The Missing Third: The Vital Role of Two-Year Colleges in Shrinking Engineering Education Deserts

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Introduction and Background

Two-year colleges have been shown to provide educational, economic, and health benefits to their surrounding communities. These colleges serve a critical role in post-secondary education by providing transferable starting access to many four-year degree disciplines along with two-year degrees and certificates. Just under half of four-year degree graduates have transferred in courses from at least one two-year college [1], and one of the key factors for making that transition successful is the connections students make with the faculty at their two-year institutions [2]. In addition to college participation and economic benefits (e.g., greater earnings and higher employment, particularly among white and Hispanic people), communities with access to two-year colleges are also associated with health benefits. These health benefits include reduced incidences of smoking, increased exercise, and higher levels of self-reported health [3]. In this paper we focus on the subset of two-year colleges that offer an associate's degree or other significant pre-engineering courses which are transferable to a four-year accredited engineering program. As part of our process, we examined two series of maps and census data. Both series of maps demonstrate the importance of the geographic placement of two-year colleges toward making engineering education accessible and inclusive of all students. While there have been important studies showing how two-year colleges broaden engineering participation for underrepresented groups, including first generation students, non-traditional, and racial and ethnic minorities [e.g. 1], little has been written about the key geographic role two-year colleges hold in expanding access to engineering education.

In the spirit of "food deserts" [4] as places where residents lack access to healthy and affordable food [5], Hillman [6, 7] studied "education deserts" as places where the residents lack access to higher education. Education deserts restrict economic opportunity in a community [8, 9]. Unlike food deserts, where debate over the exact definition continues in the literature [10, 11], Hillman has suggested a unit of analysis (Commuting Zones) and research questions to measure impact [12] of education deserts. Beamer and Steinbaum [13] did a similar study using zip codes as the unit of analysis and factoring in driving time to calculate the concentration index for every area in the United States. This paper follows Hillman's work by applying statistically created Commuting Zones to determine the availability of both lower division and upper division face-to-face degrees in engineering. We term geographic areas without access to face-to-face engineering degrees "engineering education deserts" [14].

Earlier, we made county maps of these data [14], as shown in Figures 1, 2, and 3. Counties shaded purple in Figure 1 contain at least one program accredited by the Engineering Accreditation Commission, which we call our EAC sample. Counties shaded green in Figure 2 contain at least one two-year college (TYC) offering an associate's degree in engineering, engineering technology, and/or pre-engineering, or have significant lower division engineering courses without a formal degree; we call this our original TYC sample; the updated TYC sample is described in more detail below. Figure 3 combines Figures 1 and 2. The counties shaded purple in Figure 3 have at least one EAC sample campus but no original TYC sample campuses.

The counties shaded green in Figure 3 have at least one original TYC sample campus but no EAC sample campuses. The counties shaded yellow in Figure 3 have at least one campus from both the EAC and original TYC samples.

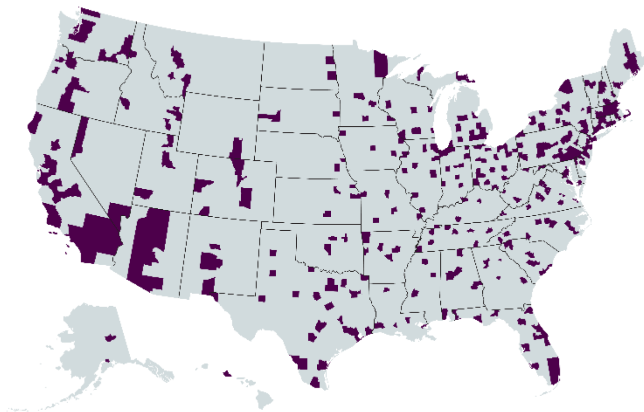

Figure 1. County map of the United States where shaded counties have one or more engineering commission accredited programs [14].

