Engineering Educators Bringing the World Together
2025 ASEE Annual Conference & Exposition
Palais des congrès de Montréal, Montréal, QC • June 22–25, 2025 ASEE
Paper ID #45794

Ten Year Retrospective – Student Engagement at the Center for Design and Manufacturing Excellence

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Abstract

The United States of America needs additional undergraduates prepared for the realities of modern manufacturing. A multitude of specific manufacturing technology sectors as well as the entire defense industry has expressed this need loudly and The Ohio State University (OSU) has developed a program to meet this need. Over the past ten years, Ohio State's Center for Design and Manufacturing Excellence (CDME) has developed and executed paid experiential learning opportunities for hundreds of students (n=367) in multiple areas of advanced manufacturing.

Leaning into the colloquial phrase "you can't fake real" CDME has embraced a model of replicating the real-world work environment as closely as is possible within a university structure. Functioning as a unique consulting company within Ohio State, students are immersed in a wide range of duties ranging from project bidding, financial management, and technical task execution. Rather than working under the watchful eyes of university faculty, students work under industry professionals who understand the work methodologies of their field. Every project comes from industry needs and are worked on exclusively by CDME students supervised by these experienced staff. With project scope varying from small fabrication jobs to million-dollar Department of Defense initiatives students receive direct mentorship from professional staff members over a multi-year period.

Over the past 10 years the center has grown from a single staff member and a few students to simultaneously employing over 35 staff and 120 students. In 2024 student employees come from a wide variety of disciplines ranging from Aeronautical Engineering to Film Studies. This paper reports on survey data from student, staff, and industry partners on the effectiveness of CDME. Based on ten years of general experience and six years of qualitative surveying students have experienced extremely positive outcomes from the program and are significantly better prepared than their peers to enter the next stage of their professional careers.

Introduction

Multiple parties have expressed a need for increasing the number of manufacturing professionals in the United States. The Department of Defense (DoD) has stated in September of 2023 that there are hundreds of thousands of job openings in manufacturing [1]. There exist eight DoD Manufacturing Institutes (MII), and seven out of eight of these private-public partnerships have a workforce roadmap and openly call for additional manufacturing workforce development programming [2] [3] [4] [5] [6] [7] [8]. Likewise, the U.S. Chamber of Commerce (CoC) identified 8.2 million job openings nationwide but only 7.2 million unemployed workers to fill these positions [9]. Multiple U.S. government agencies agree that there is a clear need for more people, and specifically more people interested in manufacturing, to enter the workforce.

Simultaneously, U.S. colleges are staring down the prospect of declining admissions. High school graduates are expected to peak in 2025 and then subsequently decline [10]. Of that declining high school graduating population less students every year are making the decision to directly enroll at a 4 year universities [11] and are instead opting for direct workforce entry [12]. University departments that previously could project growth based only on demographics now find themselves staring down not only a sharp enrollment cliff but potentially decades long drop and stagnation of college enrollment [13].

Given all these headwinds, The Ohio State University (OSU), in partnership with the U.S. Department of Commerce (DoC) and the DoD, made a commitment to developing America's manufacturing workforce in a way that few others have attempted. Identifying these looming issues back in 2014, The Center for Design and Manufacturing Excellence (CDME) was established to "Advance the Manufacturing Competitiveness of the United States" [14].

Although over the course of its almost ten years of existence CDME has made modifications to its business model, undergraduate students have always been core to its existence. In its current incarnation students spend 2-4 years working under the direct mentorship of staff engineers on a multitude of projects going in and out of the center. These projects, funded by university partners, private industry, state government, and federal government, provide students the opportunity to work in an environment that matches their experience after graduation. Students are programming robotic systems, developing medical devices, leveraging 3D printing techniques, and more [14].

In the years since its founding in December of 2014, CDME has experienced much success both financially as well as in student outcomes. By exposing undergraduates to the wide range of work opportunities in manufacturing, CDME believes it has increased the number of students interested in pursuing a career in this industry. Simultaneously, CDME is an excellent recruitment and retainment tool for undergraduate students seeking both pay to help offset the cost of university as well as hands on research experience that could lead to job offers post-graduation.

Methods / Implementation

CDME is setup more like a traditional business than an academic unit. Rather than students all being placed in a large class or research pool, each paid student employee is assigned a staff supervisor in a specific technical division. CDME has seven such divisions, focusing on a wide variety of technical topics. Each staff mentor is responsible for an average of 3-5 students and engages those students in a wide

variety of technical and professional tasks within the scope of the division. An overview figure can be seen below in Figure 1.

