Mapping Rural Students’ STEM Involvement: Case Studies of Chemical Engineering Undergraduate Enrollment in the States of Illinois and Kansas

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1. Introduction

Many, including The National Academies\(^1\), President Obama’s Administration\(^2\), and technical industry leaders\(^3\), have recently called for improving the participation and performance of America’s students in science, technology, engineering, and math (STEM) to maintain American technical competitiveness in a global economy. Ralph Cicerone, the President of U.S. National Academy of Sciences, has also advocated improving the STEM “pipeline” and science education saying:

> The reinvigorated research community must also engage the interests of new science students, so that U.S. science can maintain leadership in certain fields and be a strong, reliable partner in many critical international research efforts. That means becoming more deeply involved in improving science education at all levels, including working with pre-college students and their teachers and exposing many more students to real science and scientists. Such interactions can raise the career aspirations of young people.\(^4\)

Thirty percent of U.S. K-12 students attend rural schools, which comprise 40% of all domestic schools\(^5\). Thus, to heed Cicerone’s imperative to “expose many more students to real science,” rural students as a significant portion of the student population should be included in science education initiatives and the STEM pipeline.

Although many researchers investigate how gender, race, or socioeconomic status affect participation in the STEM pipeline, few researchers study STEM involvement from a strictly geographical perspective or focus on rural students as an underrepresented group. Rural students may face numerous obstacles to entering the STEM fields including low educational aspirations, lack of STEM role models, lack of access to STEM outreach, and lack of access to advanced math and science curricula. These factors can both limit the entry of rural students into STEM fields and hinder their progress toward degree completion.

Here, we focus on rural students in the field of chemical engineering through case studies in two states to assess the level of representation at the undergraduate level and to identify ways to improve the flow of rural students through the STEM pipeline. The primary contribution is a geographic analysis, using the software ArcGIS by Esri\(^6\), of the distribution of in-state undergraduate students studying chemical engineering at public and private universities in Kansas and Illinois. The paper also provides recommendations for actions that could be undertaken to increase STEM participation and degree attainment for rural students by various entities, including colleges and universities, chemical engineering departments, rural high schools, and industry.
2. Background

2.1 STEM pipeline

The STEM pipeline is a theoretical construct used to describe the flow of students through the K-12 education system and the higher education system toward employment in STEM fields. Students can “leak out” of the pipeline, ending the possibility of entering the STEM workforce. Examples of leaking out of the STEM pipeline include a student interested in the STEM fields in high school that chooses to major in a non-STEM field in college and a student who graduates with a degree in a STEM field but chooses to work in a non-STEM field or to become a stay-at-home parent. Students may leak out of the STEM pipeline not because of innate differences between people groups but because of structural problems in the STEM pipeline. An example of such a structural problem is the chilly climate toward women in STEM fields, which is one of the contributing factors for relatively low participation of females in STEM fields, especially in the fields of physics and engineering. Improved access and retention of rural students in the STEM pipeline could benefit rural students directly through increasing their scientific literacy and preparing them for employment in fields with high earning power, and the nation would benefit by having a more diverse STEM pipeline and a more scientifically literate citizenry. The flow through the STEM pipeline can be increased and diversified through outreach events and other interventions.

According to data published by the National Center for Educational Statistics a gap between different population areas exists in the rates of college attendance. In 2008, the percentage of 18-24 year olds enrolled in a four year college or university was 31.3% for rural locales, 42.3% for town locales, 42.1% for suburban locales, and 46.4% for city locales. Rural students are even more unlikely to attend elite universities (as measured by the top 50 liberal arts and national universities as ranked by U.S. News and World Report), even among those who are academically qualified. Based on data from a 12 year longitudinal study, participation in postsecondary education is 36.2% less likely for rural youth than non-rural youth. However, when rural youth were matched against city and suburban youth with similar economic and family backgrounds using a propensity scoring matching system, no difference was found between rural and non-rural student educational participation or attainment (not specific to STEM fields).

