of four researchers created a framework that specified content domains for coding (e.g., college choice, advising, co-curricular experiences, major choice). Using NVivo for Teams qualitative data analysis software the four researchers piloted the coding framework and further refined and elaborated it through discussions during ensuing coding. Inter-rater reliability reflecting coder agreement in applying codes to interview transcript data was high, averaging 90% to 96% agreement.

A second stage of data analysis for the current study was undertaken by one team member. This involved focused analysis of coded content for the following domains: transfer planning; college choice; worries and concerns; challenges; curricular pathways; and grades. Domain content was then sorted and re-grouped to reflect emergent and inductively identified substantive categories and recurrent themes and variations related to transfer admission (Maxwell, 2005). Since individual students were the unit of analysis, this second stage of data analysis also involved reassembling data collected over time for each student to facilitate understanding of individual cases and comparison across student cases. In some instances, simple tallies were used to gauge how common were identified phenomena. The construct *transfer capital* was operationalized in the data analysis primarily in the forms of assets, strategies, and resources that were identified as useful to students' navigation of transfer admission. The construct *field* was operationalized in terms of STEM major and institution-specific admission conditions and contexts that shaped student navigation experiences as evidenced by students' accounts.

Several aspects of the study's design enhance its credibility and trustworthiness. The longitudinal nature of the study and reliance on multiple interviews with the same participants enhance reliability through diachronic observations (Kirk & Miller, 1986). The design also facilitated identification and member checking of the interpretive validity of both general patterns and discrepant evidence (Maxwell, 2005). The thick and contextually rich descriptions and descriptions of both similar and contrastive cases increases the study's internal validity (Miles & Huberman, 1994). As indicated by the relatively large number of students referenced by pseudonym in the results, care was taken to represent the range and variability of transfer admission experiences reflected in the data. In addition, the generalizability (external validity) of

the study extends from its value for extrapolation of insights to other settings and future investigations (Patton, 1997) and from its focus on vertical transfer admission dynamics that are likely to operate similarly if less acutely in other settings (Weiss, 1994).

Results

The community college students in the study were largely successful in their STEM pathway progressions, with many beating the odds associated with low-income and minoritized student statuses and transferring to a four-year institution. At the time of this analysis, roughly three years after baseline interviews were conducted, out of 29 students, 16 had successfully transferred to a four-year institution in a STEM major (although two later switched out of STEM); three students switched out of STEM while in community college; three completed their associate degree but had not yet secured transfer admission; and seven dropped out of the study, mostly after the initial interview. Behind the overall success of a majority of students was a substantial amount of transfer capital accrual and enactment, in the forms of seeking and using information about specific transfer destinations and admission requirements, deploying strategies to become more competitive for transfer admission, and adjusting goals and tactics to secure admission often based on failures, missteps, and evolved priorities.

Uncertain transfer admission to preferred institutional destinations

The community college students in the study consistently described their interest and decision to major in STEM as grounded in long-term plans for their lives, especially their intended careers. Students seldom viewed transfer admission as guaranteed or automatic, but instead saw it as indeterminant, risky, and competitive. Six of the students (21%) had applied to a four-year institution in high school but had been denied admission, which led them instead to enroll in community college and pursue vertical transfer as a "second chance" for university access

(Schudde & Goldrick-Rab, 2014). The past experience of being rejected for admission was still salient for Kai, a first-generation student in engineering:

> I've gone through [the admission process] once before and failed miserably...it was a pretty big hit to the ego. Especially since while I was in high school, I was the class president and was in all these sports. I guess I was supposed to be, ideally, like a role model to other people [but I was not admitted].

The experience of previously being denied admission to a four-year institution heightened students' sense of risk, motivating them to apply to multiple four-year institutions in their initial attempt and to perfect their transfer admission applications. For example, Daniel, who was majoring in computer science, attended community college after having his initial acceptance to a four-year institution from high school rescinded because he did not pass calculus during his senior year. He succeeded in transferring from community college, after applying to five four-year institutions, and elected to attend the university in his home community where his initial acceptance had been rescinded several years earlier. It is possible that the experience of past admission failure could have provided a basis for and incentivized transfer capital development during community college, functioning in effect as an asset among these students.

Due to financial constraints, family commitments, and personal preferences, a central concern for most students in the study was gaining admission to a *specific* four-year institution in their STEM major. For nearly half the sample (41%), proximity to family and home community was the primary reason for choosing a particular transfer destination. In terms of timing, nearly all the students applied for vertical transfer admission to a four-year institution after completing an associate degree or 60 transferrable credits, for reasons driven by student finances, institutional transfer admission criteria, and state transfer policies. However, in neither state

context did policies ensure that transfer students would be admitted into their preferred four-year institution or major. From students' point of view this meant that securing transfer admission to their chosen four-year institution and major was "a competitive field," as characterized by Ellen who aspired to transfer to her local four-year institution in biology. In addition, despite transfer destination preferences, as described previously, it was common for students to apply to multiple four-year institutions as a tactic to secure transfer admission. Nearly half of the study participants (48%) applied or planned to apply to multiple four-year institutions.