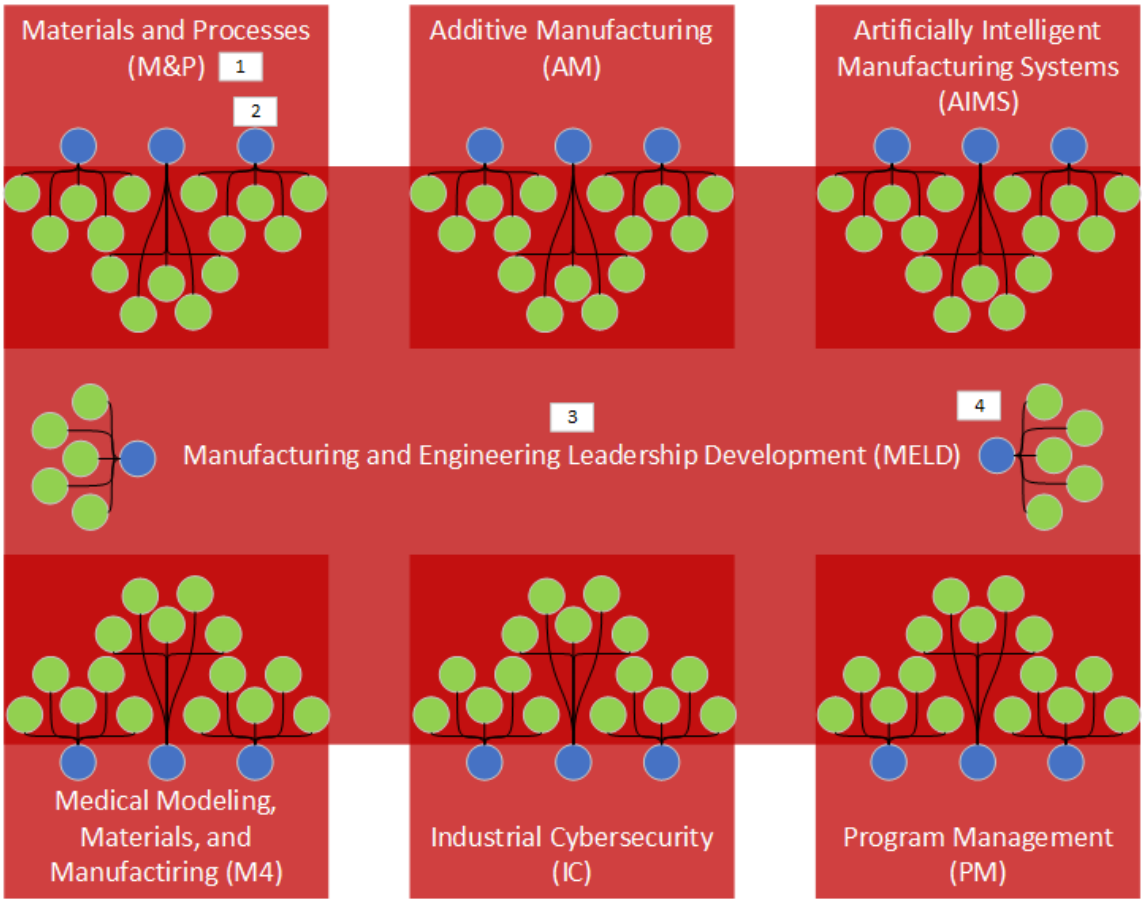

Figure 1 - Overview of Students and Staff at CDME.
(1) - Each Group of students and staff belongs to a technical division
(2) – Each staff member has between 3-5 students reporting to them and is responsible for their mentorship
(3) – MELD Division shares responsibility for mentorship and training of all students
(4) – MELD also has dedicated staff and students focused on daily center operations and improving the MELD program

When students work at CDME they are engaged in the entire project process from ideation to execution as appropriate to their current skill level. Entry level students, typically 1st and 2nd year, are primarily responsible for the nitty gritty details of physical project work. Sample preparation, basic part design, and 3D scan evaluation are all excellent examples of basic tasks a student might complete. As the student's skill progresses however, they are included in more complicated and detailed tasks across a wider range of the project. By the time students are in their 4th or 5th year, they are expected to be contributing to proposal writing, part quoting, design risk analysis, and project postmortem documentation. All the while students directly communicate with project stakeholders by phone, email, in person meetings, and other professional avenues.

While students are expected to take on more complex and technically challenging work the longer their tenure at CDME, the specific focus of the work is highly dependent on the Division the student works for. A brief description of each division is included here.

The Materials & Process (M&P) Division is focused on enhancing manufacturing through the integration of advanced materials, technologies, and processes. The division's mission is to push the boundaries of traditional manufacturing by developing new technologies and incorporating them into existing systems. This dual focus aims to improve manufacturing efficiency, agility, and sustainability.

This team of multidisciplinary researchers operates at the intersection of traditional materials, manufacturing methods and cutting-edge technology. Their approach looks at the entire manufacturing process chain, from raw material to finished part, to find opportunities for technological enhancement. Their ultimate goals are to create new manufacturing pathways by incorporating advanced technologies and to prepare the next generation of workers through educational initiatives.

The Additive Manufacturing (AM) Division is a leader in the additive manufacturing space, bringing together the equipment and technical expertise needed to foster academia and industry advancement. The AM lab houses more than $8 million in additive manufacturing equipment, including industrial 3D printers capable of processing metals, polymers, composites, biomaterials, and ceramics. They employ a team of experts in the additive manufacturing space who leverage this equipment while fostering collaboration across disciplines to advance the technology and grow the 3D printing ecosystem in Ohio.

The AM Division bridges the gap between Ohio State's research capabilities and industry needs in design, manufacturing, workforce development, and technology translation. Led by their team of AM engineers, the division is shaping the national conversation on 3D printing technology while training and educating the future AM workforce.

The Artificially Intelligent Manufacturing Systems (AIMS) Division is dedicated to the research and development of manufacturing systems that utilize or are controlled by various types of artificial intelligence. This multidisciplinary team operates at the intersection of manufacturing methods and the latest in sensing and software control to implement intelligent manufacturing systems. Utilizing advanced sensors, robotics, motion control, and software control, they improve manufacturing efficiency, agility, quality, and cost. Their primary goal is to improve manufacturing methods by incorporating advanced technologies and to prepare the next generation of workers through experiential educational initiatives.

The AIMS Division is an industry-relevant venue to develop and optimize novel, hybridized manufacturing processes, design and test custom sensors and controls, study and advance human-robot interaction, benchmark cognitive computing frameworks, and define security and ethics-based protocols. Overall, it fits into CDME's core mission of working with industry partners in applied research and while simultaneously supporting undergraduate student development during that research.

The Medical Modeling Materials and Manufacturing (M4) Division is where medicine, advanced manufacturing, and materials-related applications converge. M4 is a collaboration between CDME and the College of Medicine at The Ohio State University. Its mission is to develop engineering solutions for real-world needs in clinical medicine and support the life-saving efforts of medical professionals and Ohio State faculty through simulation training and education, medical device development, and clinical point of care manufacturing. The CDME M4 team includes engineering and program management staff, undergraduate students, and postdoctoral researchers who work closely with healthcare clinicians, medical residents, and medical students. It is through real-world funded projects that students are

integrated into the team and experientially learn project planning, project execution, and professional skills necessary to be a key contributor in the biomedical and healthcare fields.

Biomedical engineering and clinical experts utilize 3D printing and other traditional manufacturing methods to assist clinicians, faculty, and industry innovators in translating their needs into models and devices that enhance patient care. The team of biomedical, mechanical, electrical, software, and quality engineers support the design, testing, and fabrication of a breadth of medical products. The M4 team designs with the medical device product development regulatory pathway in mind, thus leading to outcomes that take innovations from "bench-to-bedside" to improve health outcomes. M4 has a diverse portfolio of medical products supporting clients in a wide spectrum of healthcare markets including clinical models, simulations, surgical tools, electromechanical devices, wound care, diagnostic testing, and therapeutic devices.

The Program Management (PM) Division at CDME serves a pivotal role in alleviating the administrative intricacies associated with overseeing translational research endeavors. Through a dedicated and proficient team, they extend support across all facets of contract administration, encompassing cost analysis, adept scheduling, project delivery, and finalization. Their operational approach is aligned with established industry standards and exemplifies best practices that facilitate successful introductions of innovative products into the market.