The literature does not clearly address rural students’ participation in the STEM pipeline; the current rate at which rural students are participating in STEM fields is unknown. Despite the lack of participation rate data, a number of programs are devoted to improving rural STEM participation, such as Purdue University’s STEM Goes Rural and Oak Ridge, Tennessee’s Rural Communities STEM Initiative. From a theoretical standpoint, many variables could cause disparities in STEM degree program participation and achievement, such as K-12 educational preparation for studying STEM in higher education, a lack of STEM role models and STEM outreach opportunities in rural areas, low educational aspirations, and differences along the lines of parental education and income. Some of these factors are discussed in the following subsections.
2.2 Rural student demographics and educational preparation

In their research on the state-by-state importance and urgency for education in rural areas, Beeson and Strange found that rural areas are comprised of diverse populations; in 1997, members of ethnic minorities comprised 17% of rural populations\(^\text{14}\). Rural areas are likely to be the most impoverished—244 of the 250 poorest counties in the U.S. were rural, and non-white rural people are especially prone to economic hardship. Large percentages of rural students live in poverty: e.g., 39% in Illinois and 30% in Kansas\(^\text{14}\). Additionally, rural schools are often underfunded and may have other problems such as long bus rides, lack of high-speed internet access, and trouble recruiting quality teachers, in part because of salaries that are lower than national and state averages (the largest gap in the nation is in Illinois where rural teachers earn nearly $10,500 less than other teachers in the state\(^\text{14}\)) and in part because teachers may desire to live in more populated areas.

2.3 Rural student educational preparedness

Rural students may be hindered from entering the STEM pipeline because of limited curricular options, especially in science and mathematics, and because of other problems that affect rural public K-12 systems. Although rural students have been shown to perform on par with non-rural students on measures of math and scientific ability\(^\text{15}\), rural students are typically limited in terms of access to advanced coursework\(^\text{16}\). As mentioned earlier, rural school districts face unique challenges that do not trouble city and suburban school districts. While a full treatment of rural K-12 educational systems is outside the scope of this paper, one aspect in particular—participation rates in advanced placement (AP) courses—may be illuminating. The Commission on Professionals in Science and Technology reported:

> African Americans and Native Americans, as are Hispanics, are underserved by our educational system in terms of gaining scientific and quantitative literacy as shown by the NAEP [National Assessment of Educational Progress] assessment results and SAT scores. Efforts must be made to increase the availability of rigorous courses, including AP Courses, especially in inner cities, in remote rural areas, and for those underrepresented groups, including African Americans and Native Americans, who have traditionally not had the opportunity to take these courses. For it is these more rigorous math and science courses that provide the building blocks for STEM careers.\(^\text{17}\)

The map of AP participation rates for each school district in the state of Illinois\(^\text{18}\) (Figure 1) shows that most of the school districts in Chicago and the surrounding suburbs had AP participation rates over 20%, with several over 30%, in the 2010-2011 school year. Moderate rates of 10% or higher were reported for several districts in the vicinities of urban areas throughout the state. Conversely, many of the rural Illinois school districts had AP participation rates under 1%. Nationwide for the 2002-2003 academic year, 93% of city and 95.7% of suburban schools offered AP classes versus 83% of town schools and 75.7% of rural schools\(^\text{16}\). In general, rural schools do not have the same access to AP coursework as students from more populated areas.
A longitudinal study on chemical engineering undergraduates at North Carolina State University showed that rural students had lower GPAs and both persisted and graduated at lower levels than their urban and suburban counterparts. The study cited better academic preparation in non-rural schools and inequality in parental educational levels as the key factors as to why rural students did not fare as well as the non-rural students.

### 2.4 Rural student educational aspirations and parental education levels

In a study comparing aspirations of rural and non-rural youth, Haller and Virkler wrote that “adolescents aspire to what they know or can imagine.” They found that rural youth had a slight but significantly lower level of educational aspirations compared to urban youth, which they credited to rural students having, on average, lower socioeconomic status than non-rural students. Using multiple regression analysis on a large scale data set comparing rural and non-rural aspirations controlling for socioeconomic status, they found that rural youth still had a significant but much smaller level of educational aspirations. They concluded that this difference was not due to rural students having less ambition but rather due to a tendency of rural students to aspire to different types of careers than urban students, with rural students leaning toward occupations that require less education, typically in agriculture, service industries, and manufacturing. Rural students aspired less frequently to professional jobs that are relatively uncommon in rural areas. Within the rural geographic and cultural context, a lack of contact with professionals in the STEM fields could prevent student awareness of STEM career opportunities, leading to “leaking” from the pipeline as students may not have interest in pursuing degrees in fields that they have little or no exposure to.

