EXPLORATION OF THE JOB PLACEMENT OF UNIVERSITY OF KENTUCKY CHEMICAL ENGINEERING GRADUATES FROM 2018 – 2022

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INTRODUCTION

The chemical engineering discipline has evolved over time, and this shift is reflected in the undergraduate curriculum's content.[1-5] The concepts of computer programming, sustainability, and biochemistry have been implemented in single courses or by restructuring the curriculum.[6,7] This shift, however, can be subtle for students and employers, as many still commonly associate chemical engineering with process scale-up and operation. This association with process/production engineering leads many students to question their place in the field. The students who complete the degree realize later that the application of a chemical engineering degree is much broader than they knew when pursuing their degree. As such, there is a need to better communicate the opportunities within the field to students.

Engineering student retention in the degree and the field is closely related to a lack of identification with the field or faculty recognition.[8] Seymour et al.[9] argue that those leaving STEM programs had high academic preparedness, but the main reasons for leaving were an overloaded curriculum, lack of support, lack of teaching coherence, and a highly competitive culture. Initial studies by Huff and Ross [10] explored students' understanding of learning and professional practice focusing on self-identity construction as engineers, indicating the need for a holistic approach to education inside and outside the classroom.

This study focused on understanding chemical engineering students' experiences in industry and research and their job prospects to better inform other students of the opportunities a chemical engineering Bachelor of Science (BS) degree holds. We explored the opportunities students and alumni undertake, particularly outside the direct route to process/production engineering.

RESEARCH DESIGN

This study was motivated by a purpose statement, and the research questions were selected based on this motivation. The questions address the number and types of job roles from a group of alumni. The data sources explain where the data are collected and how the data analysis was performed. The coding system was applied based on common terms found in the data collection part of this study.

Purpose Statement

The study's purpose is to inform educators and career counselors about the opportunities in chemical engineering and update their perceptions of chemical engineering as a process/production engineering degree only.

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Research Questions

1. Do internships, co-ops, and research opportunities correlate with students' job roles after graduation?
2. What percentage of chemical engineering BS degree holders pursue traditional process/production engineering roles, and has this percentage shifted over five years?
3. Did the pandemic impact student job placement?

Data Sources

The project's first step included data collection about chemical engineering alumni at the University of Kentucky. The Career Services department assists students and graduates in job placement. In addition, they maintain contact with alumni via LinkedIn® groups or by direct contact. With the aid of Career Services, we collected the names of all chemical engineering alumni for the past five years. We focused on Spring graduation classes from 2018 to 2022 and used publicly available LinkedIn data to collect information regarding the students' professional experiences in May 2023 by searching for profiles of our recent graduates by their names. We validated student identities by looking for the University of Kentucky and chemical engineering major being listed in the education section. From the profiles, we pulled information regarding employment company information, internships, co-ops, and full-time positions. Students who did not list any in-school opportunities (internships, co-ops, research) were not included in the analysis of in-school opportunities but were included in job analysis. We identified 416 individuals who obtained their degrees within the target period. Some individuals did not have an online LinkedIn profile, or it was not complete, so they were removed from the study list. Following these changes, the final sample size of our study is 311 for jobs analysis and 279 for in-school opportunities.

A key consideration in our study is the COVID-19 pandemic that led to a pause in industry hiring in 2020 and 2021. The most severe impact was seen during the mass shift to virtual participation starting in March 2020 and continuing until early 2021. Students in graduation years 2021 and 2022 were second- and third-year students during the pandemic, which significantly limited their 2020 opportunities. Students who graduated in 2020 and 2021 were most likely impacted in their job search and are denoted as potentially impacted by the COVID-19 pandemic.

We collected information on the first job post-graduation, its location, and any job changes recorded in the profile until May 2023. We only collected information regarding job titles, as job role descriptions are not readily found. We also recorded if the students listed any internships, co-ops, research experiences, or other opportunities they took advantage of while still in school. These opportunities were generally listed under the employment section. Lastly, we also noted the companies involved in these opportunities to learn how many individuals found a job with the same employer after such an in-school experience.