The Program Management Division priorities fostering student engagement once a project secures essential funding. This process entails a comprehensive immersion in the principles of Project Management Professional (PMP), imparting students with a profound understanding of the strategic underpinnings of effective project execution. The team's active participation extends through the entire project lifecycle, commencing with the initial project conceptualization, progressing through execution, and culminating in post-project evaluation and reporting.

The Manufacturing and Engineering Leadership Development (MELD) Division at Ohio State's Center for Design and Manufacturing Excellence (CDME) combines foundational fabrication services with exceptional workforce development. Members of this group support all the innovative work occurring across CDME's footprint of approximately 50,000 square feet. The mission of the engineers, scientists, and students of the MELD division is to ensure that every student and staff member at CDME is well equipped, properly trained, and as safe as possible when tackling the wide range of projects in the center.

In addition to foundational training and support services, the MELD division also runs CDME's safety and mentorship initiatives. Emphasizing an environment of continuous improvement, MELD operates the Center's 5S program. This program provides a monthly structure for all other Divisions to make small and incremental improvements in all areas of their operation. Along with this, MELD operates the center's monthly mentorship structure to ensure that all CDME's students receive the individualized attention they need to be successful in today's manufacturing environment.

Staff Mentors and Customers

Staff members in each division are responsible for more than the pure mentorship of their students. They are also responsible for finding and winning the project work that is used for these mentorship activities. To bring in a wide range of project work, the staff mentors at CDME come from multiple

technical disciplines. Figure 2 below shows the breakdown of each staff member's highest degree of technical attainment.

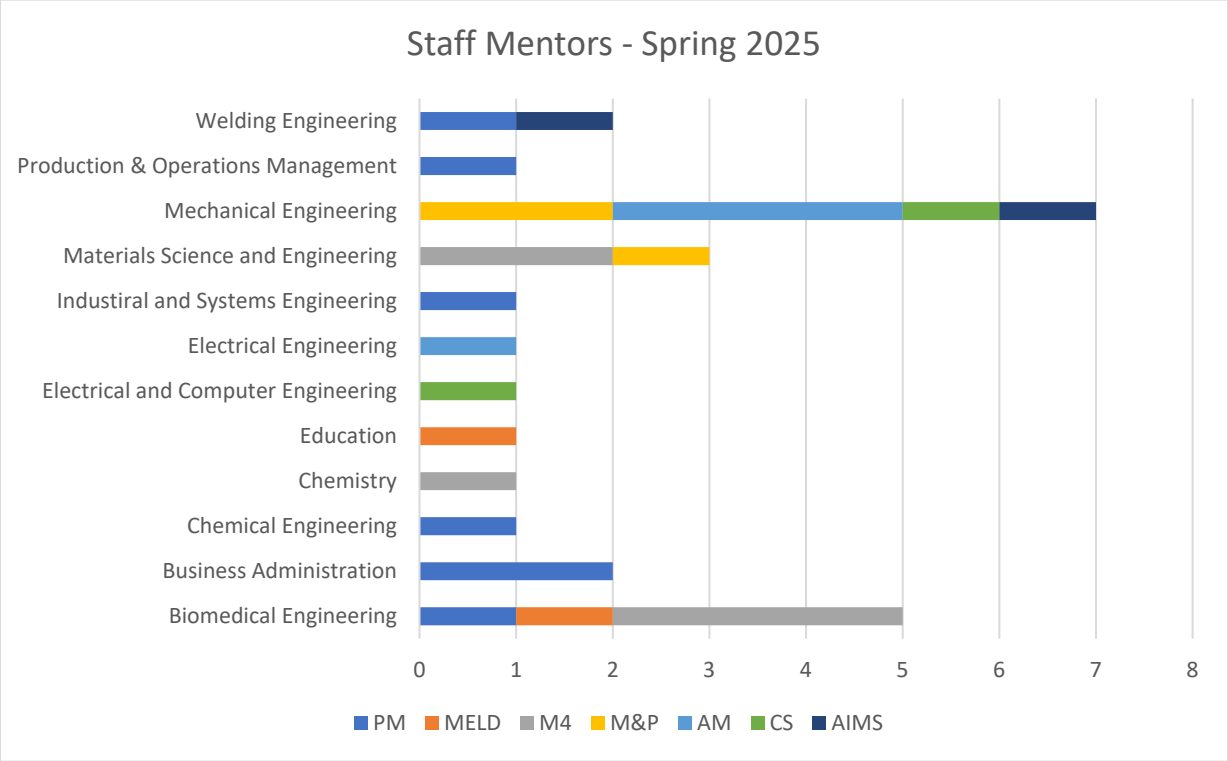

Figure 2 - Staff Mentor Highest Technical Degree Attainment, Spring 2025

The types of projects each staff member acquires vary as much as the technical focus of the mentors themselves. These projects can be as small as a $100 job for an internal research group to a multimillion-dollar federal grant. Due to the proprietary nature of many projects that come through CDME, specific company or agency names cannot be included in a paper. Anonymized data can be included though.

Broadly, CDME defines three main categories of customers. Industry projects are those sponsored by a private company or organization. Government projects are those sponsored as part of state or federal grants. University projects are those that are sponsored by a research group or other internal OSU customer. A broad summary of the types of projects each division in CDME engages student with can be seen below in Table 1.

Table 1 - Total Number of Projects Completed by Customer Type Since 2015

	Industry	Government	University	Total Division Projects
AIMS	7	10	1	18
AM	70	40	33	143
CS	9	6	8	23
M4	41	5	123	169
M&P	79	5	31	115
MELD	2	2	84	88
PM	169	49	126	344
Total CDME Projects Since 2015				900

Results

Over its ten years of existence CDME has employed 367 students across many different majors and levels of experience. Demographic data on all student employees is collected by Ohio State's central information system Workday where it can be accessed by any employer the student works for. CDME gathers this data bi-yearly and uses it to generate live reports in Tableau for all staff members to access. Results published here reflect data gathered through March 2024.

CDME has had a trajectory of student growth over its decade of existence. Starting from zero students in 2014, and only three students in 2015, it has grown to a 2023 high of 129 simultaneously employed students. Data from the second half of the 2024 fiscal year is not yet available, but based on normal student and staff attrition a similar rate of growth is projected through 2025. The drop in 2019 through 2021 is attributable to the COVID 19 pandemic, but once most businesses returned to normalcy growth had restarted by 2022. A chart plotting the growth of CDME's students can be viewed in Figure 2 below.

