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Developmental Mathematics and the Community College STEM pipeline

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The Community College STEM Pipeline and Developmental Mathematics

Abstract

Earning postsecondary credentials in science, technology, engineering, and mathematics (STEM) fields is often touted as a means to improve individuals' labor market outcomes, yet little is known about community college students who enroll in STEM programs and, in particular, those whose math skills upon college entry may be questionable for successful engagement in STEM coursework. Most postsecondary research on STEM fields has focused on four-year colleges, despite the fact that nearly half of all undergraduate students are enrolled at community colleges. Furthermore, although research has revealed that nearly 70 percent of community college students are referred to at least one developmental (or remedial) education course, it is unclear how this influences STEM credential receipt. As a first step in examining these issues, this paper describes characteristics of students who earned STEM credentials in one state community college system over eight years. Particular attention is given to developmental mathematics course-taking among the community college STEM credential recipients in the sample. Findings highlight the importance of understanding the nuanced context of STEM within community colleges.

Introduction

Community colleges are an important entry point to postsecondary education for adults with no previous college education or postsecondary credential, and they generally provide completers with a wage benefit.[1] Some research suggests that individuals pursuing and completing postsecondary science, technology, engineering, and mathematics (STEM) credentials accrue even greater labor market benefits than students in non-STEM fields.[2,3,4] However, the extant research on STEM attainment and labor market outcomes tends to focus on four-year institutions, with little regard for community colleges, despite the fact that these institutions enroll nearly half of all undergraduate students.

In addition, because community colleges are an important low-cost postsecondary option and because they provide developmental education to academically underprepared students, they appear to be well-positioned to contribute to an expansion of the STEM workforce by students from low-socioeconomic status backgrounds.[5,6] Yet even conservative estimates suggest that fewer than 40 percent of community college students complete a credential within six years; the rate of transfer is also relatively low.[7] Among students pursuing STEM programs at community colleges, completion and transfer rates are also low.[8]

A major factor that limits postsecondary STEM credential receipt is poor mathematics achievement prior to college; indeed, nearly 60 percent of students in community colleges are referred to one or more developmental math courses because they are deemed underprepared for college-level math coursework.[9] Hodara[10] has noted that apparent college-level math readiness deficits among students are a result of myriad issues including lack of math course-taking in high school, negative experiences with math, poor mastery, poor math knowledge retention, as well as inaccurate math assessment and placement. While there is evidence that an increase in math

course-taking positively affects educational attainment and earnings up to 10 years later, even after controlling for ability,[11] how this finding relates to students in STEM programs at community colleges remains largely unknown.

Purpose

Research suggests that postsecondary STEM credential receipt offers important benefits to individuals and society. Yet STEM completion has been little studied at community colleges, in part because these colleges have low graduation and transfer rates. Further complicating the matter is variation in what constitutes STEM at four-year institutions and at community colleges. STEM in community colleges represents a variety of programs that range from academic to vocational. It is important to understand what STEM programs are as well as who enters and completes community college STEM programs in order to expand access and success.

Furthermore, given the prevalence of developmental course-taking in community colleges, understanding how such course-taking relates to STEM credential receipt is important. To better understand community college STEM credential receipt and developmental math course-taking among STEM completers, this paper describes STEM community colleges students in one (unidentified) state system over eight years. The primary question guiding this work is: What are the characteristics of those students completing STEM credentials at community colleges, especially with regard to developmental math course-taking?

Theoretical Framework and Prior Literature

Recent work on socioeconomic status in STEM and, specifically, engineering education provides an important lens through which to study community colleges. In addition, human capital theory and cultural capital theory may be useful in understanding the impact of socioeconomic status on STEM program selection and outcomes. Human capital theory[12] suggests that individuals make decisions based on rational choice, evaluating the direct and indirect costs associated with their decisions. This theory acknowledges that the content knowledge, skills, and abilities that students have access to inform decision-making. Students who are referred to developmental math lack math human capital; a student with little math human capital may be less inclined to deeply consider the labor market benefits of taking additional math courses or completing STEM credentials.[6,13] Alternatively, students with more math human capital may be more likely to choose programs with math requirements because of the perceived labor market benefits. However, student conceptions of the costs and benefits of attending college (and choosing programs of study) are not uniform across groups.[14]