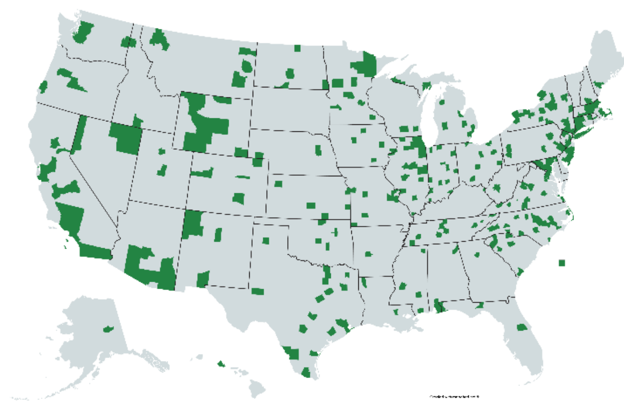

Figure 2. County map of the United States where shaded counties have one or more pre-engineering program [14].

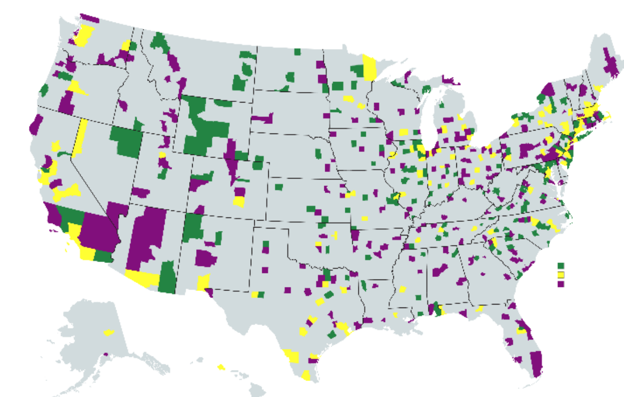

Figure 3. County map of the United States combining data from Figure 1 and Figure 2 [14].

While this illustrates the geographical spread of the engineering education deserts in the U.S., the size in area of U.S. counties varies greatly. Further, it is not clear from the county map where in the county the campus(es) is placed and how many campuses are located in that county.

Expanding the Analysis

Disseminating these data was met by some skepticism from colleagues who told us the non-shaded places are not important because "no one lives there". Additionally, we heard from some of our TYC colleagues that their campuses did not seem to be included. This spurred inclusion of an additional data set as well as two additional forms of analysis: point and radius maps and an analysis of census data. Our national baseline data come from the Economic Research Service of United States Department of Agriculture [15] and is from the 2000 census, which is the most recent available on their website. Our engineering sample is the list of every institution with at least one program accredited by the Engineering Accreditation Commission (EAC) of ABET. It was downloaded from their website (ABET.org) in September 2018. This list contains 428 campuses across the 50 U.S. states and Washington, DC. Our original two-year college (TYC) sample was developed in 2018 by going through the list of institutions in each state on the American Association of Community Colleges web site. For each institution, we looked to see if they had an engineering or pre-engineering program or the necessary pre-requisite classes, e.g., statics, dynamics, multi-variate calculus. This resulted in 323 unique institutions. After feedback from colleagues that some institutions were missing, we added in the lists of engineering associate's degree institutions and pre-engineering programs from the College Board, using their College Search tool (bigfuture.collegeboard.org/find-colleges). On the College Board's site, we found 415 unique institutions. Table 1 shows the breakdown of institutions by search term. When we compared the original TYC sample and the College Board list, we found 534 unique institutions; we call this sample our updated TYC sample. It is interesting to note that only 181 institutions existed in both the original TYC sample and the College Board list. The original TYC sample contains 135 institutions not on the College Board list; the College Board list contains 218 institutions not in the original TYC sample. To classify each institution by governance (public/private/for-profit) and undergraduate degree type (2-year/4-year), we used the Carnegie classification data from 2010 as downloaded from their website (carnegieclassifications.iu.edu).

Table 1. Number of Institutions by Search Term, College Board Search Tool

Search Category	# of Institutions
Pre-Engineering	83
Engineering, General	283
Engineering Science	29
Engineering Chemistry	1
Engineering Physics	2
Engineering Mechanics	2
Engineering / Industrial Management	15
Engineering Design, Engineering Acoustics	0