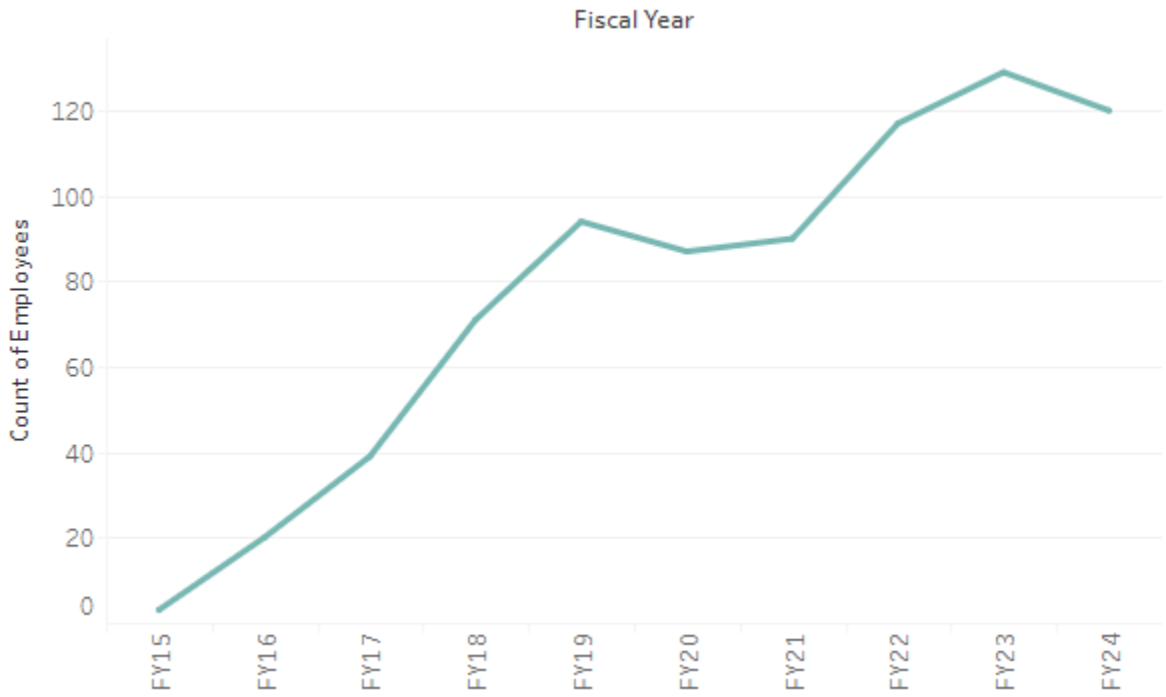

Figure 3 - Overall Number of Undergraduates Employed by Fiscal Year

Not only have CDME's raw student numbers increased, but the diversity of its students has also increased. In 2016 CDME only had a diverse percentage of students of 15%. As of 2023 that number has grown considerably to 33%. When compared to national Science and Engineering (S&E) bachelors rates, CDME falls short but is not significantly far off from the national diverse population percentage of 41% [15]. A broad representation of CDME over the past ten years is shown in Figure 3 while a detailed breakdown of 2023 and current 2024 racial diversity is seen in Figure 4 below.