Bourdieu's[15] conception of cultural capital is a useful complement to human capital theory in this case. Cultural capital theory posits that students enter schools with varying levels of relevant cultural capital (i.e., information, skills, and tastes), dispositions, and attitudes. Given that only the cultural capital that is valued by the institution will be rewarded, it is necessary for underprepared math students to understand the value of college-level math *and* actively use this information to achieve postsecondary success and positive labor market outcomes. Yet, Bourdieu and Passeron[16] have noted that while all students possess some form of cultural capital, those from higher social classes (e.g., those whose parents have more education, higher paying, and

more prestigious occupations) have more relevant cultural capital *and* are able to leverage it more effectively to navigate educational pathways. Community college students in need of math developmental education may lack those dispositions or preferences that would orient them toward choosing and succeeding in programs with stronger math requirements.

Socioeconomic Status and STEM

Socioeconomic status (as measured by income) appears to be major barrier for access to and success in postsecondary STEM programs.[17,18,19,20, 21, 22] In fact, Lundy-Wagner and colleagues[18] concluded that there are very few students from high-poverty high schools who eventually pursue engineering bachelor's degree programs, making community colleges a critical entry point for disadvantaged individuals. While current research in engineering education does not parse out the different types of human or cultural capital that may influence STEM choice and success, this body of research suggests that achievement and information disparities stemming from pre-college socioeconomic factors are not adequately addressed in academic advising, first-year engineering programs, and other interventions.[18] These findings are particularly troubling given the relatively strong value that STEM credentials carry in the labor market.[11]

Developmental Math Education in Community Colleges

Understanding the impact of developmental education is very important for understanding disadvantaged populations and patterns of persistence. However, little is known about the role of developmental education—and of developmental math in particular—on students completing community college credentials in STEM programs.

Postsecondary institutions consistently struggle with questionable college math readiness among students due to myriad factors such as students' negative experiences with math, poor math knowledge retention, and inaccurate math assessment.[10] Yet math is a critical component of many postsecondary STEM programs at both the two- and four-year levels.[23, 24]

According to an analysis by the National Educational Longitudinal Study (NELS),[25] nearly 70 percent of students in community colleges and 40 percent of students in open-access four-year institutions take at least one developmental course. Yet research findings on developmental education have been mixed with small positive, negative or non-significant outcomes[26]. In general, only 28 percent of students attending community colleges who take developmental education courses go on to earn any degree within eight years.[26]

Bahr's 2008 study[27] of more than 85,000 freshmen at over 100 community colleges concluded that 75 percent of developmental math students did not successfully complete developmental education. A nationally representative NELS analysis found that only 30 percent of students pass all developmental math courses attempted.[25] A more recent state-level study of 57 community colleges in 7 states that enroll nearly 150,000 students assigned to three levels of developmental math found that more than 25 percent never enrolled in the first developmental math course, and only 11 percent ever successfully completed college-level introductory algebra.[9] Further, among students who did eventually complete all developmental math courses, most failed to enroll in the gatekeeper college-level math course.

These findings are consistent with the work of Scott-Clayton and Rodriguez,[28] who found that community college students referred to math developmental education were likely to delay enrollment in college, although they also found that most of these students did eventually enroll within three years.

In terms of math courses in general, there is some evidence that math course-taking affects educational attainment and earnings up to 10 years later, even after ability is controlled for.[11] Although some literature on math course taking focuses on STEM credential receipt, most of it is related to bachelor's degree receipt specifically.[3, 4, 29] Overall, the relationship between developmental education and college-level math in the context of postsecondary STEM participation and success among community college students is not well understood.

Research Design

The data reported in this descriptive paper are derived from a state-level administrative dataset that includes more than 30 community colleges that offer a variety of academic and technical programs. The dataset provides basic information on academic/technical program (by CIP code), demographic information, credential type and receipt, educational aspirations, economic indicators, and other related variables.