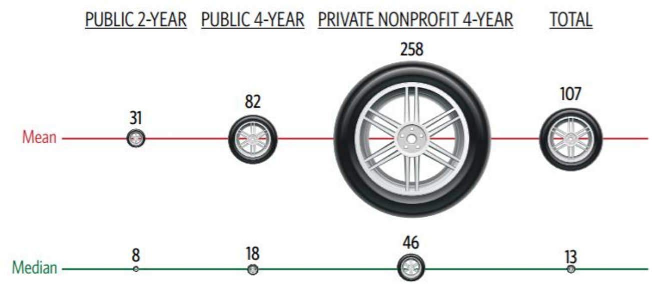

Figure 4. Distance from students' home to college (in miles) by institution type [from 7, page 3]

A point and radius map uses the location of a campus, here listed in longitude and latitude, as the center of a circle with a defined radius. As shown in Figure 4, a national statistical study commissioned by the American Council on Education found the median distance students travel from their permanent address (home) to college to be 8 miles for public 2-year institutions, 18 miles for public 4-year institutions, and 46 miles for private 4-year institutions [7]. Using these median distances as the radii of the circles and matching the institution type using the Carnegie data, we created point and radius maps for our EAC sample, our updated TYC sample, and the two samples combined. Figures 5, 6, and 7 show these samples in point and radius form.

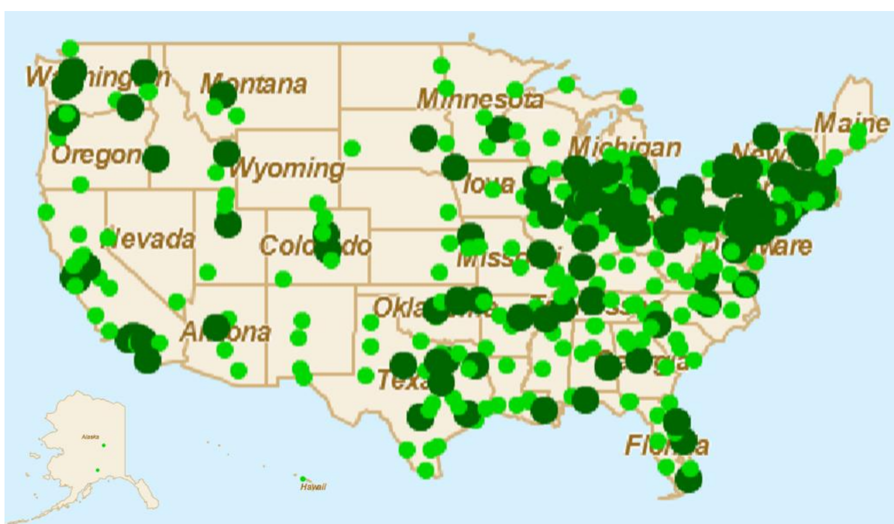

Figure 5. Point and radius map of the United States where shaded circles represent a campus with one or more engineering commission accredited programs. The smaller circles are for public, four-year institutions and the larger circles are for private, nonprofit, four-year institutions.

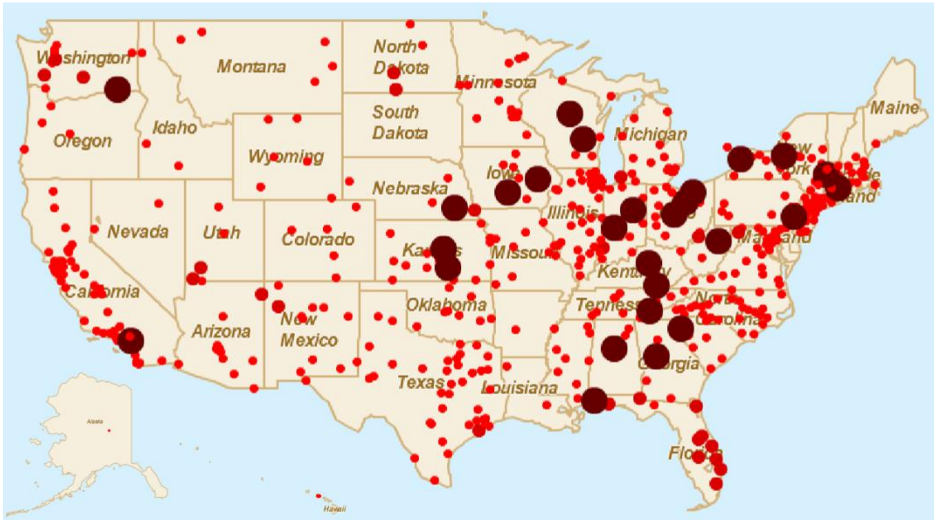

Figure 6. Point and radius map of the United States where shaded circles represent a campus with one or more two-year pre-engineering programs or equivalent. The smaller circles are for public, two-year institutions and the larger circles are for private, nonprofit, four-year liberal arts colleges.