Ambiguities of transfer admission application timing in STEM

Successfully navigating transfer admission meant that students had to secure entry to both a STEM major and an institution. This required that they know, take, and pass the correct general education and major-specific courses as well as prerequisites to those courses. For STEM majors this meant getting "on track" early in their community college especially in math, which is highly sequenced and provides entry into other required STEM courses. However, getting on track early could be slowed by entering into the math sequence below the level expected in a STEM curriculum, which is a well-documented problem in STEM majors (e.g., Cohen & Kelly, 2020) and was common among students in the study. Getting on track early could also be slowed by a lack of access to career information, which students needed to hone and confirm their choice of major (author). Consistent with previous research (e.g., Grote et al., 2021; Packard et al., 2012), the highly sequenced nature of STEM curricula could also cause delays for students, especially those in technical majors requiring interrelated prerequisite and required courses in mathematics, chemistry, and physics. Since their community colleges did not offer every course each term, students sometimes had to wait a term or a full year to register for needed courses, which because of high demand could be difficult to enroll in even when offered.

These STEM-specific curricular pacing complexities added time to many students' duration of community college studies and caused some to accrue credits beyond those necessary to complete an associate degree. Although numerous personal and institutional factors likely contributed to students' duration of community college study (including, especially, developmental education coursework in math), it was notable that at PCC the range of time that students in the study spent there was three to seven years, with two-thirds of the students taking four years to complete. In contrast, at ACC, stricter state policy regarding credit accrual was evident in the fact that students took closer to an average of two-and-a-half years to complete their associate degree. While the pattern at ACC was more efficient in terms of time-to-associate-degree and costs, as elaborated below, the longer duration of study at PCC corresponded to students more consistently having taken prerequisite courses necessary to secure transfer admission in a STEM major.

Curricular pacing complexities created ambiguity over associate degree completion and transfer timing, with students sometimes completing sufficient credits to earn an associate degree but still lacking necessary courses or performance levels to secure transfer admission. Moreover, these problems compounded when students planned to apply to multiple four-year institutions. For example, Mariella, a chemistry student, gained transfer admission to a four-year institution after earning 90 credits at her community college. Mariella recounted how meeting multiple sets of admission criteria to ensure that she was competitive resulted in four years of study at her community college. In the reverse, a computer science student's experience demonstrated the risk that STEM students navigated in timing their transfer applications and meeting admission criteria. This student, Nick, lacked one major prerequisite course, but still applied to his local four-year institution. He described his experience being denied admission:

> I got an email [that said I didn't get in]. But I was expecting that answer, because I'm missing one class and they don't accept classes over the summer...So that's what I assume it was because I didn't have all the classes completed.

Nick couched his failure in the complexities of meeting prerequisite criteria in his major for the multiple four-year institutions that he planned to apply again to, further explaining:

> When I started [at community college] I didn't know where I wanted to [transfer]. So, there's some difference between [the two local four-year institutions that I am applying to]. They have different classes [that they require] for each school that makes it a little bit complex...So, for example, I think for [one university] I don't need Calc 3, but I do need it for [the other]. I think, for that one I don't need Differential Equations, but for [the other] they do require it. I'd rather just take all of them.

Taking all possible courses that were required to gain admission to one of these two four-year institutions in his STEM major contributed to Nick accruing more than 80 credit hours at his community college.

Like Nick, two of the three students in the study who completed their associate degree but had not yet applied for transfer admission had gaps between the courses that they had taken as part of their associate degrees and the prerequisite courses required for transfer admission into their intended institution and major. Notably these gaps and their implications were not entirely evident to the students themselves prior to completing their community college studies, leaving them largely "on their own" (Wang, 2020) and mostly relying on peers to navigate admission planning and application processes. For example, Henry intended to major in computer science and relocated to the town of his preferred transfer destination after completing his associate degree. Relying on his girlfriend for transfer admission advice, Henry was aware that he lacked a

substantial number of prerequisite courses for admission but resisted paying out-of-pocket to take them due to a perception that, "I'm not going to use them." Henry also believed that he could take the courses after transferring, despite the departmental website at his intended transfer destination clearly describing them as pre-admission requirements.

The other student, Charles, was the first in his family to complete an associate degree. Charles planned to apply to a local four-year institution to pursue computer engineering. However, securing transfer admission to his intended major required completion of at least Calculus I prior to entry and Charles had only taken Algebra at his community college. He also lacked most of the higher math and physics courses listed in the institution's pre-engineering sequence as "preferred" for completion prior to admission. Charles' transfer admission success will also require relaxation of a criterion requiring applicants to "earn a grade of C- or better on the first attempt of General Physics," which unfortunately Charles failed when he first took it in community college. Although Charles retained his goal, like Henry, his transfer success will be contingent on the four-year institution flexibly applying transfer admission criteria or proactively working with Charles to help him meet entry requirements or adjust his goals.

Seeking second chance transfer admission during community college

Four of the students in the study (14%) did not gain admission to transfer to a four-year institution the first time that they applied from community college. In response, these students mostly waited and applied again to the same institution or an expanded pool of institutions the following year, using the time to rectify what they understood to be weak or missing from their applications. However, figuring out what presented a weakness in their applications was not always transparent to students.

For example, after failing to gain entry in biology at her four-year institution of choice, Erika waited a year to apply again, taking additional courses to boost her preparedness and overall GPA (and, in the process, accruing credits beyond those necessary for an associate degree). When she reached out for feedback from the admission office at the four-year institution her denial was framed in terms Erika's need to meet *required* as well as *recommended* institutional criteria. Her experience illustrated how confusion and contingency can be built into transfer admission criteria and decision-making, giving flexibility and power to admission officers at four-year institutions and credence to student views that the transfer admission process is risky and uncertain. She described encountering confusing inconsistencies in university sources of information about GPA admission criteria:

> When they rejected me, I called them. They told me that supposedly for my major the lowest [GPA for acceptance] was 3.4. And I had a 3.0, so I was below that. But on their website, it says the minimum requirement is 2.8.