Coding System

The researchers defined the traditional role in chemical engineering as process/production engineering or variations of the role, such as positions with process, production, refining, or chemical engineering in the job title. To minimize bias and our own experiences with the field, all authors agreed to code the jobs independently and shared their codes before arriving at our categories. After some deliberation, we categorized the jobs into five groups: Process/Production Engineering, Higher Education, Science and Engineering, Business/Management, and Other, as shown in Table 1.

The higher education group consisted of graduates who decided to pursue any level of graduate education (a Master of Science (MS) or Doctor of Philosophy (PhD) degree) and may have started a higher-education teaching career. The science and engineering jobs were roles defined by the influence of fundamental science and variations of technical work. Other types of engineering roles were also included in this category, such as quality engineer or environmental

TABLE 1
Coding System for Job Roles Between Graduation Years 2018 – 2022

Category	Example Job Roles
Process/ Production Engineering	Process Engineer, Production Engineer, Refining Engineer, Plant Engineer, Chemical Engineer
Higher Education	MA in Chemical Engineering, PhD in Chemical Engineering, MBA, Doctor of Medicine, Doctor of Law
Science and Engineering	Field Engineer, Distiller, Engineer I, Engineering Consultant, Associate Development Scientist
Business/Management	Leader Continuous Improvement, Distillery Supervisor, Production Supervisor, Service Coordinator, Sales Associate
Other	Bartender, Private Tutor, Medical Laboratory Technician, Associate Lawyer, Emergency Medical Technician

engineering. Management roles had a leadership component — for instance, a process engineer supervisor or a director. The last category, Other, included jobs such as professional athlete, lawyer, and bartender.

We opted for a more straightforward way to categorize in-school professional practice and technical experience into three roles: internships, co-ops, and research assistantships. We did not investigate the duration of the students' experience in these roles. We expect internships to be shorter than six months, while co-ops are typically longer. Internships in research and development were counted as internships.

RESULTS AND DISCUSSION

Students and Fresh Graduates

We first focused our analysis on undergraduate students' opportunities while still in school beyond schoolwork. The three main categories of opportunities explored in our study are: internships, usually held over the summer; co-ops, usually held during the semester; and research opportunities in academic labs. Data regarding the type of opportunities undertaken by students are shown in Figure 1.

Figure 1a shows the percentage of students who undertook each opportunity during their undergraduate career, while Figure 1b shows the students who only had a single type of opportunity versus a combination of academic and industrial opportunities noted as a combo. Generally, approximately 54% of all students have undertaken an internship during their undergraduate career. Otherwise, approximately 25% of all students participate in a co-op, 40% in research, and 46% have other jobs such as tutoring. There are no data to suggest that students who took other jobs lengthened their graduation time. A chi-square test of independence was performed to assess the relationship between graduation year and individual opportunity type undertaken by the students. We found a significant relationship between graduation year and opportunity type, X^2 (19, N = 1184) = 10.68, $p = 0.03$. By splitting up the data individually by opportunity type, we determined that there is specifically a significant association between the "Other" category and graduation year of the students, X^2 (4, N = 296) = 43.90, $p < 0.001$. The result of the Kendall's Tau correlation showed that there was a positive correlation between graduation year and "Other," $\tau_b = 0.738$, $p = 0.077$, indicating that more students may be undertaking employment opportunities not associated with their degrees during their time in college.

There are two common ideas propagated regarding internships, co-op, and research while students are still in school. First, it is assumed that research experience strongly influences an individual's decision to go to graduate school. In our data, 16 ± 5 % of all students pursued a graduate degree after a research experience during their undergraduate degree. In comparison, only 8 ± 4 % of all students in the study without research experience ended up pursuing a graduate degree. Out of all students who performed undergraduate research, 41 ± 14 % of students pursued higher education. Fisher's exact test was used to determine if there was a significant association between research and graduate school.