Not only are rural students’ educational aspirations lower, but rural and town parental expectations of their children’s educational attainment are also lower than the expectations of suburban and city parents. A U.S. Department of Education report on rural education showed that only 58.5% of rural parents expected their children to gain a 4-5 year bachelors degree. This increased to 63.2% for town parents, 70.2% for city parents, and 75.4% for suburban parents. The same data set showed that only 21.2% of rural parents expected their children to receive a graduate degree, compared to 24.5% of town parents and 34.1% of city and suburban parents. This may be due to rural parents having lower rates of college degree attainment than town, suburban, and city parents. For children ages 6-18 in 2003, only 22% of rural children had fathers with a bachelor’s degree or higher compared to 23% for town children, 30% for city children, and 38% for suburban children, and only 21% of rural children had mothers with a bachelor’s degree or higher compared to 19% for town children, 23% for city children, and 31% for suburban children. Although parental expectations for rural students were lower than for other locales, rural parents were involved in their children’s education: greater percentages of parents of rural students compared to parents of city students attended school-related events (74% vs. 65%) or volunteered at students’ schools (42% vs. 38%).
3. Methodology

3.1 Cartography

We used the geographic information system software program ArcGIS to create maps for the distribution of home address zip codes for chemical engineering undergraduate students in the states of Illinois and Kansas. Two states were chosen as models for this work to analyze the results before embarking on the more daunting task of compiling the data for all chemical engineering undergraduate programs in the country and mapping all 50 states. Illinois and Kansas were chosen specifically because they both have multiple in-state chemical engineering programs and rural agriculture as an important component of their state’s economy. They differ in the proportions of urban to rural populations with Illinois having a smaller percentage of their population considered rural compared to the national average and Kansas having a larger percentage than the national average. Illinois has four institutions that offer bachelor’s degrees in chemical engineering: University of Illinois at Urbana-Champaign (UIUC), University of Illinois at Chicago (UIC), Northwestern University (NU), and Illinois Institute of Technology (IIT). Kansas has two institutions that offer bachelor’s degrees in chemical engineering degree: University of Kansas (KU) and Kansas State University (KSU). NU and IIT are private institutions, and UIUC, UIC, KU, and KSU are public institutions. Zip code data (only zip codes and the count of students from each zip code) were obtained from each institution for the home address on record for all undergraduate students majoring in chemical engineering; no other identifying information was provided. Only students with in-state home addresses were included in the study. While some out-of-state students may come from rural areas, the data are not comprehensive enough to assess their representation. If a city with multiple zip codes was used, each zip code was mapped separately rather than combining all of the city’s zip codes into a single centralized location. The U.S. Census Bureau’s open source 2010 Census TIGER/Line Shapefiles were used to display the state maps subdivided by counties with the boundaries of the census-defined urbanized areas and clusters, referred to collectively as urban areas. The zip code data were mapped using the GPS coordinates of the geographic centers of the zip codes.

3.2 Definition of rural

Defining “rural” can be somewhat complicated. For example, the U.S. Department of Agriculture (USDA) set forth nine different rural definitions based on several sources. The National Center for Education Statistics (NCES) categorized population ranges into the labels of rural, town, city, and suburban and added the variable of distance from urbanized areas and urban clusters to the alternative more strictly population-based classification schemes defined by the USDA and others. Here, we adopted the NCES urban-centric classification system of “locale codes,” which subdivides each population range into three subcategories. Use of the NCES system of definitions enabled us to readily search for specific school districts corresponding to student home addresses using information that was acquired from the Common Core of Data and the Integrated Postsecondary Education Data System databases maintained by NCES.
Under the NCES system, a locale is rural if it has a population of fewer than 2,500 and is outside of an urban cluster; this is consistent with definition #4 from the USDA. The rural locales are categorized based on their proximity to “urbanized areas” and “urban clusters,” which are collectively referred to as “urban areas.” As defined by the U.S. Census Bureau, urbanized areas are regions with census populations of 50,000 or more and include cities and suburbs, and urban clusters are regions with populations between 2,500 and 50,000. If a rural locale is less than or equal to 5 miles from an urbanized area or less than or equal to 2.5 miles from an urban cluster, it is classified as rural fringe. Rural distant locales are more than 5 miles but less than or equal to 25 miles from an urbanized area or more than 2.5 miles but less than or equal to 10 miles from an urban cluster. Rural remote locales, the most geographically isolated classification, are defined as being more than 25 miles from an urbanized area and more than 10 miles from an urban cluster. Towns are considered to be urban clusters that are located outside of urbanized areas; this is consistent with definition #6 from the USDA. Town locales are also classified as fringe, distant, and remote based on their proximity to urbanized areas: fringe if less than 10 miles from an urbanized area, distant if between 10 and 35 miles from an urbanized area, and remote if over 35 miles from an urbanized area. City and suburban locales are located within urbanized areas and are categorized by size: small, midsize, and large. We considered city and suburban locales collectively.