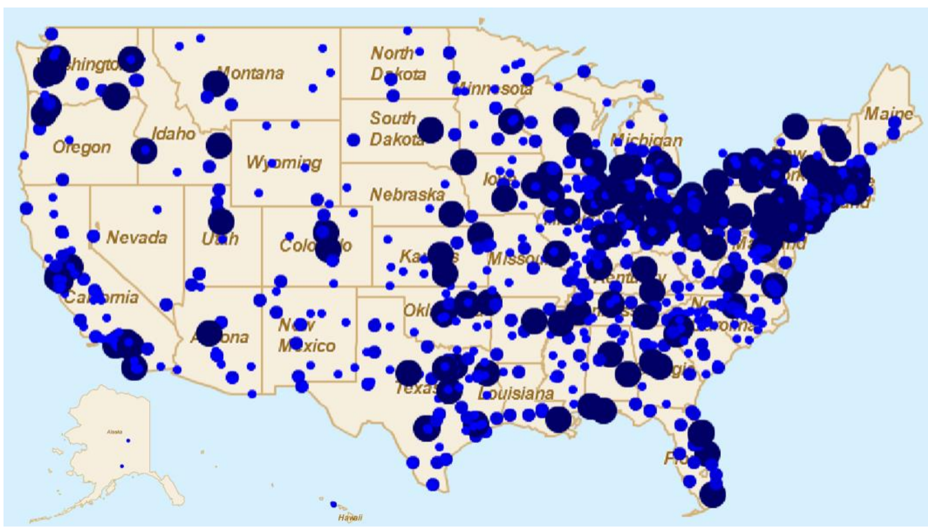

Figure 7. Point and radius map of the United States combining data from Figure 5 and Figure 6.

While the point and radius maps provide a better graphical illustration of the engineering education deserts in the U.S., we used the Commuting Zones and county population data from the 2000 census to delve further into how many people live in counties with or without geographical access to lower division and/or upper division engineering education.

Commuting Zones (CZs) are a statistically developed description of labor markets that have been in use since the 1980s [12]. Unlike other commonly used ways to define local labor markets, commuting zones have two primary advantages: they include all of the U.S. (not just metropolitan areas), and they are based on economic integration by using commuting patterns to group counties [16]. The most popular labor market definitions are Public Use Microdata Areas (PUMAs), Labor Market Areas (LMAs) and the Census Core Based Statistical Areas (Census

CBSA), which are used to delineate the metropolitan and micropolitan areas of the U.S.; all require areas to have a population of at least 100,000 people to qualify. CZs are counties or clusters of counties that share a local economy, focusing on patterns of where people live, learn, and work. The most recent data on CZs available from the Economic Research Service of the United States Department of Agriculture are from the 2000 census [15]; thus, these are the CZ and population data used here. The limited available data from the 2010 census indicate that any changes in the spatial diversity of the U.S. population will have a negligible impact on the conclusions drawn.

To confirm that CZs are an appropriate representation of geographic access to engineering education, we next considered the distance from home (their primary or permanent address) that students travel for college. In addition to the study of miles traveled discussed above, the 2018 CIRP (Cooperative Institutional Research Program) Freshmen Survey found that 56.2% of students in public 4-year institutions travel an hour or less between home and school; nearly 70% travel two hours or less [17]. These percentages have been growing steadily since 1990. Whether we consider time spent driving or distance, these studies indicate that the bounds of a county or CZ are appropriate measures of access to engineering education as a whole and to innovative programs. Access includes from where students are recruited [18], whether they are place-bound, and the geographic access to a program from their 'place'.