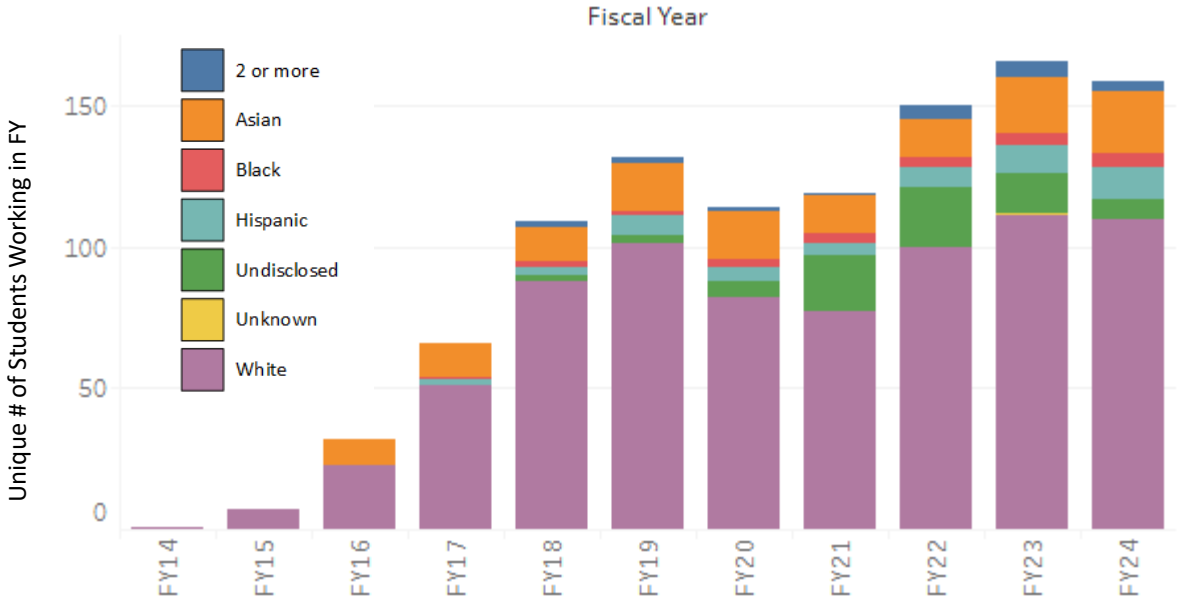

Figure 4 - Ethnic Diversity of Students and Staff at CDME

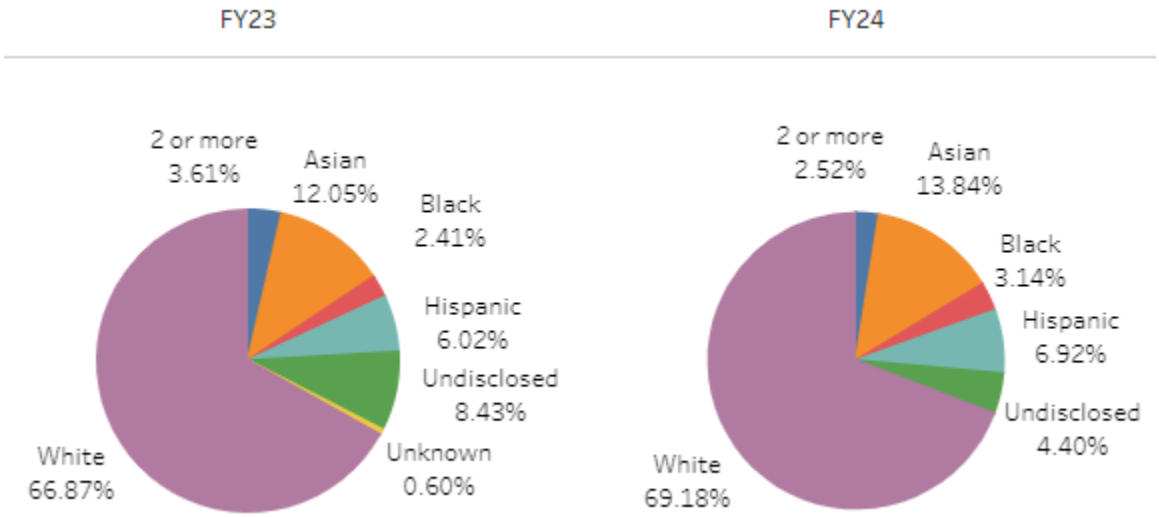

Figure 5 - Ethnic Diversity of Students and Staff for FY23 and FY24

Similar to CDME's ethnic diversity, the center also has seen growth in its gender diversity. When founded in 2014 the center had zero female students or staff members. As it has grown over the years, the percentage of female engineering students and staff at CDME has greatly increased. As of 2024, CDME's student population of females is 29%, greater than the Society of Women Engineers' 2021 bachelors STEM percentage of 25% [16]. A broad representation of CDME's gender diversity over the past ten years is shown below in Figure 5, while a detailed breakdown of 2023 and current 2024 data is seen in Figure 6.

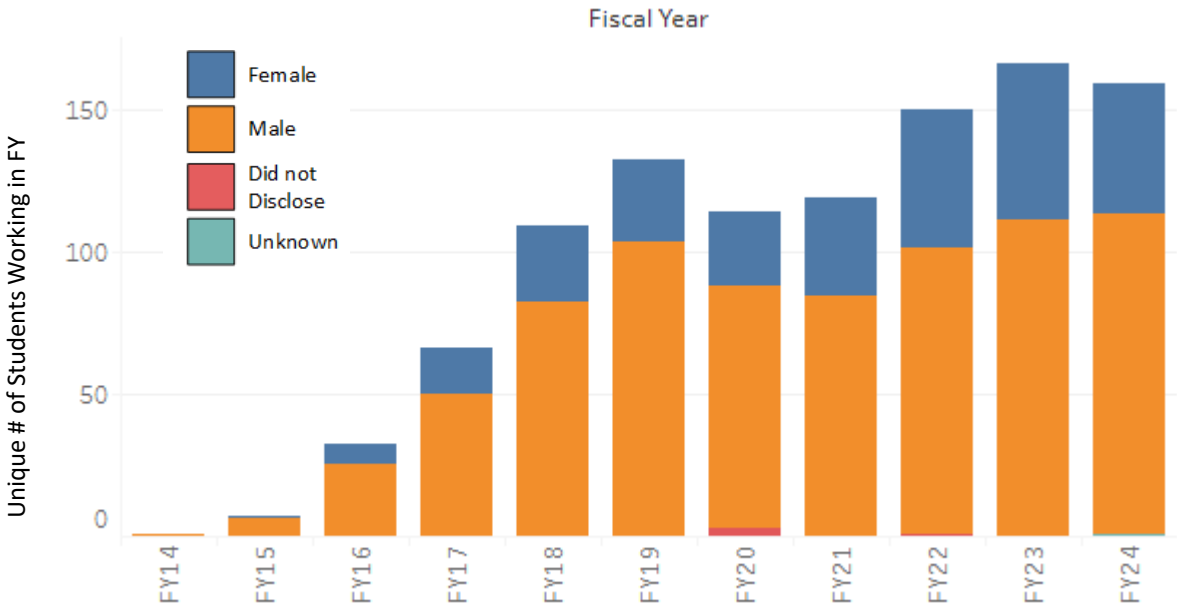

Figure 6 - Gender Diversity of CDME Students and Staff

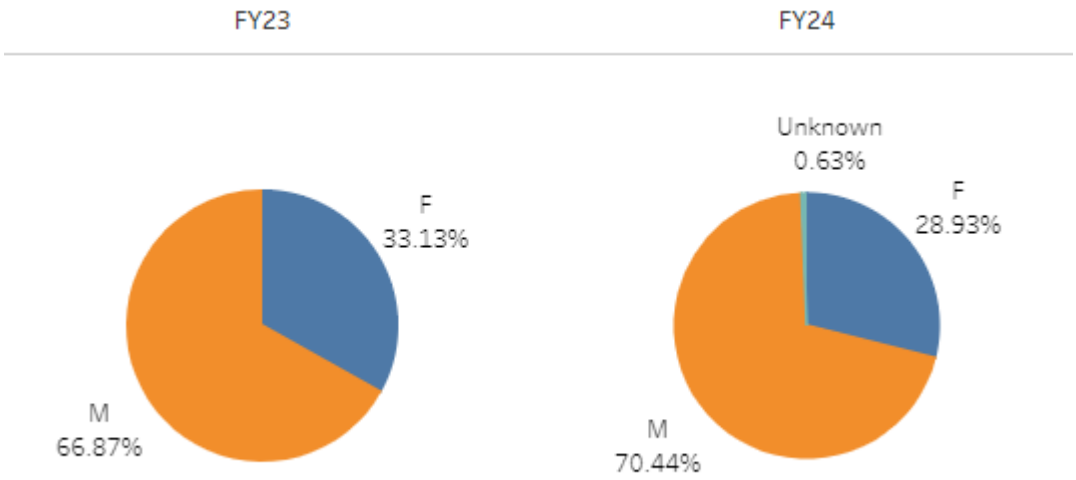

Figure 7 - Gender Diversity of Students and Staff for FY23 and FY24

CDME's contracted work is primarily focused on providing engineering services to its customers. Due to this focus, the largest group of student employes are engineering undergraduates from various disciplines. However, when interviewing students for positions staff members look not only for technical skill fit but also student intangibles such as drive and motivation. This results in CDME hiring students that are not engineers but are still interested in manufacturing. The largest three majors at CDME are Biomedical (33), Electrical/Computer (42), and Mechanical (44) but CDME has also hired art, criminology, and history students for various projects throughout its history. A full listing of all students hired at CDME is listed below in Figure 7.