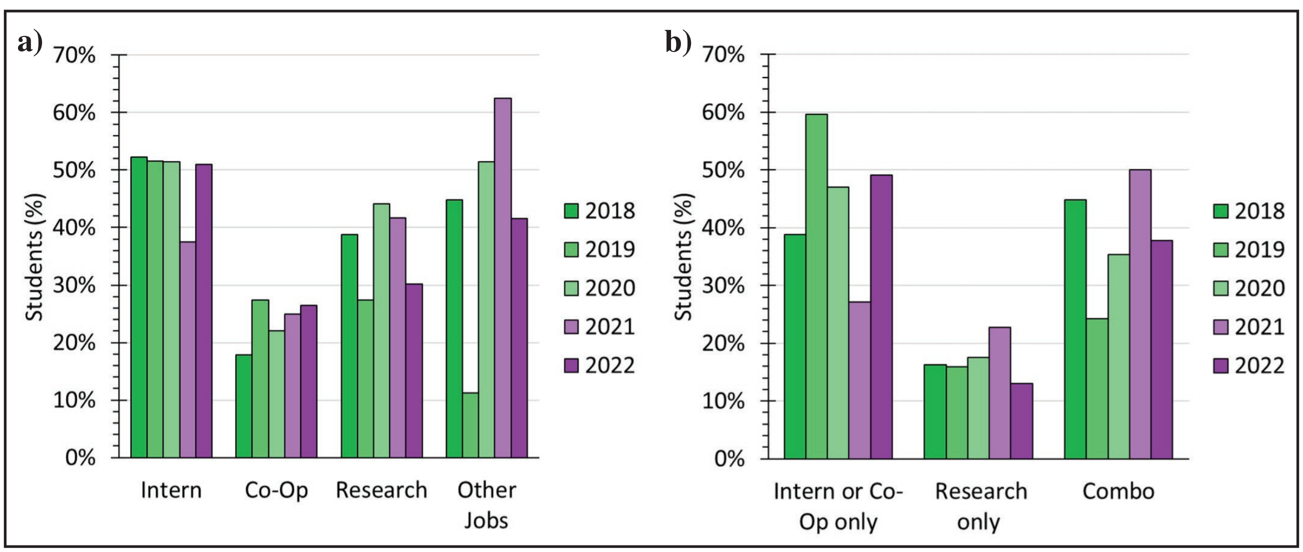

***Figure 1**. Types of opportunities undergraduate students undertook while still in university that went beyond their schoolwork. Data are arranged left to right from the graduation class of 2018 to the graduation class of 2022. The data from 2021 and 2022 in purple reflect students who were impacted by the COVID-19 pandemic lockdowns during in their second and third years of college. Figure 1a shows the total percentage of students who undertook different opportunities. Figure 1b shows the percentage of students who only participated in one class of opportunities.*

The results showed that besides the 2018 dataset, there was a statistically significant association between the two variables (2018, $p = 0.74$; 2019, $p = 0.04$; 2020, $p < 0.001$; 2021, $p = 0.04$; 2022, $p = 0.03$). The second common idea propagated about internships and co-ops is that a successful internship or co-op may land students a permanent position at a company. In our data, only 6% of individuals got a job at a company where they previously worked. There are many possible reasons for this low percentage, such as that companies may not have been hiring at the time or that the students did not enjoy the experience.

Overall, studies show that engineering-related experiences such as internships and co-ops can drastically help students see past the curriculum and truly envision their place in the field.[6, 11-13] Seevers et al.[14] found that students who took part in research laboratory experiences had increased confidence and motivation to remain in engineering.[14] Multiple studies have noted the benefits on student retention and happiness in their major through new experiences, such as working in makerspaces or with global organizations.[15-18] In our study, 284 individuals out of 311, or 91% of students who graduated, had industry or academic experiences during their time as a student.

After graduation, students transition to the next phase of their lives, commonly outside academia. Figure 2 shows a word cloud comprised of job roles we identified in our analysis, and the word "engineer" was the most common job term. Figure 3 summarizes the information we collected regarding introductory roles held by newly graduated individuals with a BS in chemical engineering via our previously described coding system. A full list of the job roles can be found as supplementary data.[19] Briefly, some graduates enrolled in PhD or MS programs, while others enrolled in medical school. Other individuals joined the industrial sector in job roles such as development engineering. This data indicates that most chemical engineering BS degree holders in our study remain in the STEM field. A limitation of the study is that our data are limited to only one university, where, on average, we found that 50% of students stay in the state to find their long-term positions. We do not know if the students found their desired opportunity in-state or chose to stay in-state for other personal reasons. Future studies should investigate the geographical impact on the type of jobs students get.