We used CZ data for the 50 U.S. states and Washington DC to calculate our EAC sample and our updated TYC sample. We also calculated data from the combination of the EAC and updated TYC samples to show the relative amount of overlap between the two. First we looked at the CZ and county level data, as summarized in Table 2. The number of campuses, number of CZs, and number of counties are the number of unique campuses, CZs, and counties in each sample. The population in each sample category is calculated by adding the 2000 census data population for each included CZ. These data indicate that individuals in 32.39% of the CZs in the country, containing 52.84% of the population, have geographical access to a four-year engineering program. Similarly, 40.70% of CZs containing 55.05% of the population have geographical access to our TYC sample, and 52.11% of the CZs with 69.02% of the population have geographical access to at least one campus in our combined sample. Correspondingly, this means that 30.98% of the population of the U.S. lives in engineering education deserts.

Table 2. Summary of CZ and County Level Data

	Nation-Wide	EAC Sample	TYC Sample	EAC + TYC
# Campuses		428	534	962
# Individual CZs	710	230	289	370
% of Total CZs	100%	32.39%	40.70%	52.11%
# Individual Counties	3141	324	438	617
Population in Sample	281,421,906	148,705,806	154,923,311	194,229,524
% of U.S. Population	100%	52.84%	55.05%	69.02%

We then considered population density by stratifying data into areas that are metropolitan, micropolitan, or neither. Metropolitan and micropolitan areas are determined by aggregating a city and its surrounding suburbs; metropolitan areas must have an urbanized area with a population of at least 50,000, while micropolitan areas must have an urbanized area with a population between 10,000 and 49,999. Table 3 summarizes the data for metropolitan areas, Table 4 summarizes the data for micropolitan areas, and Table 5 summarizes the data for areas that are neither metropolitan nor micropolitan, which we call “rural”. Base data include the number of unique areas, the population of the U.S. living within the areas, and the number of campuses from a given sample in metropolitan, micropolitan, or rural areas. We calculated the percent of sample campuses in each area type, the percent of the area type population in the sample, the percent of the total U.S. population in each area type, and the percent of the population in that area type with geographical access to a sample campus. Rural areas were determined by aggregating the unique counties not assigned to either a metropolitan or micropolitan area.

Just over 76% of metropolitan areas have geographical access to a campus in our combined samples, but that is true of less than 25% of micropolitan areas and less than 4% of rural areas. Nearly all (over 95%) of the individuals with geographic access to engineering education live in metropolitan areas while 82.65% of the entire U.S. population lives in metropolitan areas. In contrast, 95.97% of Americans living in micropolitan areas and 99.32% of Americans living in rural areas are in engineering education deserts. Micropolitan areas contain just over 10% of the U.S. population; rural areas contain just over 7%.

Table 3. Summary of Data in Metropolitan Areas

	Nation-Wide	EAC Sample	TYC Sample	EAC + TYC
# Individual Metro Areas	380	216	220	289
% of U.S. Metro Areas	100%	56.84%	57.89%	76.05%
Population in Metro	232,602,744	145,754,448	148,420,413	185,079,102
% of Total Metro Population	100%	62.66%	63.81%	79.57%
% of U.S. Population	82.65%	51.79%	52.74%	65.66%
% of Sample Area Population		98.02%	96.22%	95.29%

Table 4. Summary of Data in Micropolitan Areas

	Nation-Wide	EAC Sample	TYC Sample	EAC + TYC
# Individual Micro Areas	560	50	92	139
% of U.S. Micro Areas	100%	8.93%	16.43%	24.82%
Population in Micro	28,955,051	2,639,081	5,330,611	7,827,834
% of Total Micro Population	100%	9.11%	18.41%	27.03%
% of U.S. Population	10.29%	0.94%	1.89%	2.78%
% of Sample Area Population		1.77%	3.44%	4.03%

Table 5. Summary of Data in Rural Areas

	Nation-Wide	EAC Sample	TYC Sample	EAC + TYC
# Counties, Rural	1377	9	48	55
% of U.S. Rural Counties	100%	0.65%	3.49%	3.99%
Population in Rural Counties	19,864,111	312,277	1,172,287	1,322,588
% of Total Rural Counties Population	100%	1.57%	5.90%	6.67%
% of U.S. Population	7.06%	0.11%	0.42%	0.47%
% of Sample Area Population		0.21%	0.76%	0.68%