Through her admission failure Erika also gained transfer capital in the form of insider knowledge about the distinction and consequence of recommended versus required transfer admission criteria. As she recounted:

> Then they told me that I was still missing a couple of classes, which also on their webpage says that they're not required for transfer. I mean it's better [i.e., recommended] if you have them, but they're not required for transfer. But [when I apply] if another person has those classes, then I'll be at a disadvantage. So that's what they told me.

Based on additional insider knowledge and interpretive support gleaned from her community college advisor, Erika came to further understand that she had been denied admission the year

before because of heightened competitive conditions brought on by the high number of transfer applications received at her chosen transfer destination that year.

When Erika was ready to apply for transfer admission the second time the following year, her advisor encouraged her to apply to an additional four-year institution. However, because of different transfer admission requirements for the biology major, applying to the second institution would have required Erika to take more advanced chemistry courses to meet that institution's criteria. Perceived being caught in a catch-22, Erika was hesitant to take those additional chemistry courses for fear that her performance in them could cause her overall GPA to decline and therefore make her less competitive for transfer admission.

Luis, a first-generation college student in computer science, was the third student in the study, in addition to Henry and Charles, who had completed his associate degree but not yet successfully applied to transfer. Luis floundered for several semesters, aware of his lack of understanding of the admission process, yet hesitant to seek support from advisors or faculty members at this community college, "because I have to learn it myself." When he first applied for transfer admission to his preferred, local four-year institution after completing his associate degree, Luis learned he was lacking two prerequisites, Statistics and Linear Algebra. He maintained his community college enrollment, took the courses, and planned to apply again a year later. Notably, the formal online guidance provided by his chosen transfer destination indicating that these two courses were required was the university catalogue. The catalogue listed these courses among more than a dozen pre-major courses for all students (regardless of entry or admission status), rather than providing an explicit list of courses required to be taken in community college before applying for transfer admission.

In his second round of applying for transfer, Luis initially resisted his advisor's urging that he apply to four-year institutions away from his family and home community. This option became more feasible when his aunt who resides in another part of the state offered that Luis could reside with her if he gains admission to a four-year institution in her geographic area. Although somewhat more confident in the application process after going through it unsuccessfully a first time, Luis felt that a "roadmap" of the process would have helped. He still hesitated to seek help from advisors or others at his community college for reasons that he himself seemed to not entirely understand: "That's been something for me all my life, really. I guess it's just a stubbornness, a stubbornness that I should be able to do it by myself." When he was last interviewed, Luis was planning to work on his computer programming skills as he began the lengthy period of waiting to hear back about admission decisions.

Insider knowledge and support as assets in the admission process

As Erika and Luis' cases illustrated, vertical transfer admission success in STEM could require community college students to navigate competitive dynamics, meet multiple sets of major and institutional admission criteria, and adjust their transfer destination choices with each possible transfer destination entailing its own suite of required and recommended courses for admission to STEM majors. Through formal supports at their community colleges, trial-and-error, and happenstance, over time many students in the study gained informal knowledge about the subtleties of transfer admission and how to become a more competitive applicant that contributed to students' eventual success. For example, Christopher discovered information about transfer requirements, the average GPA of those admitted, and transfer rates on the websites of several four-year institutions. This had not previously been a self-evident source of information to him, and he wished "someone" at his community college had pointed it out to him sooner.

From these websites Christopher also came to understand the difference between *required* and *recommended* courses for transfer admission to his major and the competitive implications of this distinction. This insider knowledge had similarly not been obvious to Christopher.

In other cases, students in the study attributed their accrued knowledge about vertical transfer admission to the support of institutional agents at their community college or, more rarely, at their intended transfer institution. One community college in the study held regular workshops for students who were applying for transfer and transfer advisors gave students advice about course selection and transfer application timing. Lidia, who succeed in transferring in biology, received a substantial amount of personalized support from the four-year institution she applied to. Having someone at her intended transfer destination who was available to simply answer her phone calls and respond to her questions as needed was extremely helpful to Lidia during the application process, as she recalled:

> [When I was close to transferring] I was definitely not ready. I didn't have all the information that I thought I [needed]...But the communication [with the four-year institution] was really good. I called them all the time and they explained to me what steps I have to take or what is missing...I could call them anytime for simple things that I was supposed to know but I didn't, and they explained each step.

Institutional agents also gave students strategic advice about overcoming bureaucratic hurdles in obtaining the courses that they needed to be competitive for transfer admission. At one community college, for example, an advisor helped Franco avoid curricular misalignment by suggesting that he take specific biology courses at a different community college. In another case, Lara, also a biology student learned that her local preferred transfer destination expanded transfer admission openings for the spring semester to transfer students in the local area through

her special program scholarship advisor, who Lara said had better connections to the university and therefore better access to insider information about this opportunity than advisors elsewhere.

Despite the clear benefits to students of supportive institutional agents during the transfer application process, admission criteria and policies at four-year institutions in STEM majors could be subtle and transitory, causing confusion not only for students but also for institutional agents at community colleges who sought to support students. One biology student described how the requirements for transfer admission to his local transfer destination had changed over the four-year period that he spent at community college, with the former advanced calculus requirement shifting to a required statistics course. Students and community college advisors benefitted from access to institutional agents at four-year institutions during the admission process. However, both advisors and students could encounter a lack of responsiveness and subtle discriminatory bias when they reached out, as Jessica, an aspiring engineer, recalled:

> [My advisor] called up [two private universities] for me during our meeting. She asked, 'What does my student need to do to get in your school?' What the school said was basically what was on their website. And they said, 'We don't have a big transfer rate from community colleges, which I'm sure you know...It's all there.'

