

Promoting Transfer Students' Success through Articulation Agreements: An Empirical Case Study in Mechanical Engineering

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Abstract

The desired diversification of the engineering workforce would benefit strongly from an inclusion of the diverse group of students served by community colleges [1]. However, community college students transfer to four-year-institutions to complete their four-year degrees can be daunting for students. Articulation agreements are one tool that appears to be successful in ensuring transfer students' bachelor's degree attainment rates [2]. Articulation agreements establish course equivalencies and transferability of academic credit within specific engineering major programs to facilitate seamless transfer of students' credit across postsecondary institutions [3]. In this paper, we are investigating how historic changes in the articulation agreement for the mechanical engineering major impacted the 4-year university's success in supporting students' successful graduation using institutional data on student course-taking behavior after transfer. To investigate the impact of modifications made to the articulation agreement, course enrollment patterns of 453 mechanical engineering transfer students that transferred either before and after the modification of the articulation agreement were compared. Results revealed that, while the socio-demographic diversity of the transfer students did not increase, more transfer students were able to graduate within two years after the change in articulation agreement than before the change. An investigation of the course-taking patterns of transfer students before and after the change in the articulation agreement suggested several mechanisms that might have impacted this finding. Strategies such as the reclassification of articulated courses that were not offered sufficiently in community colleges as well as the addition of non-gateway courses to the agreement likely support transfer students' success. In addition to the actual changes made to the articulation agreement, transfer students' success after the change in articulation agreement was likely also dependent on the support provided by the 4-year university. In particular, course offerings at the appropriate terms throughout the academic year and guidance for on-time course-taking for key engineering courses at the 4-year university likely improved transfer students' on-time degree completion. Findings provide important insights for mechanical engineering administrators to help them improve transfer articulation agreements and course scheduling to better cater to the needs of transfer students.

Introduction

The desired diversification of the engineering workforce would benefit strongly from an inclusion of the diverse group of students served by community colleges [1]. However, community college students transfer to four-year-institutions to complete their four-year degrees can be daunting for students. In an effort to support community college students' success in transferring to 4-year bachelor-degree awarding institutions, formal agreements between sending institutions (i.e., community colleges) and receiving institutions (i.e., 4-year universities) have

been established widely throughout the higher education system in the U.S. [3]. These formal agreements are typically called articulation agreements and they establish course equivalencies and transferability of academic credit within specific major programs to facilitate seamless transfer of students' credit across postsecondary institutions [3]. Their purpose is to facilitate transfer, avoid credit loss for courses that students have taken at the community colleges and improve degree completion for students after the transfer. However, research has shown that articulation agreements do not necessarily affect transfer rates [4,5], but that they do help with degree attainment rates [2,6]. This indicates that well defined articulation agreements prepare students sufficiently to successfully complete their degrees.

Nevertheless, the successful implementation of articulation agreements is complicated, as badly defined articulation agreements can increase time to degree leading transfer students to stay at the 4-year university for more than the originally planned two years. For instance, students might be able to transfer credit, but for elective courses rather than for courses in their desired degree program if the articulation agreement is not developed enough [7,8]. This has negative consequences for transfer students as they have to spend more time and financial resources to complete their education.

In addition, articulation agreements are often difficult to understand and navigate for community college students [9]. For articulation agreements to work well, additional advising is often needed not only at the community colleges that need to support students in completing the course requirements articulated in the agreement to ensure they qualify for transfer, but also at the receiving institution [7]. To ensure that students can graduate within two years, immediate guidance on course-taking might be needed to avoid any potential delays in course-taking. Qualitative research into the enrollment management of transfer students at 4-year institutions has shown that managing the course-taking of transfer students at the 4-year university often requires close personal guidance, including the implementations of modifications in course-taking policies to ensure their timely degree completion [10].

In this paper, the success of a transfer articulation agreement in mechanical engineering at a public 4-year university in the Southwest of the U.S. in preparing transfer students to complete their degree at the four-year-institution on time is explored using institutional data on student course-taking behavior after their transfer. More specifically, we are investigating how historic changes in the articulation agreement impacted the 4-year university's success in supporting students' successful graduation in an effort to better understand the underlying mechanisms at work. Thus, we are posing the following research questions:

R1. To what extent does the socio-demographic diversity of transfer students change after the articulation agreement was modified?