The census data show that 87,192,382 people in the U.S. do not have access to a geographically contiguous lower and/or upper division engineering program. This represents 30.98% of the total U.S. population. Interestingly, of this group lacking access to our EAC and TYC samples, 54.50% are from metropolitan areas, 24.23% are from micropolitan areas, and only 21.27% are from rural areas, as shown in Figure 8. This means that though rural areas in engineering education deserts are the largest geographically, metropolitan areas in engineering education deserts are the largest by population. The inverse is true when the data are examined in terms of the percentage of the overall population within each group lacking access. Here, 93.33% of rural areas, 72.97% of micropolitan areas, and 20.43% of metropolitan areas lack geographic access. It is reasonable to conclude that the lack of geographic access to engineering education is significant in both the metropolitan areas and the micropolitan and rural areas, but for different reasons. In metropolitan areas, large populations mean the overall total number of individuals affected is significant, while in the micropolitan and rural areas the overall total percentage of the population affected is significant.

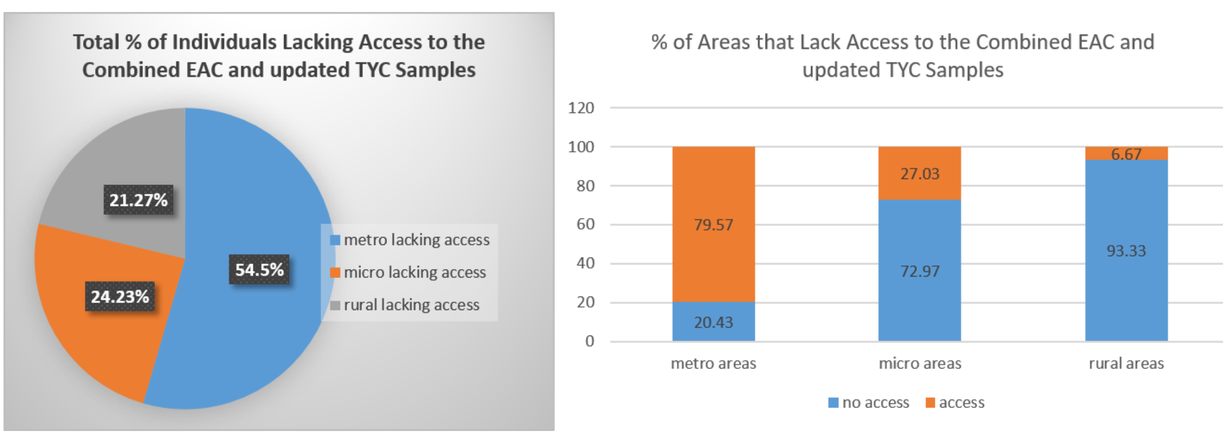

Figure 8. Visual representations of individuals lacking access to campuses in our sample populations.

Discussion

A common factor emerges to illuminate the significance of one out of every three Americans living in engineering education deserts, regardless of their area type: place-boundedness. Students who have barriers, whether perceived or real, to leaving their immediate geographic area [19] are considered place-bound [20, 21]. This is not a new concept [e.g. 22, 23]; however after a bubble of studies in the 1980s and 1990s, this phenomenon has been significantly under-studied since then [20]. More recent studies in this space have focused on connecting the curriculum to a place [e.g. 24, 25], rather than identifying what makes a student place-bound, or more importantly, how to broaden the future options in which they can see themselves. The concept of a student being 'place-bound' grew from the social psychological literature on 'place-dependence', which is the strength, as perceived by the individual, of their association with a particular place [26]. The association strength is the differential between how the individual feels the current place satisfies their needs and goals in comparison to other possible places. This is an absolute difference and does not depend on whether the individual is currently satisfied or dissatisfied with their place. Stronger associations are generally considered to "bond" an individual to the place or environment [27] and are regarded as a positive [28].

The majority of literature looking at the impact of being place-bound on college participation assume that attending college is a single decision made from an economic [e.g., 29], costs vs. risks [e.g., 30], or social, family, and cultural factors [e.g., 31] standpoint. If instead we adopt Hossler and Gallgher's [32] three-stage model of college choice, we maintain our definition of place-bound while opening up additional opportunities to influence the decision-making processes of these students. The three stages are predisposition (wanting to attend college), search (determine the set of potential colleges), and choice (selecting the institution to attend). While there have been some studies investigating the college choice influences in the three-stages, they mostly leave out the idea of place-bound students completely [e.g.,33] or compare only living with one's parents to moving away for college [e.g., 34]. This excludes many non-traditional students by default.