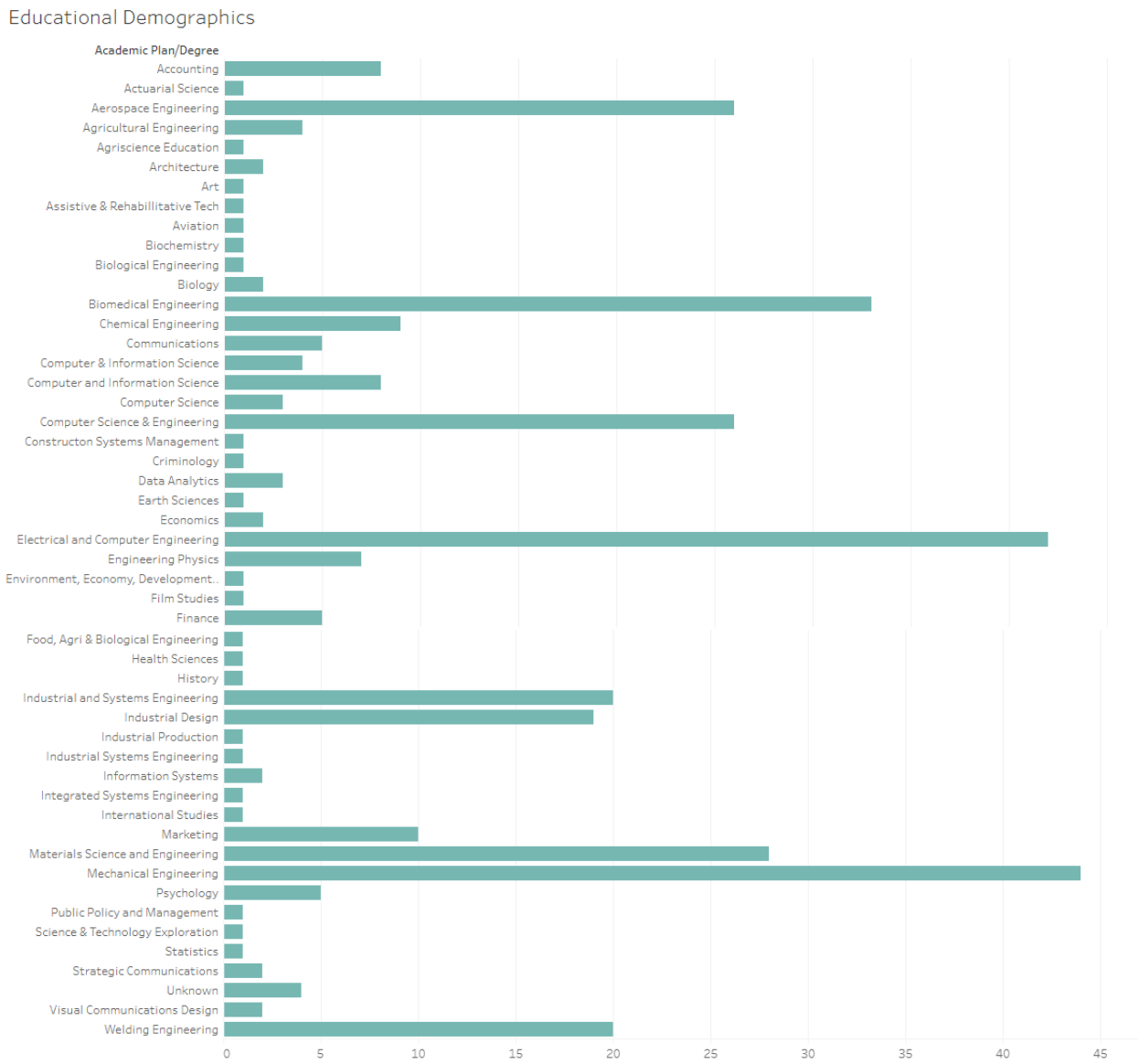

Figure 8 - Undergraduate Student Majors at CDME

Although each division has a stated mission and industry niche they target, the students hired in each division vary depending on the technical needs of the project work to be completed. As a representative sample, Figure 8 below visually shows a breakdown of undergraduate majors for all student employees at CDME for Spring Semester of 2025. A tabular view of this data can be found in the Appendix in Table 2.