This paper employs an expansive definition of STEM program so as to include traditional as well as additional relevant community college STEM contexts. Of the 21 CIP codes in which students earned credentials, 10 are considered relevant to the two-year STEM context in this analysis: agriculture and natural resources, allied health, automotive and aeronautical technology, computer and information sciences, engineering and architecture, engineering/science technologies, manufacturing, mathematics and science, mechanics and repair, and nursing. Descriptive analyses are performed to describe students earning credentials in these fields, with specific attention given to developmental math course-taking; where relevant, tests of significance are conducted.

This analysis has important limitations, the most important of which is related to the focus on community college STEM completers. Community colleges have multiple missions, including credential receipt but also non-degree course-taking, which exacerbates low transfer and completion rates. Given the relatively low completion rates in postsecondary STEM fields overall, I focus in this paper only on community college STEM completers (i.e., those who received a credential). As a result, this study does not provide a comprehensive understanding of all STEM students in community colleges. However, this particular sample does allow for an in-depth consideration of those individuals succeeding in STEM at the two-year college level.

Findings

There were 848,711 students enrolled in this state community college system between 2002 and 2010; approximately 12 percent completed a postsecondary credential. Nearly 45 percent of all completers earned credentials in STEM fields. Data on non-STEM completers are provided for comparison where relevant; these students are individuals who earned community college credentials in fields other than STEM.

STEM credential recipients were dispersed across 10 CIP codes (see Table 1 below). Almost half of all STEM credentials were earned in allied health programs (47.2 percent). After that, mechanics and repair (11.3 percent), engineering/science technologies (10.3 percent), and computer and information sciences (9.6 percent) were the most popular STEM programs in this community college system.

Table 1: *Summary of Community College STEM Completions by CIP Code*

STEM CIP Codes	Proportion of STEM Awards
Allied health	47.2%
Mechanics and repair	11.3%
Engineering/science technology	10.3%
Computer and information sciences	9.6%
Manufacturing	5.7%
Mathematics and science	5.4%
Nursing	4.4%
Agricultural and natural science	2.8%
Engineering and architecture	1.9%
Automotive and aeronautical technology	1.5%

Demography

In terms of ethnicity/race, White students comprised the vast majority of community college STEM completers (74 percent). African American, or Black, students comprised approximately 18 percent of the community college STEM completers, and Latina/o students comprised only 2.3 percent.

Sixty percent of STEM completers and 60 percent of non-STEM completers were women. Women comprised the majority of STEM completers; they were overrepresented in allied health (91 percent) and nursing (93 percent) and underrepresented in mechanics and repair (3 percent), automotive and aeronautical (6 percent), and manufacturing (6 percent). Women were also underrepresented in computer and information sciences (34 percent); however, their participation in this field was notably higher than in other traditionally male-dominated fields.

In terms of age, the average age at first enrollment for both STEM and non-STEM completers was 27; however, there were important differences by STEM field. On average, the youngest students were in mathematics and science (22 years) and engineering and architecture (22 years); the oldest STEM completers at enrollment, on average, were in allied health (29 years), manufacturing (29 years), computer and information sciences (30 years), and mechanics and repair (30 years).

High School Preparation

In general, there were relatively small differences among STEM and non-STEM completers regarding the need for adult basic skills courses or the prevalence of high school versus GED completion. The vast majority of STEM completers earned a high school diploma. Among students in automotive and aeronautical technology, 83 percent were high school graduates, compared with 92 percent among mathematics and science completers. Among all STEM completers who eventually earned an associate degree in applied science, only 12 percent had not graduated from high school with a diploma.

Work and Financial Aid

Approximately half of STEM (as well as half of non-STEM) completers held a job while enrolled (measured as employed upon first enrollment), and this varied by program. For example, more than 60 percent of engineering and architecture and math and science completers worked while enrolled. However, only 37 percent of manufacturing completers worked while enrolled. Among STEM completers, those who worked while enrolled were slightly younger, on average, than those who did not (26 compared with 29 years of age).

In terms of financial aid, the estimated average financial need (EFC), state grant, and state loan amount awarded to STEM and non-STEM completers were nearly the same. The average financial need among STEM completers working while enrolled was slightly higher than among those who were not working. The average federal loan per term was higher for STEM versus non-STEM completers ($102 versus $77), and total loan amounts were almost double for STEM versus non-STEM completers ($600 versus $395).