R2. How did transfer students' course-taking patterns change after the articulation agreement was modified?

R3. What is the difference in transfer students' time to degree completion before and after the change in articulation agreement?

Methods

Sample

The current study used institutional data from 453 transfer students (16 % Female, 28% Underrepresented ethnic minority, 27 % Low-income, 58% First-generation College-going) majoring in mechanical engineering that transferred from community colleges to the mechanical engineering program at a public 4-year university in the Southwest of the U.S. between the years of 2016 and 2021.

As the 4-year university's existing articulation agreement for the mechanical engineering major was updated in the academic year 2019/2020, the sample was chosen to represent three cohorts of students transferring before the change in articulation agreement (n= 267, Academic years 2016/2017, 2017/2018, 2018/2019) as well as three cohorts of students that transferred after the change in articulation agreement (n= 186, Academic years 2019/2020, 2020/2021, 2021/2022). This allowed for the comparison of student's course-taking patterns and degree completion before and after the change in articulation agreement.

Measures

To be able to investigate the differences in students' course-taking patterns and degree completion before and after the change in articulation agreement, changes in the articulation agreement were identified in a first step.

Articulation agreement for mechanical engineering major. The articulation agreement articulates the specific lower division courses at the 4-year university and their equivalent counterparts at community colleges whose credit can be transferred between institutions. By taking the articulated equivalent courses at their community colleges, students will be able to transfer their credit for the courses taken to the 4-year university and enroll at the 4-year university with junior status. In the articulation agreement courses are classified into four categories: *Required courses for transfer*, *suggested courses for 2-year graduation* (at the 4-year university), *additional major requirement courses*, *additional elective courses*. Only required courses for transfer are mandatory to be able to transfer to the 4-year university. Courses in the three other categories are optional. However, the more courses are taken at the community colleges for credit transfer, the better the chances are for students to be able to graduate on time

at the end of their senior year. This holds particularly true for courses identified in the suggested courses for 2 year graduation category.

The articulation agreement under study was changed prior to the admission of transfer students in the academic year 2019/2020. In particular, two courses that were categorized as *required courses for transfer* previously were moved into the *suggested courses for 2 year graduation category*. The reduction of the required courses was implemented to make it easier for transfer students to transfer at an earlier point in time. In addition, the courses that were moved to suggested courses, a statics course and a computer-aided design course, were chosen as students tended to struggle with follow-up courses to these courses indicating that they might gain from taking these and follow-up courses consecutively at the university.. Thus, fewer courses were required for students to be able to transfer. In addition, one new course was articulated as an *additional major requirement course*, i.e., an economics course, and two new courses were articulated in the *additional elective course* category, i.e., an introduction to engineering course series. This means that overall more courses for credit transfer were articulated. This allowed students to potentially take more credit at the community colleges before transferring, reducing their workload at the 4-year university.

Students' admission and transcript data was used to explore their socio-demographic diversity, course-taking patterns and rates of degree completion.

Socio-demographic diversity. Using institutional data, we measured key socio-demographic characteristics of the students. This included students' gender, whether they were classified as low-income, first-generation college-going or an underrepresented ethnic minority student. Indicator variables were dummy-coded (1=Female/Low-income/First-generation college-going/Underrepresented ethnic minority). In addition, students' ethnicity was assessed. Indicator variables were created for the following ethnicities: Asian, Latinx, Native Hawaiian/Pacific Islander, White (1=Member of ethnic group). Lastly, we assessed the number of community colleges students transferred from to measure geographic diversity as well as their final GPA at their community college as a measure of their academic achievement.

Course-taking patterns. To analyze students' course-taking patterns at the 4-year university, we used their transcript data to identify whether students had enrolled in the courses identified in the articulation agreement during their time at the 4-year university. Identified course enrollments were then classified into the course categories described above. Students' enrollment in any of the articulated courses was seen as an indication that students transferred to the 4-year university without having taken the respective courses at their community colleges.