Shields' [20] study of the aspects of place-bound college students' perception of their ability to leave their geographic area for college found perception was related to financial resources, family commitments, attachment to individuals (e.g., family and romantic partners), locus of control (internal or external), and rootedness (associated with emotion toward a place as well as length of association). Rootedness and, for women only, locus of control were statistically significant; both of these factors are social psychological. Further, Shields found that place-bound students do not have an academic disadvantage relative to their peers.

This lack extends into the engineering education literature. Geographic access and/or place-bound students are not a category in the otherwise thorough overview of literature in diversity, inclusion, and cultural awareness in science, technology, engineering and math (STEM) education (sponsored by multiple national organizations and funded through the National Science Foundation) [35]. Literature in STEM education space that discusses place-bound students is largely on new interventions designed as technology has evolved [e.g., 36] and specifically for lab-based courses [e.g., 37, 38]. There is a knowledge gap, however, around the needs and perceptions of place-bound students with limited geographic access to engineering education.

At its heart, the issue of being place-bound has another critical component, one rooted in physical and cultural access. While not all place-bound students live in rural areas, those who do are vested in communities that are very different from urban and suburban environments. They are often characterized by isolation [39], and these communities compensate for that isolation by developing strong interpersonal connectedness and personal relationships. Thus, departure from the rural environment for educational reasons starts them out in a psychological space filled with loss, as in order to achieve levels of higher education they are forced to migrate away from their support network [40]. Burnell [39] interviewed 26 college age individuals in Appalachia and found that “proximity to childhood home, self-esteem, and financial resources were significant positive predictors of life satisfaction.” These are elements that one would need to give up if they were to leave to pursue higher education. Because the cost of higher education is significant, many rural potential students become work-bound as well while saving for school. In Burnell’s study of 26 college-able, work-bound rural students, 0 of 26 planned to attend college right away. However, they shared the characteristic of “goal-directedness”, and those with long-term college plans were either working to raise money for college or doing a vocational sequence with a long-term college goal in that industry.

A similar cause for being place-bound exists amongst metropolitan area populations. The majority of the engineering education deserts in metropolitan areas are located in areas that have already been marginalized due to lack of public transportation, presence of food deserts, historical redlining, and lack of other infrastructure issues; these areas also tend to be home to individuals under-represented in engineering. Similar cultural and socio-economic constraints exist amongst both populations. De Oliver’s [41] case study of the creation and location of the University of Texas at San Antonio, and the results of the LULAC (League of United Latin American Citizens) lawsuit against the state of Texas over the inequities created, illustrates the important role of campus geography to inclusion. In this case, class and race inequities were magnified through disproportionate costs of transportation, on-campus “franchise products” (e.g., food, bookstore), and access to student support and activity services borne by non-Anglo and lower-income students. Costs of transportation were disproportionate due to both the average distance traveled by non-Anglo and lower-income students and the lack of direct public transportation between their home areas and the university. Franchise products are items like food, textbooks, and school supplies that are available through storefronts on campus at a higher price than off-campus; when dependent on public transportation to get to school, shopping around for better prices becomes particularly difficult. Similarly, student support offices are only open during daytime hours and student activities occur outside of class, both of which may be particularly difficult to access when a student must also work and has limited transportation.

To many, the solution for the place-bound student seems obvious – why not just use distance and online programs? For some students, these programs work well and they are able to use the virtual world to connect without leaving their sense of place [42]. There are several accredited engineering degree programs serving this need. However, distance and online programs have disadvantages that limit the population of students who will thrive. Internet access is not equal through the nation, particularly in rural areas, meaning online or distance education will not work in these areas at all. Provided a student has the internet access needed, most distance and online instruction is video and/or reading based with little or no interaction among the students and instructors. This has potential negative effects on: collaborative learning, instructor facilitation, and a student’s ability to seek and receive help in the moment [43]. Further, opportunities for active learning and interactive experiences are limited due to lack of access to labs, equipment, and learning environments specifically designed for interactive learning [44]. There are also minimal opportunities to explore the ‘hidden curriculum’ [45] and support students’ development in areas other than technical content, such as participating in mentoring and the development of social capital, one of the keys to recruiting and retaining low-income, racial or ethnic minority, and first generation college students [46-49]. Being place-bound thus becomes an issue of inclusion and access when place-bound students live in an engineering education desert, which is a geographic region where there is no access to face-to-face engineering education programs.