Community college students' STEM pathway progression could also be confounded by state transfer policy. Nearly half of the students in the study at ACC were unable to complete major prerequisite courses for admission into their intended STEM majors at a four-year institution within the credit accrual allotment (60) that state policy allows for completion as part of a transfer associate degree. This led students to pay out-of-pocket to take major prerequisite courses after completing their associate degree but before gaining admission to a four-year institution. An aspiring computer scientist, Pete, had to rationalize his "high number" of accrued

credits as part of his transfer admission application. Ironically, Pete perceived that his success in advanced placement courses in high school constrained his ability to rely on financial aid to meet course requirements for transfer admission. Still distressed at the time of his third interview in the study, Pete explained:

> There is this stupid law about trying to get people in and out of universities as quick as possible...But over half of my excess credit hours are AP classes. It's very upsetting. Because I had no idea what I was going to do when I was 14 in high school. They said, 'Take AP classes because it's college credit.' And I said, 'Okay, I can, so I will.'...Many of those AP classes didn't end up counting for the major that I declared, so they were just automatically tossed in as electives.

Securing admission through deploying transfer capital

As described so far, securing transfer admission to a four-year institution and major was a widespread concern among students, many of whom strongly prioritized gaining admission to a specific transfer destination or had experienced admission rejection from high school (which was the case for six students) or community college (which was the case for four students). Securing transfer was not automatic and transcended the completion of a degree or curriculum, or demonstration of having met minimum admission criteria. Instead, the transfer admission process for many students involved the development and use of transfer capital in the form of planning acumen, trial-and-error learning, finding and interpreting information, adjusting personal plans and goals to new information and circumstances, and coping with failures and unexpected life circumstances along the way. Consistent with Schudde et al. (2021), results provided evidence that gaining transfer admission involved a lot of effort expended over lengthy periods of time by students and their supporters. Students relied especially on advisors, faculty,

step-ahead peers, and family members to help them understand and navigate transfer admission fields. Advisors' insider knowledge was especially important in helping students find and interpret information and its implications, such as the distinction between required and recommended courses for admission, the significance of major-specific transfer admission criteria, and assessment of competitive conditions for a particular transfer destination or major. In two cases, advisors were also instrumental in alerting students to a last-minute opportunity to apply for spring semester transfer admission. Transfer capital in the form of tacit and tactical knowledge about STEM transfer admission helped students achieve their transfer goals and, in some cases, helped them to adapt to a changed goal, especially revised transfer destinations. As the following details, results showed that students used their knowledge about transfer admission to pursue strategies to gain advantage, manage risks, and become more competitive for vertical transfer admission in STEM.

Co-curricular opportunities

For the students who successfully transferred to a four-year institution, gaining transfer admission was not a discrete event and was much more than completing applications. Instead, some described having devoted the entirety of their time in community college planning and preparing for the transfer admission process, including developing their "transcripts," as Mariella, who was majoring in chemistry, described:

> I feel like I'd been preparing all these years. I have applied to [co-curricular] things. I have had the time to make my application very strong in extra curriculars and my essays. Also, I had great mentors at [my community college]. My advisors helped me, and my professors helped me.

Like Mariella, among those who gained admission to a four-year institution there was widespread awareness about the importance of gaining practical experience in the form of internships, undergraduate research, or work related to their major to "be competitive."

However, there was some unevenness between and within the two community colleges in how formally and proactively students were connected to co-curricular opportunities, with some students securing multiple opportunities and others struggling to find just one. Professionally related opportunities on campus were a valuable starting point for many, including students who worked as tutors in STEM at their community college. Charles, who aspired to transfer in computer engineering, had persevered for several years until he finally secured an unpaid position at his community college, as he explained:

> I've reached out to the IT department here on campus for an internship. She told me that I could intern with them, but it wouldn't be a paid internship... I'm so excited because I've been waiting to get into IT work. They finally opened-up the doors for me. Even though it's been, I think about four years. But I'm here now so that's all that matters.

As a first-generation college student from a low-income family background, Charles also worked in food service to support himself and contribute to his family. His perseverance in securing unpaid STEM employment, despite its opportunity cost in time available for paid employment, demonstrates Charles' knowledge of its value as an asset likely to be useful in his STEM pathway progression.

Coursework intensity regulation

Another strategy that students used to increase their competitiveness for transfer admission was pro-actively regulating the intensity of their coursework, with many taking 12 credits a term (the minimum required by Pell and other grants) and only rarely taking summer or other short session

courses. While this tactic was effective in helping students learn and earn acceptable grades and therefore to stay on track to secure transfer admission, it also slowed and extended the duration of time that some spent in community college. Moderating coursework intensity was yet another reason that many students in the study spent four or more years at their "two-year" institution.

The importance of coursework intensity regulation for student transfer success was attributed to the rigor of STEM curricula and the associated time required at the day-to-day level for students to earn acceptable grades. Students described how the amount of time and effort required to be successful in STEM courses was much more than non-STEM courses and was not commensurate with the corresponding number of credits associated with STEM courses. Kai explained that Physics III was only three credits, which did not correspond to the amount of study time required to be successful in the course, especially in comparison to the much lower study time required to be successful in his five-credit Spanish class. Nick described the same situation as applying to math courses:

> I would say that with some classes, the amount of work that they have [does not correspond] to the credits they have, especially the upper math classes. It's a lot of work and they are worth three units, but they should be worth more. For example, psychology class, it’s worth four units. Compare that with Differential Equations. The work, it’s completely different and Differential Equations is only worth three units.