Aspirations and Goals

Often STEM is narrowly conceived of as a program in which community college students transfer to a four-year institution as the obvious next step. Yet in this sample more than half of all STEM completers had the goal of earning an associate degree (55 percent), and only 9 percent had the goal of transferring to a bachelor's degree program. In fact, almost all STEM completers noted that their schooling was related to occupational/vocational training (99 percent); very few associated their education with the goal of improving their job prospects by obtaining a bachelor's degree (7 percent).

There were also important differences in goals by STEM field. For example, engineering and architecture and mathematics and science STEM completers had the greatest intent to transfer (45 percent and 33 percent, respectively), compared with manufacturing and mechanics and repair, where fewer than 10 percent of completers had intentions to transfer.

Developmental Math Education

As noted earlier, a majority of community college students are referred to and take developmental education courses. The highest rates of developmental course-taking among STEM completers in this study were in allied health (53 percent), computer and information

sciences (48 percent), and nursing (44 percent); the lowest rate of developmental course-taking was in engineering and architecture (15 percent).

With regard to developmental math, most STEM completers took developmental math courses *and* passed them. Given that research suggests that developmental course-taking and failure in developmental courses can contribute to attrition,[21] I examine those STEM completers who failed at least one developmental math course. Only 6 percent of STEM completers who took at least one developmental math course ever failed a developmental math course (see Table 2 for a summary by STEM CIP code).

Table 2: *Summary of STEM Completers Who Failed at Least One Developmental Math Course*

STEM CIP Codes	% Ever Failed Developmental Math
Manufacturing	15.1%
Mechanics and repair	12.4%
Agricultural and natural science	9.3%
Mathematics and science	8.0%
Nursing	4.6%
Computer and information sciences	4.6%
Engineering/science technology	4.5%
Allied health	5.3%
Automotive and aeronautical technology	3.4%
Engineering and architecture	0.0%

Of the 10 STEM program types, in only two cases (manufacturing and mechanics and repair) did developmental math failure comprise 10 percent or more of STEM completers in that field. Interestingly, none of the students who completed STEM credentials in engineering and architecture ever failed a developmental math course.

Some student characteristics differed among those who ever failed developmental math and those who did not. There were no significant differences in age between STEM completers who failed and those who did not. However, students who failed developmental math were more likely to also have failed developmental English. The number of college-level math credits attempted and earned was higher among students who enrolled in and never failed developmental math. There was a modest difference in the average amount of financial aid received (and, specifically, federal grants received per term) by students who failed a developmental math course compared with those who never failed one. Students who failed developmental math on average had fewer federal grant dollars ($671 compared to $725) than their peers who took but never failed developmental math.

Credentials

Among students who earned more than one associate degree in the state system, nearly half were STEM completers (44 percent). Only 3 percent of community college STEM completers eventually earned a bachelor's degree. Further, among students who eventually earned an advanced degree, 0.25 percent were STEM completers.

Discussion and Implications

This paper examines STEM credential recipients at two-year public colleges in one state, and it calls attention to the role of developmental mathematics in STEM fields. Given that half of the completers from this state system were in STEM fields, it is clear that community colleges represent a critical pathway for students who wish to earn STEM credentials. In what follows, I discuss important findings about STEM completers.

In the eight-year period covered by this study, the proportion of STEM completers in community colleges was similar to the proportion of STEM completers in the state's four-year colleges. This suggests that the status quo seems to be operating relatively well in terms of STEM credential receipt—perhaps many community college students have the cultural capital needed to choose appropriate STEM fields and successfully complete STEM credentials. The notable proportion of community college STEM students in healthcare (i.e., nursing and allied health), for example, suggests that community colleges and their students understand the value of medicine-related sub-baccalaureate credentials in the labor market that have been promoted for the past 20 years. Nevertheless, given the calls for more STEM-educated workers both nationally and in the state under study here, more research is warranted to understand and support students pursuing STEM fields.

What is more, the fact that the vast majority of community college completers (both STEM and non-STEM) in this study were high school graduates (as opposed to GED completers, for example) suggests that even within community colleges there may be structural barriers to entering STEM. Students who graduated from high school appear to have been more equipped to overcome cultural capital deficits, complete credentials, and choose STEM fields than their peers who earned alternative high school credentials.