Degree completion. To assess students' rates of degree completion, three measures were created. Using students' transcript and degree data, we first identified the percentage of students that had successfully graduated. Second, we identified the percentage of students that had

successfully graduated within two academic years of their first enrollment at the 4-year university. Lastly, we identified the amount of time in years that students were enrolled at the 4-year university before they completed their degree.

Data analysis

To answer our research questions, we compared descriptive statistics for our outcomes of interest for two groups of transfer students: the three cohorts of transfer students that transferred before the change in the articulation agreement and the three cohorts of transfer students that transferred after the change. For our first research question (R1. To what extent does the socio-demographic diversity of transfer students change after the articulation agreement was modified?), we looked at the percentage of female, underrepresented ethnic minority, low-income and first-generation college-going students and students from different ethnicities before and after the change in articulation agreement. We also investigated descriptive differences between the groups in the average final GPA at their community college and the number of community colleges students transferred from. For our second research question (R2. How did transfer students' course-taking patterns change after the articulation agreement was modified?), we compared the average number of courses students enrolled in for each of the identified course categories within the articulation agreement for cohorts before and after the change in articulation agreement. To further explore course-taking patterns, we also compared the frequency and timing of students' course enrollment for specific key engineering courses identified in the articulation agreement. For our third research question (R3. What is the difference in transfer students' time to degree completion before and after the change in articulation agreement?), we compared both groups on the percentage of students that graduated successfully, graduated within two academic years of their first enrollment and the average amount of time that students were enrolled before graduating. To test for significant differences between transfer students that enrolled before the change in articulation agreement and those that enrolled after the change, chi-square tests were conducted for categorical variables and t-tests were conducted for continuous variables.

Results

R1. To what extent does the socio-demographic diversity of transfer students change after the articulation agreement was modified?

To investigate any potential differences in the socio-demographic diversity of transfer students that transferred before and after the change in articulation agreement, we compared the cohorts of students that transferred before the change to those that transferred after the change on key socio-demographic characteristics. Findings are presented in Table 1. Significance tests showed significant differences only for some of the socio-demographic characteristics under study. No significant differences between groups were found for gender, underrepresented ethnic minority status or ethnicities (i.e., Asian, Latinx, Native Hawaiian/ Pacific Islander, White students).

While no difference by low-income status was found, a significantly lower percentage of transfer students after the change in articulation agreement were first-generation college-going students compared to the students that transferred before the change ($\chi^2 (1, N = 453) = 30.252, p < .001$). In addition, transfer students after the change ($M = 3.58, SD = .22$) had a significantly higher average community college GPA than transfer students before the change ($M = 3.49, SD = .28, t(451) = -3.690, p < .001$).

Table 1. Descriptive statistics of socio-demographic characteristics of transfer students before and after change in articulation agreement

	Cohorts before change (n=267)	Cohorts after change (n=186)
% Female	16	16
% URM	26	31
% Asian	42	33
% Latinx	18	21
% White	29	33
% Native Hawaiian/Pacific Islander	4	7
% Low-income	28	25
% First-generation college-going	69	43
Average community college GPA (M(SD))	3.49 (.28)	3.58 (.22)
N of community colleges represented	72	53

R2. How did transfer students' course-taking patterns change after the articulation agreement was modified?

To investigate any potential differences in course-taking patterns between students that transferred before and after the change in articulation agreement, we examined the average number of articulated courses taken at the 4-year university. Table 2 presents the average number of articulated courses taken by course categories identified in the articulation agreement. The average number of *required courses for transfer* taken by students at the 4-year university are minimal, as the completion of these required courses at the community colleges is mandatory for transfer. It appears, however, that a small number of students did retake some of the required courses with significantly more students doing so before the change. With regards to the courses that were reclassified from *required for transfer* to *suggested for 2-year graduation* as part of the

updated articulation agreement, transfer students that transferred before the change took at least one of the two articulated courses at the 4-year university despite the courses being required for transfer at the time. This means students retook at least one of the courses despite already having taken the course at the community college. After the change, transfer students took significantly fewer courses with an average of less than one course. For the two course categories *suggested for 2-year graduation* and *additional major courses for all cohorts*, transfer students after the change in articulation agreement took significantly fewer courses than those before the agreement. However, for both course categories, transfer students in both groups took at least half of the articulated courses at the 4-year university. For the one additional major course added as part of the updated articulation agreement, at least half of the students took the course at the 4-year university. Almost none of the students before and after the change took the articulated courses in the *additional elective course* categories at the 4-year university. This indicates that they successfully completed their requirement to complete these non-major-related courses that are required for graduation in the major at the 4-year university before their transfer from their community colleges.