Moderating the intensity of coursework was also an important strategy for students when personal and family obligations arose. Solana, who intended to major in math, sometimes had to work more hours to contribute to her family's income. The need to work directly affected the number of community college courses Solana felt that she could handle successfully:

> [How many classes I take] depends. If I need to work, if my family's struggling financially, I only take [a few classes]. Right now, I'm a part-time student. I've been a part-time student for three semesters. The rest of the semesters, I was a full-time student and before coming to college I took one year off to work.

It should be noted that Solana was a typical aged college student, and that the family she needed to contribute to financially consisted of her mother and sister. In the reverse, Andre, a biology student, learned the importance of regulating the intensity of his coursework the hard way, after failing several classes. In retrospect Andre wished he had been advised to be more cautious since he had had to retake the classes:

> [My advisor] could have just said, 'Wake up, that's not going to happen,' because I tend to over-extend myself and then I've failed classes because of it. She could have said, 'Hey stop, don't even think about it. You know yourself. I know you. It's not going to work.'

As a result of missteps regulating the intensity of his coursework, Andre was fearful that his GPA had dropped to a level where he might not be competitive for admission to his chosen four-year institution, despite his technically having the minimum required GPA:

> I don't want to say [my GPA] out loud. It's a 2.4. It's a downer to the point where I'm kind of scared about getting into [the university] because I still haven't been accepted. The minimum is 2.0. But at the same time, I'm sure there are a whole bunch of applicants that have a better GPA than I do...Hopefully I'll hear back within the next week-and-a-half about the decision because, if they don't accept me, I don't know what I'm going to do.

Managing grades and GPAs

Because of their outsized importance in vertical transfer admission, grades and GPAs were deeply preoccupying to the STEM students in the study. Moreover, the GPA requirements for

transfer admission into intended transfer destinations and majors for many students pursuing engineering and biology were notably higher than other majors. Detailed admission requirements also often specified a required minimum grade (typically a C) in particular STEM courses. Consistent with Wang et al., (2020), grades signaled information to students about the major and career pathway decisions they had made. The stakes associated with the success of those decisions were particularly high for students from low-income family backgrounds, who, like Angie, were highly sensitive to the risks of academic costs:

> Everybody gets their moment of doubting because for me, I got my first B and I was like, 'Okay, it's fine, it's only a B just move on.' Then I got my second B and I was like, 'What's going on here?' Then finally, I got my first C and that's when I was like, 'Okay, what *is* going on?!' I started to doubt myself, am I actually going to make it? It's so much money [to attend school], how much time is it going to take me?

Another student, Bora, who intended to transfer in chemistry, held motivations to earn good grades and succeed that were grounded in his family's recent immigration experience, particularly the sacrifices made by his mother:

> I knew I wanted high grades [in community college]. I was really a different student in high school. I had the worst grades ever, and I was the worst student. Then after my second term here, I just started studying and picking my grades up... I don't know what caused the switch, but after a while I asked myself, 'What am I doing?' All the sacrifices that my mom did because we stayed here. It's just, finding a purpose for myself, I guess.

Although family struggle and sacrifice could motivate students to achieve, family traumas and tragedies in some cases disrupted students' academic performance and could slow their pathway progress. For several students in the study, personal challenges, including a serious illness or

death in the family, residential instability, and transportation problems, took a toll on their grades. In each case, students endeavored to do better, sought understanding from faculty, and eventually accepted grades that they knew did not reflect their talent.

Grades loomed large in students' perceptions of the competition inherent in securing transfer admission, and many gained tacit knowledge that helped them exert more control over their grades. One strategy, described above, was managing the intensity of STEM coursework. A related strategy concerned time management, including "doing enough work, putting in enough time, sacrificing things to get that work done," as described by one student. Another strategy that some students used to gain better control over their GPA was to take challenging STEM courses with less harsh instructors, including enrolling in courses outside their home institution.

In one of the community colleges in our study, physics instruction was informally known among students to be extremely harsh, prompting some to take it elsewhere. For example, during his time in community college, an engineering student learned to "play the game" required to get good grades, although he realized this had little to do with competence in STEM. He came to understand that his performance in a course was contingent not only on his own effort, but that of his instructors as well:

> It’s kind of working the system a little bit. Like the universities, they want GPAs. They want a good GPA and if you can't appeal to that then they will just get rid of your [application]. I would love to just fail everything and really read my textbook and be able to talk with my professors about subjects and get really into it. But it’s like, you can’t fail them...I passed calculus, but failed Physics I. I thought, 'Oh my goodness, this is horrible, I actually failed a college class. It's not good on my transcript.' I took it again, the next semester but with a different professor, and I managed to get to a C.

This student's ongoing struggle to obtain reasonable grades in physics was directly connected to his concern over maintaining his competitiveness for transfer admission, as he further explained his decision to take a second physics course elsewhere:

> ... So, then, I had to take Physics II because I'm in computer engineering, which is basically like electrical engineering. I got to the midterm, I took it, I did fine, but I was just like, 'I really don't want to work this hard and get a C because my GPA is not going to look good, I'm not going to look good, competitively, for universities.' So, I dropped it. The next semester I took it at [another community college] and I got an A. Unfortunately, it was way easier. I was like, 'Are you kidding me, what the heck?' It goes back to being competitive in the college application season. It's like, 'Do you want your transcript to look good? Do you want your GPA to not fall? Then take [physics] somewhere else.' 'But if you really want a good lecture, then stay.'

Two other students at the same community college did not learn this tacit knowledge about how to maneuver through physics and became stymied by it, including one who languished in his community college, semester after semester, with "physics as the only barrier left."