The findings also indicate that many of the STEM (and non-STEM) completers worked while enrolled. They also show that age appears to have been a factor in the STEM population, resulting in age bimodality: (1) recent high school graduates and (2) adults over 25. Regarding the latter group, adults may be completing STEM programs to remedy their work status and improve their human and economic capital. Alternatively, students entering community colleges directly from high school may have more relevant cultural capital, making them more likely to choose STEM programs for which transfer is a traditional part of the pathway (e.g., mathematics and science or engineering and architecture). Regardless, characterizing students and age groups in terms of their human and cultural capital may be insightful, given the aspirations for associate and bachelor's degrees, the age distribution of STEM programs, and the prevalence of working while enrolled.

The finding that so many women earned STEM credentials in computer and information sciences is an important one given recent research on the small number of women studying that subject in

high school, taking computer science AP exams, or majoring in the field in four-year institutions.[33] In this analysis, computer science in community colleges may be contributing in significant ways to the proportion of women in the postsecondary STEM pipeline.

This study focuses much attention on developmental education. The more workforce-oriented STEM programs at community colleges appear to have had higher rates of developmental math course-taking, whereas STEM students completing programs that led to transfer to bachelor's degree programs were enrolled in developmental math courses less frequently. In fact, very few students completing engineering and architecture even enrolled in developmental courses, whereas other programs had noticeably higher enrollment rates (e.g., allied health and computer and information sciences). Still, only six percent of STEM completers who took at least one developmental math course ever failed in this area, suggesting that there were some community college students who initially lacked human capital in math but overcame such deficits.

Future Research

This paper provides a partial framework for future research on the community college STEM pipeline, including about how developmental education experiences and outcomes may influence STEM decision-making around major, prerequisites, program length, and workforce placement. More in-depth research is needed to better understand the dynamic role of demography in STEM program choice, with particular attention to age, working while enrolled, and financial aid receipt.

Future research should evaluate the effectiveness of developmental math and examine why students in community colleges choose STEM fields; furthermore, additional work on how developmental course-taking and attrition affects STEM credential outcomes as well as labor market outcomes would also be helpful. Research identifying the presence and size of the potential wage benefits to community college STEM course-taking and credential receipt may indeed be helpful for incentivizing students into these fields.

Future research on developmental math education should also explore the extent to which student expectations and experiences influence STEM aspirations and credential receipt. In terms of research on social class, engineering, and academic advising,[31, 32, 33] there are many unexplored opportunities for using developmental education student advising to encourage students into STEM fields and to direct struggling students to programs or services that can support their progress along a coherent pathway. Recent research suggests that one place to support students is during the intake process, by addressing misperceptions about math placement testing.[34]

Work by Mesa[35] suggests that while many students in community college developmental math courses are eager to become proficient and are optimistic about completing developmental education, faculty may tend to underestimate developmental math student's abilities, motivation, and goals . Thus, understanding the dissonance between student, faculty, and even policy-maker expectations regarding developmental math may be an important step toward improving the policies and pathways related to community college STEM programs.

Finally, although this paper does not address community college STEM non-completers, understanding what happens to students who are diverted away from these programs, especially by way of developmental math courses, may be helpful for understanding the effect that such courses have on the STEM pipeline. In addition, information on students who fail to gain admittance into selective STEM programs (e.g., engineering or nursing) after taking developmental courses is unknown. Though it is known that developmental education can discourage persistence, whether and how developmental students may be redirected to STEM community college programs remains unclear.

Conclusion

Many students enrolled in community colleges (like many of their counterparts at four-year institutions) are academically underprepared for postsecondary STEM programs, especially in terms of associated math skills. Using data from one state, results from the current study shed light on community college STEM completers and provide a glimpse into the relationship between developmental math and STEM credential receipt. Through its description of completers, this study highlights the potential that community colleges hold for increasing STEM credential receipt and transfer. That so many community college STEM completers have taken developmental math courses and still complete credentials is promising. There are community college students who, despite a lack of math human capital, are leveraging their cultural capital to improve their math skills sufficiently and persist through completion or transfer. However, low overall rates of completion and transfer suggest that there is more work to be done.

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