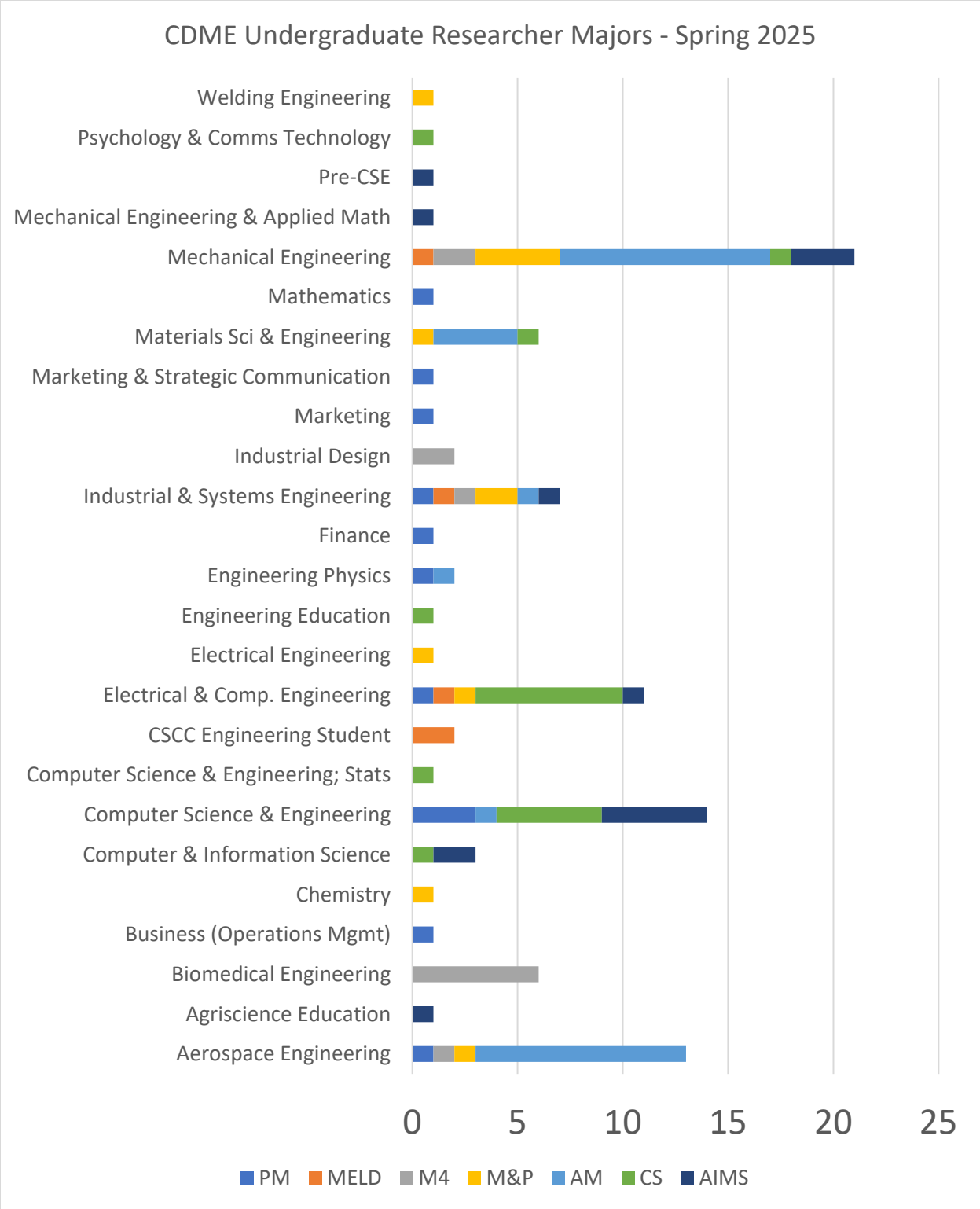

Figure 9 - Undergraduate Major Composition - SPR 2025

Students working at CDME appear to be committed to the center for a significant percentage of their academic career. Rather than being a multi month transient job, most students stay at least 11 months (functionally a full academic year after time allowances for HR processes) with many students being hired as 1st year students and staying for the entire duration of their five-year undergraduate career. Anecdotally, most students who leave before 11 months do so for other research positions at Ohio State that better serve their interests. Of the 367 students historically employed at CDME, 202 of them (55%) have stayed a year or longer. A detailed breakdown of student length of employment can be seen in Figure 8 below. Note that this figure covers all student employees at the center both former and current and so includes students who were just hired in FY24.

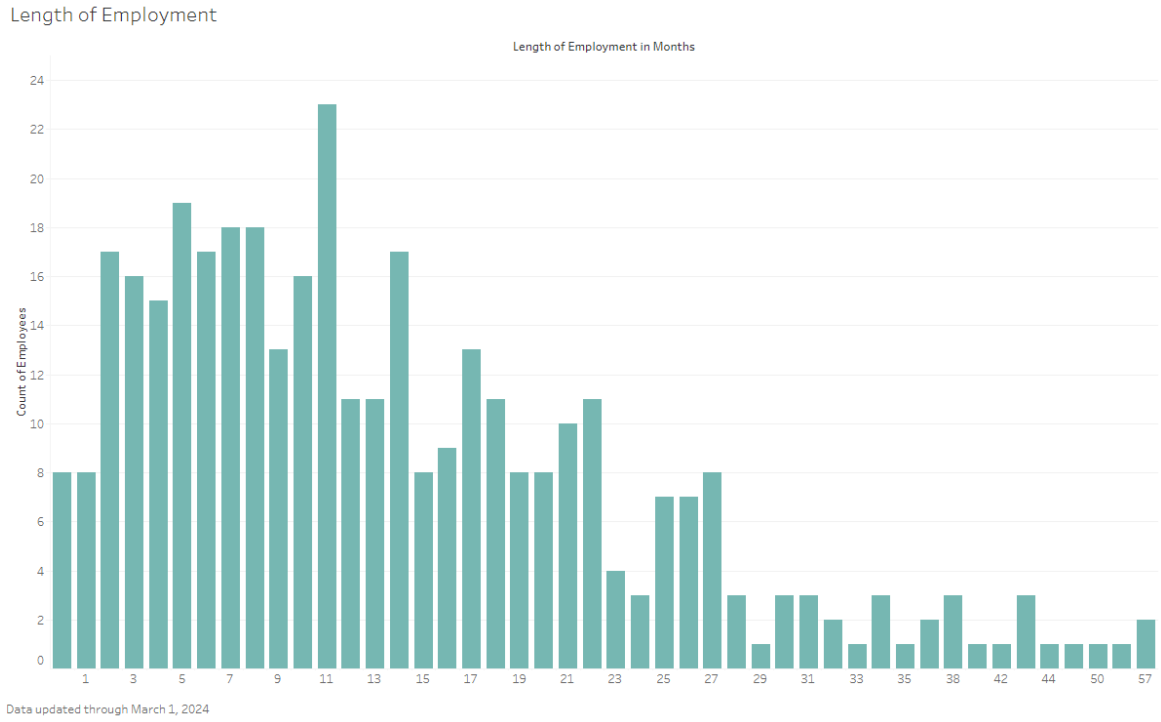

Figure 10 - Student Length of Employment

All students who work at CDME are asked to complete an end of year survey based on their experiences. CDME has been collecting these same survey data since 2019, and the results have been positive throughout. Specifically, the question: “Rate CDME’s ability to prepare you for your future career” has shown a steady increase from 7.6 to 8.4. A summary of the number of survey participants and response rate for the subsequent data can be seen below in Table 1 and Figure 9.

Table 2 - Response Rate for CDME Survey Data

Year	Students Contacted	Number of Responses	Response Rate
2019	39	18	46%
2020	66	33	50%
2021	55	26	47%
2022	83	28	34%
2023	95	23	24%
2024	95	39	41%