Benefits and risks of withdrawing from courses

Consistent with prior research about STEM majors (King, 2015; Minaya, 2018; Weston et al., 2019), it was common for the community college students in the study to withdraw, fail, and retake STEM courses. Over a third of the students in the study failed and had to repeat at least one STEM course, with several others receiving disappointingly low but passing grades. Yet, most of these students eventually transferred. Grade forgiveness--withdrawing and retaking a course to improve or replace a poor grade--was allowed at both community colleges and was used by students as a strategy to protect or elevate their GPAs. However, one of the four-year

institutions that was a priority transfer destination for some students in the study implemented a transfer admission policy that recalculated the GPAs of transfer applicants to account for withdraws and repeated courses. This had the effect of lowering transfer students' GPAs. Withdrawing late from a STEM course in community college was therefore a strategy that could backfire by harming students' chances of securing transfer admission to some four-year institutions. A biology student, Ellen, gained informal knowledge about this nuance in transfer admission policy, which spurred her to accept grades in the C-range rather than withdraw from a course and gamble on the possibility of earning a higher grade. As Ellen recounted:

> I think the lowest grade I've ever gotten was a C in one of my calculus classes and the first organic chemistry class. I don't have any Ws. I don't have anything lower than a C. [For transfer admission] I know that for the pre-major prep courses you need to have a C-and-above, which I do. The W thing, I don't know if it's a big thing. They tell you it's better to not have them. Because the way that they said it was, if it comes down to somebody who has Cs in everything and no Ws, but you have the Cs and the Ws, then they're going to take the person who has all Cs and no Ws over you. Which makes sense.

Ellen went on to acknowledge, however, that this transfer admission policy might disadvantage students who withdraw from courses for a variety of reasons:

> ...But I personally don't see why Ws would be so bad. I just think Ws do get a negative rap. But it doesn't tell you why a student dropped the class. It's just a W on your transcript. So, we don't know if it was for like personal, really bad reasons, or if they just weren't doing well.

Lidia's experience illustrated this point. Due to her mother's cancer diagnosis, Lidia stopped out of school. She eventually re-registered but was at the time driving four hours a day to campus

and back home to care for her mother. By the end of the semester, she dropped all of her classes, "even the ones I was doing great in," she recalled, because "I just lost my mind." Despite these withdrawals and personal challenges, Lidia eventually gained transfer admission to a four-year institution. A third biology student's experience reveals yet another negative consequence of students' use of withdrawals to protect their GPA as a tactic to secure vertical transfer admission. Angie became stuck in her pathway progression due to fear of earning less than perfect grades, which she foresaw as necessary not only for vertical transfer admission but for her longer-term goal of attending medical school. Angie's experience illustrates the possible trade-off inherent in efficient time-to-associate-degree and need to secure good grades:

> When I started with my harder classes it took me a while to accept that, 'Hey, you're not going to be always getting A's,' because I started to drop from my classes. I said [to myself], 'Okay, I'm not getting an A, I'm getting out.' It was hard for me to accept, you can't be quitting just because you're getting to B in a class, because you're never gonna get out of here. So, I had to refocus and look at the bigger picture. In the end, what I want is to go to medical and I want to get there as quickly as possible, but I also want the best grades I can get before getting there.

Discussion

The results of this study provide fundamental insights into a neglected aspect of vertical transfer pathways: the transfer admission process. Results both confirm and build upon previous studies, shedding light on transfer admission as a source of time and effort expenditure, uncertainty, risk, and complexity for students and their supporters. Literature critiquing community college programming and student indecision as sources of confusion undermining transfer success (Bailey et al., 2015; Deil-Amen & Rosenbaum, 2003; Scott-Clayton, 2011) may neglect

complexities that are sourced in the transfer admission process, which is typically controlled outside of community colleges by four-year institutions that set the rules and norms for transfer (Schudde et al., 2021). Yet, as this study revealed, finding, interpreting, and adhering to transfer admission rules and criteria in STEM majors represented a substantial learning curve and transfer capital gap for many students. In addition to advising support and participation in formal programs such as workshops, students learned insider knowledge about transfer admission by trial-and-error, happenstance, or past experiences of having failed to secure admission to a four-year institution on a first try either from high school or community college. Additionally, although the majority of students in the study were ultimately successful in gaining transfer admission, their experiences and struggles navigating the transfer admission field in STEM suggests that as Monaghan and Attewell (2015) hypothesized, the admission process is at least one of the reasons that many community college students who accrue 60 or more credits do not transfer when expected.

The study results affirmed the need for major-focused vertical pathway investigations and confirmed that features of STEM undergraduate education influence the transfer admission process. In particular, the competitive dynamics found to exist in STEM undergraduate education (Dowd, 2012; Grote, et al., 2020; Riegle-Crumb, et al., 2019; Rodriguez et al., 2012; Seymour & Hunter, 2019) extended to the vertical transfer admission process. The STEM grading penalty (King, 2015; Weston et al., 2019; Witteveen & Attewell, 2020) manifested in student transfer pathways as high levels of student concern and effort to influence their GPAs. The complexly sequenced nature of STEM curricula (Grote, et al., 2021; Reeping & Grote, 2019) were evident in ambiguity in transfer application timing and in instances in which students had missing prerequisite coursework that caused them to be rejected when they applied. Further, STEM

transfer admission criteria appeared to account for some portion of students' excess credit accruals and time-to-completion delays during community college. Relatedly, there was evidence that strict excess credit policy might have the unintended consequence in STEM majors of hastening students' completion prior to taking the courses necessary to be minimally qualified and competitive for transfer admission. Possibly because related literature has not been STEM-specific (e.g., Giani, 2019; Hodara, Martinez-Wenzl, Stevens, & Mazzeo, 2017; Roksa & Keith, 2008), connections between the transfer admission process and excess credit accrual have not been fully investigated and the results of this study might inform future work.