Conclusions

The geographic spread of two-year colleges throughout the United States makes them a vital link in connecting place-bound students with opportunities for 2- and 4-year degrees in engineering and engineering technology. However, many of them do not offer the two-year foundational classes required to enter the upper division classes and needed to transfer into a four-year degree program. The data show that there is a significant problem for place-bound students in accessing a full four-year engineering degree; even if they are able to complete their first two years in a community college, they will experience the same lack of access in attempting to complete their remaining two years at a four-year institution.

Returning to the three-stage model of college choice [32], we can see opportunities in all three stages (predisposition, search, and choice). The recently launched Bell program has created a solution for the place-boundedness constraint in access to the upper division of the four-year engineering degree. Bell is a new delivery method for the Iron Range Engineering program located in northern Minnesota, offers the junior and senior years of an engineering degree through the department of Integrated Engineering in the Minnesota State University, Mankato (MSU), and was specifically designed to fill this gap. Students complete their lower division courses at two-year colleges around the United States that are located where they are, whether their area is metropolitan, micropolitan, or rural. The students then transfer to MSU where they complete one upper division semester on MSU’s partner campus in northern Minnesota followed by two years of completing their coursework while working as co-op engineers. Their co-op positions can be anywhere in the world, including the area from which the student came. They only need spend 18 weeks outside of the place to which they are bound. This goes beyond initial forays into programs designed for the place-bound, such as the four-year degree in horticulture from the University of Florida that combines distance education with off-campus instruction at three sites around the state [50].

The presence of two-year colleges throughout the nation increases the likelihood that students will be aware of the possibilities of higher education and know people who have taken college classes [3, 49], both of which positively affect their predisposition. Taking that one step further, predisposition for engineering education is positively affected by presence of engineering education and engineers in the student’s community. The search stage has similar correlations, particularly for place-bound students. Knowing that their local two-year college offers the lower division courses needed for an engineering degree, and that opportunities like the Bell program exist to which to transfer their credits opens up new opportunities in the set of potential colleges the student considers ‘available’. These significant opportunities to impact the predisposition and search stages open the door for more place-bound students to access engineering education. We can expand this access impact to more place-bound students by providing resources to two-year colleges to strengthen the network of available engineering education and bridging transfer gaps that impede student success.

Finally, we apply an inclusion lens to consider the implications of our data and interventions that support recruiting and retaining place-bound students. These interventions are both local to a particular college such as curricular elements and student affairs strategies, and broader across the network of two-year colleges, four-year colleges and industry, such as articulation agreements and partnerships in all directions. Explicitly valuing two-year college partnerships with local industry, simultaneously highlights the role of two-year colleges in the economic development of their region and opens the conversation about engineering education deserts to considering pathways to careers for place-bound students.

Future Work

The process of defining and describing geographical access, and lack thereof, is by no means complete. We have identified two primary lines of future work in this area in which we will focus. First, following our observation that only a third of the institutions in our updated TYC sample are on both of our input lists, it is clear that there is a need for a systematic process by which we define what elements an institution must offer to be classified as offering a two-year engineering or pre-engineering option (e.g. some combination of specific coursework, experiences, and/or degrees) and then search every campus of every two-year college in the U.S. to develop a complete list. This data can be used to replicate this analysis for verification as well as for recruitment of students into these programs nation-wide. One of our co-authors represents a team of learning coaches who has begun this work.

The second area of future work is to cross the engineering education deserts data with other data sets of interest. We hypothesize that there may be correlations between access to engineering education and measurable indicators of unintended results of this restriction of access. Potential indicators include access to broadband internet, density of jobs requiring technology skills, and other forms of community demographic data such as ratings of K12 schools and voting patterns.

Acknowledgement

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