Table 2. Frequency of course-taking for articulated courses before and after change in articulation agreement

Type of Course	Number of articulated courses	Cohorts before change (n=267) M (SD)	Cohorts after change (n=186) M (SD)	Difference test
Required for transfer all cohorts	14	0.30 (.71)	0.06 (.30)	t(451) = 4.270, p < .001
Required before change/ Suggested for 2-year graduation after change	2	1.12 (.93)	0.62 (.78)	t(451) = 6.009, p < .001
Suggested for 2-year graduation all cohorts	2	1.52 (.87)	1.19 (.91)	t(451) = 3.822, p < .001
Additional Major Courses all cohorts	3	2.15 (.84)	1.93 (.66)	t(451) = 2.995, p = .001
Additional Major Courses after change	1	0.66 (.50)	0.55 (.52)	t(451) = 2.257, p = .012
Additional Elective Course all cohorts	1	0.01 (.11)	0.01 (0.07)	t(451) = 0.655, p = .257
Additional Elective Courses after change	2	0 (0)	0.01 (.07)	t(451) = -1.199, p = .116

Note. Courses taken include repeat courses.

To better understand the course-taking patterns at play, we further investigated in detail the specific articulated courses that were taken more commonly at the 4-year university: the two courses that were *required before change/suggested for 2-year graduation after change*, the two courses that were *suggested for 2-year graduation* throughout and the *additional major courses* that were articulated either throughout (3 courses) or after the change (1 course). Table 3 shows the frequency at which these courses were taken by transfer students before and after the change in articulation agreement. Transfer students before the change in the articulation agreement took all of the presented courses, with the exception of one course (Thermodynamics course), at a greater frequency than students after the change in articulation agreement. More importantly, there are a number of courses that were taken at high frequency (>50%) by both groups of transfer students. This could indicate a lack of articulated course offerings at the community colleges forcing students to take these courses at the 4-year university.

Table 3. Frequency of specific engineering courses taken by transfer students before and after change in articulation agreement

	Course	Cohorts before change (n=267) n (%)	Cohorts after change (n=186) n (%)	Difference test
<i>Required before change / Suggested after change</i>	Statics course	122 (46)	44 (24)	t(451) = 4.904, p < .001
	Computer-aided design course	155 (58)	67 (36)	t(451) = 4.716, p < .001
<i>Suggested for 2-year graduation all cohorts</i>	Materials science and engineering course	197 (74)	107 (58)	t(451) = 3.668, p < .001
	Electric circuits course	178 (67)	103 (55)	t(451) = 2.447, p = .007
<i>Additional Major Courses all cohorts</i>	Experimental physics course	39 (15)	8 (4)	t(451) = 3.581, p < .001
	Dynamics course	227 (85)	147 (79)	t(451) = 1.653, p = .049
	Thermodynamics course	252 (95)	183 (98)	t(451) = -2.153, p = .016
<i>Additional Major Courses after change</i>	Basic economics course	174 (65)	101 (54)	t(451) = 2.339, p = .010

Note. Bolded courses are prerequisite engineering courses suggested to be taken in sophomore year in degree plan.

In an effort to illuminate how course-taking patterns might contribute to students' successful degree completion given the high frequencies of course taking for some of the articulated courses, we further investigated the timing of course-taking for important prerequisite engineering courses that are suggested to be taken in the sophomore year in the degree plan of the 4-year university (see bolded courses in Table 3). These courses are of special import, as transfer students that have to take these courses after their transfer not only already lag behind students at the 4-year university, but these courses are also gatekeepers for enrollment for future upper division courses and thus are affecting their enrollment options for future terms.