In addition to qualitative analysis, we analyzed the proportions of students who pursued different career tracks in Higher Education, Leadership/Management, Process/Production Engineering, Science and Engineering, or Other. First, we note that approximately 25% of students pursued a higher education degree and that this percentage value remains constant over time, regardless of the pandemic.

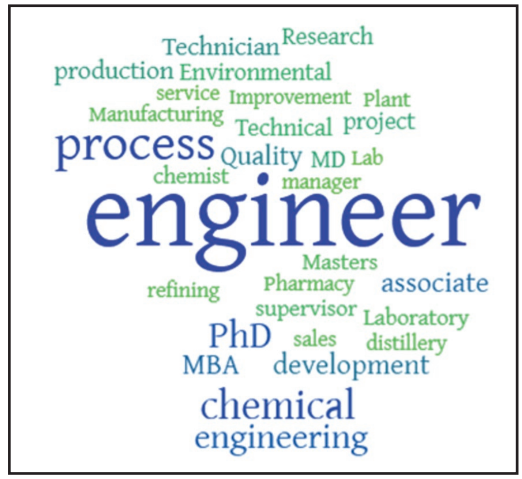

Figure 2. *Word cloud for the most common job roles of University of Kentucky chemical engineering alumni from 2018-2022. Each word appeared at least four times in the data.*

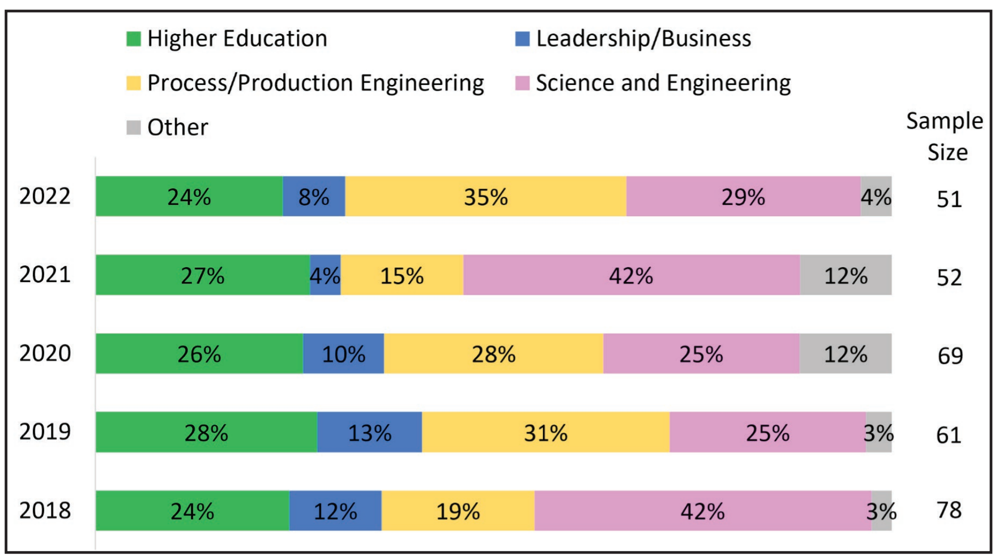

Figure 3*. Percentage of alumni sorted by their graduation year who got their initial jobs/continued education after graduation in the following five categories: Higher Education, Leadership/Business, Process/Production Engineering, Science and Engineering, and Other. The sample size is noted on the right-hand side of the plot.*

Leadership/Business jobs also remained relatively constant, with one decrease in 2021, which is not significant ($p = .13$). Other jobs categories experienced a lot of variability yearly, with the interquartile range spanning 8%, 18%, and 11% for Other, Science and Engineering, and Process/Production, respectively. It is possible that this variability, particularly in 2020 and 2021, could be due to the COVID-19 pandemic, which impacted the industrial sector more than the higher education sector. Many businesses during this time had hiring freezes and needed specific approvals to hire. These challenges may have translated to students looking for broader opportunities to find positions than before. Despite the variability, a chi-square test of independence showed that there was a significant association between graduation year and a job in science and engineering, X^2 (4, N = 312) = 9.78, $p = 0.04$. Kendall's Tau was further performed to determine the direction of the association and found a marginal positive correlation over time $\tau_b = 0.222$ for all years albeit not a significant one, $p = 0.30$. Generally, these data indicate a potential slow change in the career paths with a chemical engineering BS degree. There is some evidence suggesting the impact of the pandemic on the types of jobs students obtained in 2020 and 2021, but long-term trends will need to be explored further by obtaining data outside the pandemic years.