3.3 Assessing rural student representation level in chemical engineering

We used geographic proportional parity as our primary metric for assessing the representation of rural students in chemical engineering as a case study for STEM fields in general. We define the geographic proportional parity (GPP) ratio as the ratio of the percentage of students studying chemical engineering from a specific locale class (rural, town, or city and suburban combined) to the percentage of the population from the same locale class. Students from specific locale classes are underrepresented if the percentage of students studying chemical engineering is lower than their percentage of the population and the GPP ratio is less than unity; likewise, students from specific locale classes are overrepresented if the percentage of students studying chemical engineering is higher than their percentage of the population and the GPP ratio is greater than unity. Equal representation is indicated by GPP ratio equal to unity. The population data for rural areas and towns, using definitions #4 and #6, respectively, were obtained from the USDA for Illinois and Kansas. Based on anecdotal evidence, we expected to see small differences in rural student representation in chemical engineering between institutions, with an overall underrepresentation of rural students at all the institutions studied.

4. Results

The distributions of home address zip codes for in-state undergraduate chemical engineering students at the four institutions in Illinois that offer bachelor’s degrees are displayed on maps of Illinois (Figures 2, 3, 4, and 5 for IIT, UIC, NU, and UIUC, respectively); likewise, the corresponding data for the two institutions in Kansas are displayed on maps of Kansas (Figures 7 and 8). The zip code data are presented for each institution separately to reduce data clutter and enhance readability. Additionally, maps of urban areas and urban clusters without data are provided for reference (Figure 6 for Illinois and Figure 9 for Kansas). Figure 10
displays the GPP ratios for rural and town locales and the combination of city and suburban locales for each institution and both states.

4.1 Findings for the state of Illinois

Two major trends were observed for the three metropolitan institutions—IIT and UIC are located in the city of Chicago, and NU is located in the Chicago suburb of Evanston—most of the in-state chemical engineering students were from the Chicago urbanized area, and none were from rural locales. Of the 69 in-state undergraduate chemical engineering students enrolled at IIT (Figure 2), 68 students were from the Chicago urbanized area, and 1 student was from the St. Louis urbanized area. UIC had 174 in-state undergraduate chemical engineering students with 170 students from the Chicago urbanized area, 2 students from urbanized areas outside of Chicago, and 2 students from towns (Figure 3). The 37 in-state chemical engineering students enrolled at NU were distributed among urban areas throughout the state (Figure 4): 29 were from the Chicago urbanized area, 4 were from urbanized areas outside of Chicago, and 4 were from towns.

In contrast to the metropolitan institutions, UIUC—located downstate in Champaign (city small) and Urbana (town distant)—had in-state undergraduate chemical engineering students from rural and town locales of all three categories (Table 1). UIUC’s chemical engineering in-state enrollment (368 students) was much larger than the other three institutions combined (280 students). While the majority of in-state undergraduate chemical engineering students were from the Chicago urbanized area, the students were distributed throughout the state (Figure 5) to a larger extent than corresponding students from IIT, UIC, or NU. Despite the geographical distribution of the students, many of those students from outside the Chicago urbanized area were from other urbanized areas.

According to data from the USDA\textsuperscript{21}, 12.2\% of Illinois residents live in rural locales, 9.4\% live in town locales, and 78.4\% live in city and suburban locales. Rural students were not only underrepresented among in-state undergraduate chemical engineering students at IIT, UIC, and NU, but they were not represented at all. Only 3.5\% of UIUC in-state undergraduate chemical engineering students were from rural locales (Table 1) for a GPP ratio of 0.29 (Figure 10) indicating that rural students were underrepresented. State-wide, rural students represented only 2.0\% of in-state undergraduate chemical engineering students, for a GPP ratio of 0.16 (Figure 10).

Students from towns were well-represented at UIUC and statewide with GPP ratios of 1.27 and 0.82, respectively (Figure 10). In all four institutions, students from city and suburban locales were overrepresented among in-state undergraduate chemical engineering students (GPP ratios of 1.26, 1.28, 1.14, 1.08, and 1.08 for IIT, UIC, NU, UIUC, and state-wide, respectively. See Figure 10).
4.2 Findings for the state of Kansas

Both KU (Figure 7) and KSU (Figure 8) had in-state undergraduate chemical engineering students from rural and town locales of all three categories (Table 1). Both institutions displayed enrollment distributions with many students clustered in urban areas and some students from outside of the urban areas. KU is located in Lawrence (city small) and is closer to Kansas City than KSU, which is located in Manhattan (town remote). KU’s geographic distribution was slightly skewed to the East compared to KSU’s more uniform state-wide distribution, and KU had a higher proportion of city and suburban students than KSU. Despite its smaller in-state chemical engineering undergraduate enrollment (165 students compared to 275 for KU), KSU had a larger number of rural in-state students than KU in addition to a higher proportion of rural students.