Table 4. Timing of coursetaking for prerequisite engineering courses suggested to be taken during sophomore year in degree plan

	Statics course		Materials science and engineering course		Electric circuits course		Dynamics course		Thermodynamic s course	
	Before change (n=122)	After change (n=44)	Before change (n=197)	After change (n=107)	Before change (n=178)	After change (n=103)	Before change (n=227)	After change (n=147)	Before change (n=252)	After change (n=183)
% Summer Yr 0	0	0	1	1	0	0	1	2	2	2
% Fall Yr 1	69	86	40	53	3	34	56	81	43	77
% Winter Yr 1	25	12	43	34	87	55	33	12	0	0
% Spring Yr 1	0	0	7	9	1	4	7	3	47	15
% Summer Yr 1	2	2	3	2	0	1	1	1	3	2
% After Sumr Yr 1	4	0	6	1	9	6	2	1	5	4

Note. Yr = Year.

Table 4 shows the timing of course-taking for the selected prerequisite courses suggested to be taken during sophomore year in the 4-year university's degree plan for the students that did take these courses at the 4-year university. For four of the five courses, there were significant differences in the timing of course-taking before and after the change in articulation agreement. With the exception of the Statics course, transfer students after the change in articulation agreement took all other courses at an earlier time than transfer students before the change in articulation agreement. For the Electric circuits course, transfer students before the change in agreement took the course either during their second or third term at the 4-year university on average ($M = 2.47$, $SD = 1.56$), whereas students after the change took it during their second term on average ($M = 2.11$, $SD = 2.01$, $t(279) = 1.669$, $p = .048$). For this specific course, the earlier course-taking of transfer students after the change might have been influenced by the extension

of the course offerings at the 4-year university starting in the academic year 2018/2019. Due to the added course offering, transfer students were able to enroll in the electric circuits course in their first term after transfer (Fall Year 1). This change allowed for more advantageous course-taking independent of the specific changes of the articulation agreements. For the Materials science and engineering course, transfer students before the change took the course during their second term ($M = 1.96$, $SD = 1.31$), whereas students after the change took it slightly earlier on average ($M = 1.69$, $SD = 1.15$, $t(302) = 1.779$, $p = .038$). For the Dynamics course, transfer students before the change enrolled in their course either during their first or second term ($M = 1.60$, $SD = 0.92$), whereas transfer students after the change enrolled in the course during their first term at a greater rate ($M = 1.28$, $SD = 1.05$, $t(372) = 3.153$, $p < .001$). For the Thermodynamics course, transfer students before the change in agreement took the course at similar rates during their first or third term ($M = 2.32$, $SD = 1.47$), whereas transfer students enrolled at a higher rate during their first terms after the change ($M = 1.61$, $SD = 1.54$, $t(433) = 4.848$, $p < .001$). For all three courses the higher enrollment rates during their first term are likely due to improved counseling at the 4-year university ensuring their enrollment in these important prerequisite courses at the earliest possible time.

R3. What is the difference in transfer students' time to degree completion before and after the change in articulation agreement?

To investigate any potential differences in time to degree completion between students that transferred before and after the change in articulation agreement, we compared their degree completion rates overall and within two years and their overall time to degree completion. Results can be seen in Table 5.

Table 5. Descriptive statistics for degree completion for transfer students before and after change in articulation agreement in total and by cohorts

	Before change				After change			
	Total (n=267)	Cohort 2016 (n=86)	Cohort 2017 (n=81)	Cohort 2018 (n=83)	Total (n=186)	Cohort 2019 (n=61)	Cohort 2020 (n=66)	Cohort 2021 (n=59)
% Degree completed	94	92	94	95	89	97	92	76 [^]
% Degree completed in 2 years	35	17	40	48	57	59	55	56
Time to degree completion (graduates only) (M (SD))	2.36 (.55)	2.52 (.51)	2.32 (.49)	2.24 (.61)	2.04 (.43)	2.09 (.51)	2.08 (.42)	1.89 (.29) [^]

Note. [^]Data for Cohort 2021 subject to change as only two full academic years have passed.