Mid-Career Individuals: Shift Over Five Years in a Career

The first job is an important entry point into a field, but we also sought to see if individuals stay in that sector or seek other opportunities in the future. As a part of this study, we looked at how job roles have shifted over the five-year period of this study for the 2018 graduating class. The results are shown in Figure 4.

First, there is naturally a decrease in the Higher Education category, as many students finished their higher education degrees and moved on to other jobs such as lawyers (Other), service technicians (Science and Engineering), and process engineers (Process/Production Engineering). We also saw a large increase in leadership/management positions undertaken by professionals. In another few years, we expect the higher education group to decrease significantly as most students finish their degrees, but we should also acknowledge the fact some may start graduate degrees later. A chi-square test of independence was performed to assess the relationship between the type of job and years since graduation. There was a significant relationship between the variables, X^2 (19, N = 156) = 9.82, $p = 0.04$. Lastly in our study, we saw a number of students who pursue careers in the medical field by getting their doctorate in medicine (4%) or doctoral degree in pharmaceutical science (3%). This significant number of individuals moving to the medical field may stem from the drive to help others, which many engineers feel.[20]

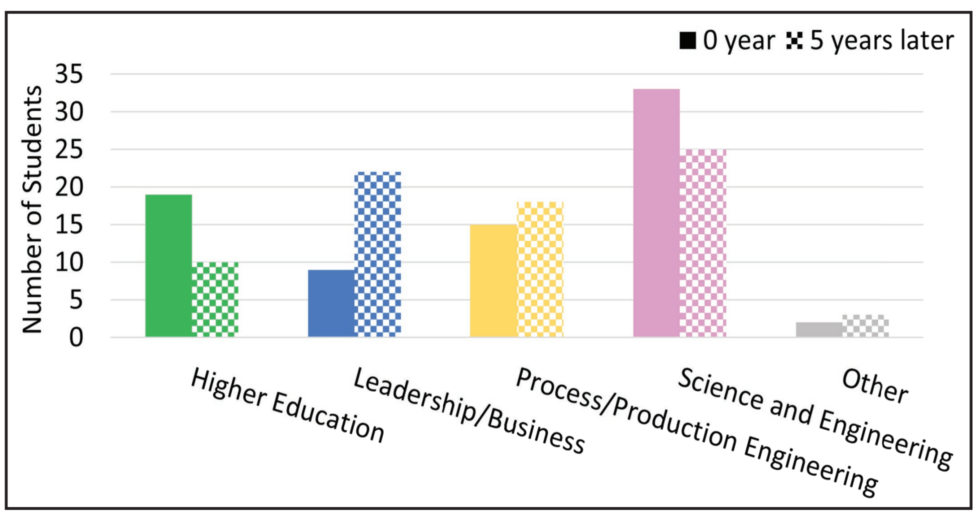

***Figure 4**. Job title progress of 2018 graduation class over a five-year career progress.*

CONCLUDING REMARKS

This study was the beginning of an interesting and necessary investigation into what roles chemical engineering graduates pursue. Using publicly available information, we explored the type of initial post-graduation jobs obtained by undergraduate chemical engineering students graduating between 2018-2022 and the types of in-college opportunities they had at the University of Kentucky. We found that 90% of students undertake opportunities outside the traditional curriculum during their undergraduate years, such as internships and research. We also noted that more individuals have non-engineering jobs such as tutoring while in school. Post-graduation job prospects displayed a high degree of variability over the five-year period, which could be due to additional factors related to the COVID-19 pandemic. Future research studies should focus on identifying student identity development and perception of chemical engineering over their undergraduate career and shortly after entering the work field. The authors expect that more data collection from other institutions (nationally or globally) could shed light on the chemical engineering field as a whole.

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