According to the USDA\textsuperscript{22}, 28.6% of Kansas residents live in rural locales, 26.5% live in town locales, and 44.9% live in city and suburban locales. At KU, 9.5% of the in-state chemical engineering undergraduate students were from rural locales (Table 1) for a GPP ratio of 0.33 (Figure 10) indicating that rural students were underrepresented. At KSU, 19.4% of the in-state chemical engineering undergraduate students were from rural locales; while substantially larger than the percentage for KU, the GPP ratio of 0.68 (Figure 10) indicates that rural students were also underrepresented at KSU, just to a lesser extent. The GPP ratios for rural locals for KU and KSU were much larger than those for the institutions in Illinois, but rural students in Kansas were still underrepresented in chemical engineering compared to their proportion of the state population (GPP ratio of 0.46 statewide. See Figure 10).

Students from towns were well-represented the in-state chemical engineering undergraduate population at KSU with GPP ratio of 1.03 (Figure 10). In contrast, students from towns were underrepresented at KU and statewide with GPP ratios of 0.64 and 0.79, respectively (Figure 10). In both institutions, students from city and suburban locales were overrepresented among in-state undergraduate chemical engineering students (GPP ratios of 1.64, 1.19, and 1.47 for KU, KSU, and statewide, respectively. See Figure 10).

5. Discussion

None of the six universities in this study had rural student representation levels among in-state chemical engineering undergraduate students that met or exceeded geographic proportional parity (rural GPP ratios < 1 for all), confirming our expectations. The complete lack of rural student representation at IIT, UIC, and NU was not expected. Statewide, Kansas had better representation of rural students than Illinois (GPP ratio of 0.46 compared to 0.26). Illinois had an overrepresentation of town students while Kansas had an underrepresentation of town students (GPP ratio of 1.26 compared 0.79). Illinois had a slight overrepresentation of city and suburban students, whereas Kansas had a substantial overrepresentation of city and suburban students (GPP ratio of 1.08 compared to 1.47).

Three case studies and factors believed to influence the representation levels of suburban and rural students are discussed in the following subsections. We conclude this section with limitations of this study and future research ideas.
5.1 Case studies: suburban high socioeconomic status and large chemical engineering enrollment

Viewing the zip code data though the lens of critical theory provides insight into how socioeconomic status and race intercepts with STEM enrollments. The Kansas data show an unequal distribution of chemical engineering students from wealthy, racially homogeneous suburbs. Overland Park, KS, a Kansas City suburb of 176,185, is a perfect example of the geographic and economic inequality that occurs in the distribution of chemical engineering students; 54 KU students and 15 KSU students were from Overland Park for a total of 69 statewide in-state chemical engineering undergraduate students. While Overland Park comprises only 6.14% of Kansas total population, 15.68% of the 440 in-state undergraduate chemical engineering students in Kansas were from Overland Park. The city is 90.7% White non-Hispanic or Asian—the two populations most represented in STEM fields according to the National Science Foundation—compared to the state average of 86.2%. The median income of Overland Park is $71,513 compared to the state of Kansas’ median income of $49,242.

Naperville, IL, a Chicago suburb had 25 students studying at UIUC accounting for 6.8% of the in-state chemical engineering undergraduate students. This is an overrepresentation considering that Naperville’s estimated 2011 population was 142,773 or 4.98% of the total Illinois population. For comparison, the city of Chicago (city proper only) had 31 students from all zip codes combined and had a total population of 2,707,120. Naperville’s overrepresentation is not surprising considering the area’s demographics. Naperville’s median household income is almost double that of the rest of the state at $101,911 versus $55,735. Naperville’s median value of owner occupied housing (a key figure for public school funding via property taxes) is also almost twice the state average. Naperville is not very racially diverse with 87.9% of the population being White non-Hispanic or Asian. By comparison, the state of Illinois as a whole is more racially diverse with only 68.3% of its citizens reporting as White non-Hispanic or Asian.

Suburbs like Naperville, IL and Overland Park, KS and others are doing excellent work in preparing students for higher education. The high number of suburban students raises the possibility that rural students are not filtered from but crowded out of the STEM pipeline by more qualified applicants. Although showing some preference toward qualified rural STEM applicants during the admissions process likely would lead to quicker rates of geographical proportional parity, we do not advocate making efforts that impede city and suburban students from studying at the universities they choose in fields that they are interested in. Instead, we hope that those in the STEM fields will take actions to increase the flow of students into the STEM pipeline for rural and other underrepresented populations.