For two of the three measures, significant differences emerged. No significant difference in the rate of degree completion for transfer students before and after the change in articulation agreement was found. However, transfer students before the change completed their degree within two years at a lower rate than transfer students after the change in articulation agreement ($\chi^2(1, N = 453) = 21.580, p < .001$). In addition, transfer students before the change took more time on average to complete their degree ($M=2.36, SD = .55$) than transfer students after the change in articulation agreement ($M=2.04, SD = .43, t(451) = -4.550, p < .001$). However, as only two full academic years have passed for the latest cohort (Academic year 2021/2022), the data for degree completion in total and the time to degree completion need to be treated with caution as some students are currently still enrolled at the 4-year university. Degree completion rates within two years are, however, final. Lastly, we found an indication that the timing of course-taking is a relevant mechanism for the time to degree completion. We found significant positive associations between the timing in course-taking of the prerequisite engineering courses suggested to be taken during sophomore year in degree plan (shown in Table 4) and the time to degree completion ($r = .18-.42$): The earlier students took these courses the more likely they were to finish their degree at an earlier time point.

Discussion

The current study investigated how historic changes of a transfer articulation agreement in mechanical engineering at a public 4-year university in the Southwest of the U.S. impacted the 4-year university's success in supporting the transfer of a diverse student body, their course-taking and their subsequent successful and timely graduation.

We found that the socio-demographic diversity of the student body was not positively affected by the change in articulation agreement. The transfer students enrolled after the change in articulation agreement were actually found to be slightly less diverse on some of the characteristics of interest. However, the differences found in the diversity of socio-demographic characteristics of students before and after the change in articulation agreement can likely be attributed to the COVID pandemic that was ongoing during the academic years 2020/2021 and 2021/2022. The change in instruction to online instruction affected students' enrollment negatively and can be seen in the overall lower enrollment rate for students in the cohorts after the change ($n=267$ vs. $n=186$), which likely also resulted in a lower diversity of community colleges represented. These changes along with the ongoing economic challenges likely acted as a deterrent for some students. For instance, many first-generation college-going students can not rely as easily on guidance and support from friends and family in their college journey. Thus, the change to online instruction and the resulting lack of in-person support systems might have contributed to first-generation college-going students being less inclined to transfer to the 4-year university.

Findings clearly indicated that more transfer students were able to graduate within two years after the change in articulation agreement than before. The course-taking patterns found in the current study provide important suggestions on why this might be the case and the underlying mechanisms that might be at play. Firstly, the strategies applied in the modification of the articulation agreement might have played a role. Some of the courses that were required for transfer were no longer required, but only suggested for 2-year graduation. Considering the course-taking patterns for these courses, it is likely that these courses were either not offered consistently or at high quality at community colleges. By no longer requiring these courses, students have more time to take other courses that are articulated in the agreement. More importantly, students might also not be forced to retake courses possibly due to insufficient preparation through the courses offered at the community college. Secondly, more courses were added to the articulation agreement that are relevant, but not gateway engineering courses. Articulating as many additional lower division major courses as possible allows students to transfer more credit and subsequently enables them to focus on upper division courses after transfer. However, findings showcase that a well articulated articulation agreement alone is not sufficient for successful and early degree completion at the 4-year university. Success is still dependent on course offerings and appropriate course-taking at the 4-year university. Our findings suggest some important mechanisms that might be able to improve students' time to degree completion. Firstly, the 4-year university should consider offering important prerequisite courses in the appropriate term or multiple terms to ensure that transfer students do not need to delay their course-taking, as was done for the electric circuits course in this case study. Secondly, ensuring appropriate counseling on the timing of when to take important prerequisite courses appears to be key. In this case study, the timing of the course-taking of transfer students in particular for the (thermo-)dynamics courses was improved.

Empirically investigating course-taking patterns could prove to be a useful and important tool for the development of articulation agreements and course offerings in many engineering departments, as it can provide information on which courses are commonly taken, repeated and taken late by transfer students, thus affecting students' time to degree completion. Using this information, articulation agreements can be adjusted as needed and course offerings and counseling guidelines for course-taking can be developed.

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