In conjunction with the construct field, transfer capital proved to be a useful framework for answering the research question guiding this study, which was how students succeed in securing transfer admission in STEM. Results confirmed many previous formulations of and results from studies of transfer capital, including the importance of information acquisition about transfer and specific transfer destinations, advising and mentoring support, and pre-transfer academic performance (Grote et al., 2019; Hayes et al., 2020; Laanan et al., 2010; Moser, 2013; Wang et al., 2020). Support identifying crucial information and interpreting insider knowledge (Grote et al., 2020) was especially important but was often not available to or used by students.

The value of transfer capital in the form of knowledge about admission and practical strategies was evident in helping students to navigate competitive and often labrinyth-like transfer admission fields (Morris & Cox, 2016). Indeed, very little of what students experienced about transfer admission resembled transfer's frequent characterization as something that is guaranteed or follows automatically from timely, rational student choices. At the same time, some strategies that students relied on could have contradictory effects. The importance of GPAs to securing transfer admission in STEM led many students to take a low intensity of coursework

or to withdraw from courses rather than risk a low grade. Although both strategies could bolster students' competitiveness for transfer admission, they could also backfire, such as when transfer admissions policies involved recalculating students' GPAs to account for withdrawals. Similarly, to increase the chances of securing admission to at least one transfer destination, many students applied to multiple four-year institutions. However, consistent with previous research (Handel, 2013) this strategy created complexity for students who had to discover and take multiple sets of courses for transfer admission, which could extend the time and costs associated with community college as well as pose risks for maintaining a competitive GPA.

In addition, it was not uncommon for students in the study to face unexpected personal and family challenges over the time they spent in community college. These challenges sometimes coincided with and delayed progress toward applying for transfer admission, especially when students' grades and ability to maintain enrollment were affected. Because transferring to a local four-year institution in proximity to family and home community was important for many students, several who were initially denied admission to their preferred local transfer destination waited a year to apply again and resisted applying to an institution in another part of their state. It is possible, therefore, that not gaining admission to a *specific* local four-year institution and major might also account for why some portion of community college students who earn 60 or more credits do not transfer (Monaghan & Attewell, 2015) as well as why some excess credits are accrued. Relatedly, consistent with recent research (Jabbar et al., 2017), findings from this study indicated that gaining admission to a specific transfer destination, typically in their home community, was important for students from ethnically and racially minoritized and low-income backgrounds, largely because of the need to maintain supportive

family and community ties, continue to make contributions to family well-being, and reduce the financial burden and risks associated with moving to a new location.

Conclusion

Areas for future research

The results of this study indicated that fuller understanding of the barriers and opportunities influencing students' transfer pathway experiences as well as sufficient predictive modeling of factors explaining disparities in transfer outcomes can be strengthened by explicitly incorporating the transfer admission process, operationalized both as a student level phenomenon and as a set of contextual and institutional conditions. The vertical admission process itself warrants further study in a wider array of major pathways and institutional, geographical, and policy contexts. Simply describing the variability in how transfer admission is configured and implemented would be useful, including how state policies influence both students' transfer admission outcomes and institutional transfer admission practices.

The current study identified numerous transfer admission case scenarios that occurred among STEM students as well as several strategies used by students to bolster their competitiveness. It is unclear, however, how complete or widespread are these descriptions, which suggests the need for future student-centered research. For example, how common is it for students to complete their associate degree without having taken courses required to secure transfer admission in their major; how do students address gaps in their qualifications and competitiveness for transfer admission; and what institutional practices mitigate these problems and bolster more equitable access to limited access majors?

In addition, it would useful to understand how administrators and faculty understand vertical transfer admission processes, criteria, and goals. This includes questions such as what

institutional complexities and priorities shape transfer admission processes; what are necessary navigational and advising supports for students; and how do the views of institutional agents compare to those of students?

In comparison to the substantial research base on some transfer policy reforms and programs, such as articulation agreements, credit mobility, and guided pathways, there appears to be close to a void in investigations of dual or joint admission programs, which provide students with simultaneous admission to both a community college and a university (Morris & Cox, 2016). Results of this study suggest that many of the risks and uncertainties that community college students encountered in their navigation of transfer admission in STEM could be remedied by dual admission programming, which appears to be increasing across the country. For example, Connecticut's Transfer Compact and New Hampshire's Dual NH are dual admission policy interventions that address the entire state, while Rhode Island and Massachusetts are incorporating aspects of joint admission into existing programs and agreements (New England Board of Higher Education & Education Commission of the States, 2015). While dual admission into a community college and university may hold promise for addressing many of the transfer admission navigational complexities and risks encountered by students like those in this study, their effectiveness and impact on equity remain unclear and warrant future research.

Implications for practice

Researchers, policymakers, and higher education practitioners could be more sensitive to the possibility that generic transfer models, such as 2+2 articulation agreements and coursework intensity norms of 15 credits a semester, might disadvantage community college students seeking to transfer in STEM and therefore contradict the goal of advancing equity in STEM fields.

Because of the need to succeed, in terms of maintaining a competitive GPA and adequate course grades in rigorous STEM curricula, students in the study tended to take a relatively low intensity of coursework and sometimes had to drop, withdraw, and retake courses. This STEM-centered curricular pace appeared to be one reason that many students spent considerably more than two years in their community college.