5.2 Case study: rural/small town low socioeconomic status and large chemical engineering enrollment

While rural students attended UIUC for chemical engineering in appreciable numbers, improvements could be made to increase the number of in-state rural students studying chemical engineering in Illinois, especially for the three universities in the Chicago area. Rural school districts and those involved in STEM fields, both in industry and academia, could look to the best practices of areas that have been successful in preparing students for STEM fields. The map...
of in-state chemical engineering undergraduates at UIUC (Figure 5) shows a relatively large cluster in the southeastern part of the state in Robinson, IL. In 2011, Robinson (town distant) had an estimated population of 7,726 people and $39,493 median household income$^{27}$ and had four UIUC students studying chemical engineering with four more from neighboring rural areas. This high level of enrollment in a small town and the surrounding rural areas with low socioeconomic status was likely due to a variety of factors, of which two seem to be the most important for overcoming obstacles typically encountered in rural areas and small towns—limited exposure to engineering as a career option and opportunities for advanced coursework. The first factor is the significant presence of industrial sites that value STEM outreach. Robinson is home to an oil refinery and a chocolate factory. In addition to the outreach performed by the companies, the number of engineers in the area is likely to provide several engineering role models, which may help to attract and retain students in the STEM pipeline. The second factor is the educational opportunities for K-12 students. The Robinson school district provides some courses for preparing for the challenging engineering curriculum, including calculus, physics, and two chemistry courses$^{28}$. Although less than 1% of students take AP classes, Robinson High School students may take dual credit courses offered through Lincoln Trail College located in Robinson. Other schools in rural areas may not be able to follow Robinson’s example if they lack nearby industrial sites, face school district budget and staff shortfalls that may prevent them from providing rigorous college preparatory curricula, and are not located in the vicinity of community colleges or universities with viable dual-credit options.

5.3 Public outreach through land grant institutions

With a sample size of only seven chemical engineering departments in six different cities, it is hard to generalize about the factors that influence rural enrollments. Being a land-grant university is one common factor that seems likely to influence rural enrollment for the two institutions with the highest representation levels of rural students for their states (UIUC and KSU). The Morrill Act of 1862 set aside land to create schools focusing on the agricultural and mechanical arts. The land grant institutions evolved into research universities that also emphasize outreach to their state’s citizens and farmers through extension offices throughout each state. Additionally, land grant institutions play a key role in their state’s 4-H programs. 4-H is a co-educational youth organization originally developed as a joint effort of the land grant universities and the USDA to teach young people about new advances in agriculture and home economics$^{29}$. While 4-H still holds to its original purpose of agricultural education and continues activities such as livestock competitions, 4-H’s mission now extends to city and suburban students and has a strong focus on STEM fields. It is not inconceivable to picture a rural child learning about STEM careers though 4-H and choosing to study at the in-state land grant institution because of its 4-H affiliation. Both UIUC and KSU are heavily involved in 4-H at the K-12 level in communities throughout the states of Illinois and Kansas and at the collegiate level. It may be that rural students are attracted to land grant universities because of familiarity with these schools and their missions or that the schools’ missions cause higher level of recruitment and acceptance of rural students.
5.4 Limitations and future research

While this work clearly shows that rural students are underrepresented in Illinois and Kansas chemical engineering undergraduate programs, questions still remain. The main limitation of this paper is that it is not possible to interpret whether or not the low rural representation levels are specific to chemical engineering or are generalizable to all STEM fields. Although an aim of this paper is to serve as a call to recruit rural students into all STEM fields, the data are drawn from one STEM discipline, two states, and only the students studying in-state. Perhaps another engineering discipline such as electrical or civil engineering that is offered at more university campuses in closer proximity to more rural areas may have a higher representation level of rural students. Other STEM fields such as biology or chemistry seem to be more ubiquitous and may have higher rural student representation levels as students are exposed to these disciplines at the high school level and many more community colleges and regional universities offer degrees in these fields.

Several data sets from different years were used to make the maps and analyze representation levels in chemical engineering: the 2000 census data on rural populations, Illinois data for the 2010-2011 school year, Kansas data for the 2011-2012 school year, and geographical data from the 2010 census for the urban areas (urbanized areas and urban clusters). While it would be best if data sets from similar years could be used, we used the most recent data available and emphasized comparisons of percentages of the population rather than numerical values.