Community college students who intend to transfer would likely benefit from larger networks of insiders in both community colleges and four-year institutions who are knowledgeable about STEM curricula and transfer admission criteria and processes. Access to institutional agents and resources in four-year institutions has been shown to benefit community college students who aspire to transfer in STEM (Grote, et al., 2020; Wang, et al., 2021). Four-year institutions could therefore create more means and incentives to bolster faculty and staff participation in this important work. Students in this study benefitted from transfer admission workshops held at their community college, and from supportive advisors and faculty. Access to admission advising could be expanded through incorporation into classroom advising models (Packard, Tuladhar, & Lee, 2013). Online resources such as course equivalency tools and departmental websites were also useful to students but were sometimes discovered only through happenstance or were not fully understood. Students sometimes experienced transfer admission information as contradictory, misleading, or incomplete. Transfer admission information may also have presumed inappropriate levels of prior college knowledge. Community college students who seek to transfer would benefit if four-year institutions routinely implemented some version of Handel's (2013) "deciphering" inquiry, which assesses how difficult it is for students to locate and use available information to plan for transfer. This type of formative evaluation

could inform relatively simple fixes to transfer admission information and guidance by making it more centered in actual student navigational perspectives and needs.

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Declaration of Interest Statement

The author reports there are no competing interests to declare.

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Appendix A

STEM Students Participating in the Study

Pseudonym	College	Major	Background Identities	Status in STEM Transfer Pathway
Christopher	Pacific College	Computer Science	First-generation, Pell-eligible, Latino student	Transferred to four-year institution; expect graduation spring 2022
Solana	Pacific College	Math	First-generation, Pell-eligible, Latina student	Unknown; dropped out of study after baseline interview
Nick	Pacific College	Math & Computer Science	First-generation, Pell-eligible, Asian/Latino male student	Unknown; dropped out of study after baseline interview
Franco	Pacific College	Bioengineering	Pell-eligible, Latino student	Transferred to a four-year institution; expect graduation spring 2022
Jessica	Pacific College	Engineering	Pell-eligible, Latina student	Interviewed three times in community college before dropping out of study
Maria	Pacific College	Chemistry to Psychology	First-generation, Pell-eligible, Latina student	Switched to a non-STEM major during community college, after two-and-a-half years in the study
Daniel	Pacific College	Computer Science	Male, Asian/Pacific Islander student	Transferred to four-year institution; expect to graduate spring 2022
Luis	Pacific College	Computer Science	First-generation, Pell-eligible, Latino student	Completed associate degree; applied unsuccessfully to transfer; applying again to more four-year institutions
Angie	Pacific College	Biology to Italian	First-generation, Pell-eligible, Latina student	Transferred to a four-year institution; dropped out of study after transferring
Leticia	Pacific College	Structural Engineering	First-generation, Pell-eligible, Latina student	Transferred to four-year institution; expect to graduate spring 2022
Lara	Pacific College	Biology	First-generation, Pell-eligible, Latina student	Transferred to a four-year institution; dropped out of study after transferring
Kai	Pacific College	Computer Engineering	First-generation, Pell-eligible, male Asian/Pacific Island student	Transferred to four-year institution; expect to graduate spring 2022
Erika	Pacific College	Chemistry	Pell-eligible, Latina student	Transferred to four-year institution; expect to graduate spring 2022
Javier	Pacific College	Computer Science	First-generation, Pell-eligible, Latino student	Dropped out of study after baseline interview
Lidia	Pacific College	Biology	First-generation, Pell-eligible, Latina student	Transferred to a four-year institution; completed degree in December 2021
Zoe	Pacific College	Math	Pell-eligible, Latina student	Unknown; dropped out of study after baseline interview

Ellen	Pacific College	Biology	Asian/Pacific Islander, female student	Dropped out of study after baseline interview
Mariella	Pacific College	Chemistry	First-generation, Pell-eligible, Latina student	Transferred to four-year institution; expect to graduate spring 2022
Malcolm	Atlantic College	Switched from computer science to education	Black, male student	Switched out of STEM after two interviews
Ann	Atlantic College	Biology	First-generation, Pell-eligible, White, female student	Transferred to a four-year institution
Pete	Atlantic College	Computer Science	Pell-eligible, White, male student	Transferred to a four-year institution
Henry	Atlantic College	Switched from Biology to Computer Science	First-generation, White, male student	Completed his associate degree; taking pre-requisites as non-degree student and planning to apply to four-year institution
Ken	Atlantic College	Computer science	Non-traditionally aged, White, student	Switched to business while in community college.
Andre	Atlantic College	Biology	Pell-eligible, Black, Latino student	Transferred to a four-year institution
Charles	Atlantic College	Computer Engineering	First-generation, Pell-eligible, Black male student	Completed associate degree but has not yet applied to transfer to a four-year institution
Bora	Atlantic College	Chemistry to Exercise Physiology	Pell-eligible, Turkish-American, male student	Transferred to a four-year institution; switched pathways
Callista	Atlantic College	Biology & paralegal certificate	Pell-eligible, white, female, first-generation college student	Unknown; dropped out of study after baseline interview
Jennifer	Atlantic College	Biology	Latina student	Transferred to a four-year institution
Adriana	Atlantic College	Mechanical Engineering	Brazilian-American, female student	Transferred to a four-year institution; expected to graduate December 2022

Note. Since students are pursuing vertical transfer, first-generation college status is defined as those whose parents/guardians have not completed a bachelor degree.