By only considering in-state enrollment in two states, we do not have enough data to assess whether the representation of rural students from Illinois and Kansas among STEM majors across the country is in geographic proportional parity with the rural population of the states. Disregarding the out-of-state chemical engineering undergraduate enrollment data for the six institutions does not have a substantial effect in assessing the representation level of rural students at each institution. The out-of-state enrollment percentages for UIC, UIUC, KU, and KSU were small (1.1%, 8.0%, 9.3%, and 11.2%, respectively). IIT and NU had higher percentages of out-of-state students (20.8% and 62.5%, respectively), but the overwhelming majority were from non-rural areas. This data would be important for studies of town, suburban, and city representation levels.

Another limitation of this study is use of home address zip code rather than information about high schools attended. In a number of cases, the home address zip code cannot accurately reflect where the student went to school. Students may have attended multiple schools in a variety of school districts in a mixture of rural and non-rural schools. Students may have attended high schools outside of the school district closest to their address; locally, rural students may have attended a school in a neighboring small town or adjacent district, or outside their home area, students may have attended advanced college preparatory schools such as the residential Illinois Mathematics and Science Academy and Kansas Academy of Mathematics and Science. Conversely, if just high school location was used without home addresses, the data may not adequately capture the locale background of students who attend schools in other locales. However, obtaining details on high schools attended and implementing a qualitative component where rural students are interviewed as part of the study would provide more information and partially lessen this limitation.
Because of the somewhat narrow scope of the project and the limitations, further research is still needed to assess rural students’ participation in STEM fields collectively. We plan to expand our maps to include more states and also more STEM fields, particularly engineering disciplines, along with a control group of non-STEM majors. It could also be useful to perform a cross-sectional study of student enrollments before and after a campaign targeted towards increasing rural STEM students for a given university or geographic area. A large scale qualitative study could provide insight into the rural pathways into STEM fields and various obstacles that rural students face. Finally, while this paper focused on rural students, an equally interesting and important study using a similar methodology could consider the geographical distribution of STEM students in an urban region to assess whether disparities in STEM enrollments exist between neighborhoods whose students predominately have higher socioeconomic status and those whose students predominately have lower socioeconomic status.

6. Summary and recommendations

We analyzed the geographic distribution of in-state chemical engineering undergraduate students at six universities in the states of Illinois and Kansas. Rural students were underrepresented at all six institutions, with the three institutions in metropolitan Chicago (IIT, UIC, and NU) completely lacking rural in-state students. We discussed several factors that may pose a threat to rural student access and success in STEM fields and may contribute to the underrepresentation of rural students in chemical engineering and their leaking from the STEM pipeline, including the lack of STEM role models, lower career aspirations without exposure to STEM career options, and limited access to advanced coursework. We conclude with recommendations for improving the representation of rural students in chemical engineering and other STEM fields.

The existence of a gap in the general higher education attainment of the rural population does not preclude efforts to improve the representation of rural students in STEM fields and chemical engineering in particular, just as the participation of other underrepresented groups is an active area for research and policy changes. Changes may be made by rural schools, industry, and academia and others interested in improving rural education and STEM access and persistence. This list is by no means exhaustive.

Recommendations

- **Recognize rural students as an underrepresented group in STEM**
  Institutions or societies could offer pre-college enrichment programs for rural students and provide scholarships for rural students with financial needs. Likewise, once rural students matriculate into a STEM major, colleges should aim to provide academic, financial, and social support for rural students in STEM programs, in manners similar to the support provided for other underrepresented groups.

- **Invest in rural educational infrastructure**
  Students would benefit from opportunities for advanced coursework and pre-college enrichment programs. Teachers and counselors would benefit from training on STEM topics and career opportunities to foster enthusiasm and interest in their students.
• Foster educational partnerships between rural schools and industry
Industrial companies with facilities located away from major metropolitan areas and college campuses can play a large role in expanding STEM outreach to rural areas. Numerous benefits exist for industry to participate in STEM outreach including the short term benefits of improved relations with local citizenry and the long term benefits of contributing to the pool of local students that may be interested in returning to work at the industrial sites near rural areas after receiving training in STEM fields\textsuperscript{31}. Rural or remote schools benefit by exposing students to technical professions that require advanced training and career choices that may motivate academic achievement. Students gain in awareness of opportunities outside their experiences and encounter STEM role models, and students can benefit from having industrial mentors, workplace visits, and job shadowing experiences\textsuperscript{32}.

• Increase the capacity of the chemical engineering portion of the STEM pipeline
In addition to working towards recruiting more chemical engineering students from rural backgrounds, it may be worthwhile to investigate whether the chemical engineering pipeline needs to increase the number of students that it could train. Chemical engineering departments could be enlarged to accommodate more students, or more programs could be added. Illinois is the fifth most populous state, and the top six most populous states in the U.S. have in respective order 13, 9, 15, 5, 4, and 10 chemical engineering programs. Only six community colleges across the country offer chemical engineering coursework.

• Recruit high school students to chemical engineering
Unlike other professions that are highly visible in the media such as medical doctors and crime scene investigation scientists, chemical engineering is not well publicized. Many in the public do not know about the contributions chemical engineers make in society. Public education is thus important for attracting students from all backgrounds to the field. The chemical engineering curriculum is more highly sequenced than most other majors making it difficult to add chemical engineering during the sophomore year, so early recruitment of students into the field is important.

• Introduce rural students to STEM professions through outreach activities
Many organizations from industry, academia, professional societies, and the non-profit sector engage in STEM outreach activities targeting K-12 students. Although STEM events are not exclusive to urban areas, it is likely that most STEM outreach efforts are held in urban areas due to proximity of the host organizations. While some individuals do participate in rural stem outreach\textsuperscript{33}, much more outreach is needed for rural students to have the same opportunities as their urban and suburban counterparts.
Figure 1: Advanced placement participation of Illinois public schools by district (reprinted with permission of the Illinois State Board of Higher Education)
IIT Students

1
2-3
4-5
Urban Areas
IIT Location

Sources:
U.S Census Data 2010

IIT Office of
Institutional
Information and
Research,
2010-2011 Academic
Year

Figure 2: Illinois Institute of Technology in-state undergraduate chemical engineering students mapped by home address zipcode
UIC Students

- 1
- 2-3
- 4-5
- Urban Areas
- UIC Location

Sources:
U.S. Census Data 2010
UIC Office of Public Affairs, 2010-2011 Academic Year

Figure 3: University of Illinois at Chicago in-state undergraduate chemical engineering students mapped by home address zip code
Figure 4: Northwestern University in-state undergraduate chemical engineering students mapped by home address zip code

Sources:
U.S. Census Data 2010
NU Department of Chemical and Biological Engineering, 2010-2011 Academic Year
Number of UIUC Students
- 1
- 2-3
- 4-5
- 6-7
- 10-11

UIUC Location
Urban Areas and Urban Clusters

Sources:
U.S. Census Bureau, 2010
UIUC Division of Data Management, 2010-2011

Figure 5: University of Illinois at Urbana-Champaign in-state undergraduate chemical engineering students mapped by home address zip code
Figure 6: State of Illinois with urban areas

Source:
U.S. Census Data 2010
Figure 7: University of Kansas in-state undergraduate chemical engineering students mapped by home address zip code

Sources:
U.S. Census Data 2010
KU Office of Planning and Analysis, 2011-2012 Academic Year
Figure 8: Kansas State University in-state undergraduate chemical engineering students mapped by home address zip code

Sources:
- U.S. Census Data 2010
- KSU Office of Institutional Research and Planning, 2011-2012 Academic Year
Figure 9: State of Kansas with urban areas

Source:
U.S. Census Data 2010
Figure 10: Geographic proportional parity (GPP) ratio comparison by locale for different institutions and the states of Illinois and Kansas: GPP < 1 indicates underrepresentation, GPP = 1 indicates equal representation, and GPP > 1 indicates overrepresentation of in-state chemical engineering undergraduate students compared to the locale distribution of the state population.

Table 1: Distribution of in-state undergraduate chemical engineering students enrolled at University of Illinois at Urbana-Champaign, University of Kansas, and Kansas State University categorized by NCES locale codes using home address zip codes.

<table>
<thead>
<tr>
<th>Locale</th>
<th>UIUC</th>
<th>KU</th>
<th>KSU</th>
<th>City and Suburban</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Students</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percentage of Students</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rural Remote</td>
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<td>8</td>
<td>13</td>
<td>311</td>
</tr>
<tr>
<td>Rural Distant</td>
<td>9</td>
<td>16</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Rural Fringe</td>
<td>3</td>
<td>2</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Town Remote</td>
<td>8</td>
<td>21</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>Town Distant</td>
<td>19</td>
<td>22</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Town Fringe</td>
<td>17</td>
<td>4</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>City and Suburban</td>
<td>311</td>
<td>202</td>
<td>88</td>
<td>53.33%</td>
</tr>
</tbody>
</table>
Bibliography


29 4-H. (n.d.). History. Retrieved online from http://www.4-h.org/about/4-h-history/