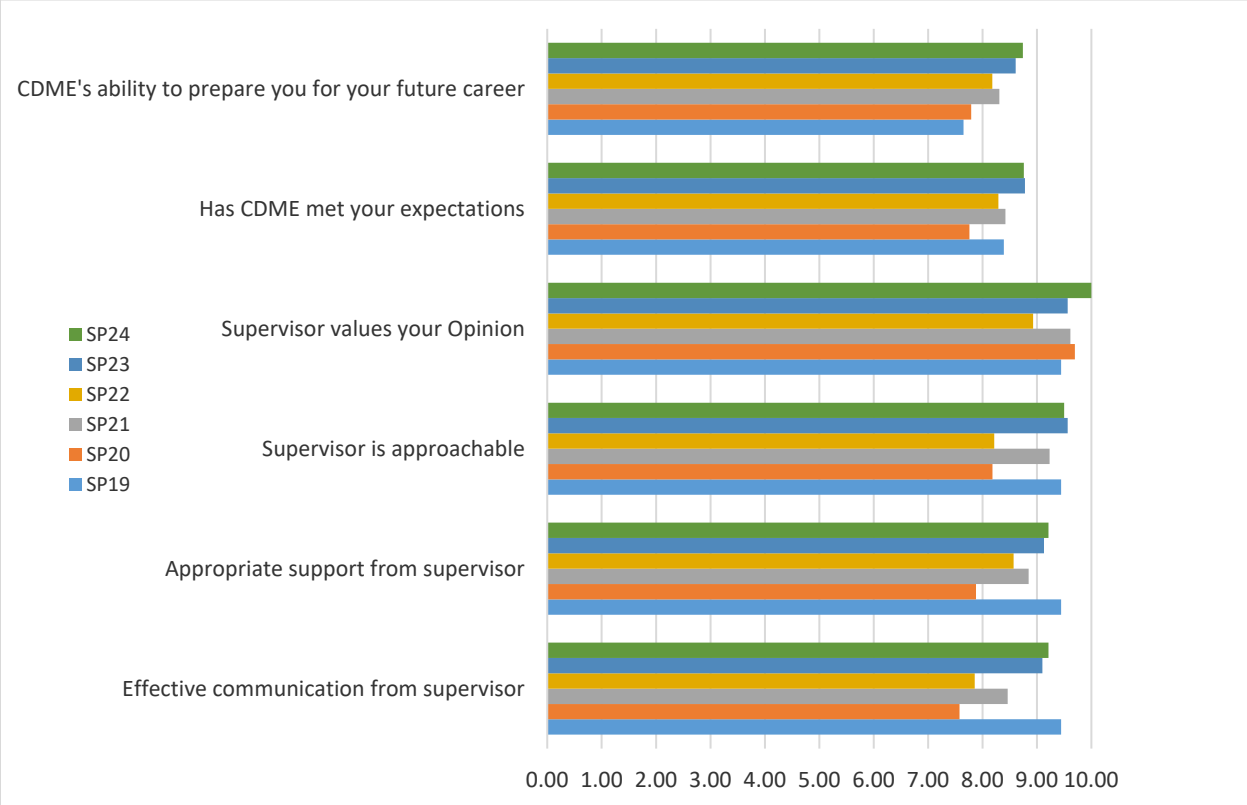

Figure 11 - Quantitative Survey Results

Beyond quantitative demographics and data, CDME also has an extensive library of qualitative testimonials from students that show its overall impact. These are collected through both the aforementioned survey as well as though one on one spotlight interviews [17] [18] [19] [20] [21]. As an

informal representation, a word cloud of the most mentioned words in the survey can be seen below in Figure 10.

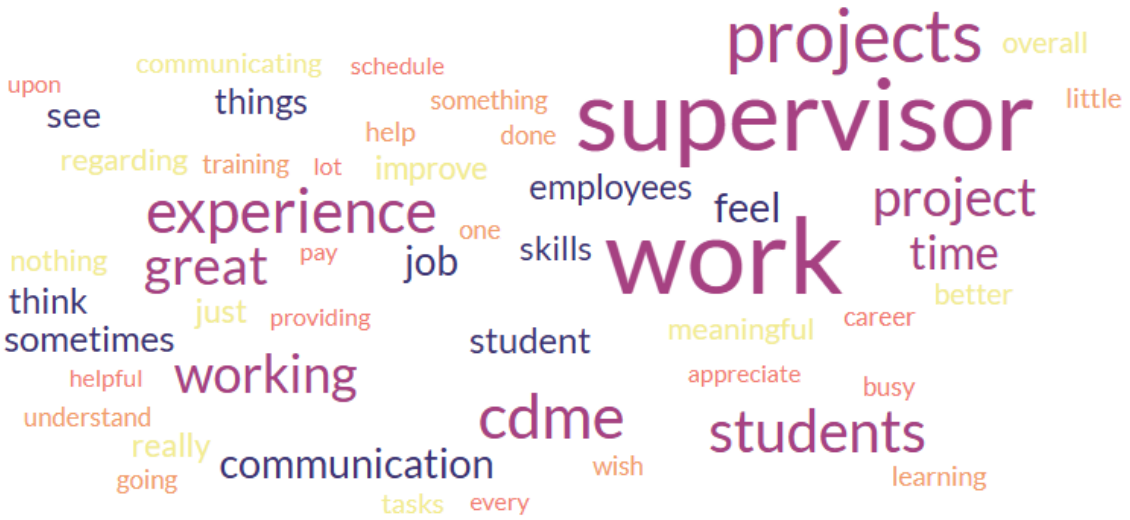

Figure 12 - CDME Survey Word Cloud

In addition to the above word cloud, a few survey response highlights from 2024 are as follows:

- [Supervisor] is an excellent boss to work for, he provides students with enough responsibilities so that we grow independently as engineers while providing consistent support whenever needed.
- CDME has been the highlight of my college experience. I enjoy all of the experience I have received and I'm happy to keep working here as long as I can before graduation.
- My supervisor has set me up incredibly well for graduate school and I could not be more grateful for them and all they have done during my time here.

Conclusions

In 2014, Ohio State made a commitment to help fill the manufacturing workforce pipeline with qualified students. Rather than focusing solely on additional academic courses, they invested in the idea that experiential learning opportunities in manufacturing would help develop high quality students for that pipeline. Ten years after its founding, CDME has grown substantially by engaging and training undergraduate students from many different majors at Ohio State. The center has cultivated a diverse student population from multiple majors, genders, and ethnicities all targeted at increasing the manufacturing competitiveness of the United States.

The implications of this retrospective study on the general efficacy of CDME are encouraging. Given the resurgent demand for manufacturing talent across the country CDME has proven to be an effective model for developing undergraduate students for careers this field. CDME has continued to grow the program year over year in terms of number of students, indicating both steady demand as well as the program's ability to meet this demand. The demographic cross section of students recruited into CDME meets or exceed the ethnic and gender expectations of similar engineering programs, indicating that the

program is attractive to a wide range of STEM students. Students who are hired at CDME tend to stay at least a full year with many students staying for longer than a year indicating that the substance of CDME's work is interesting and engaging to those students as well as relevant to their future careers.

Many of the students who work at CDME have excellent experiences that prepare them well for careers in manufacturing. Many students who work at CDME often have multiple internships and full-time job offers from relevant manufacturers before their undergraduate education is complete. In return, companies can work with students on extended duration projects as a prolonged vetting and corporate training process. When these two party's interests align it results in better trained undergraduate students who are more productive and more technically competent in their jobs. This productivity and technical competency gains are also realized more quickly than an average undergraduate student.

Overall CDME appears to be an effective way to engage undergraduate students in the nitty gritty details of modern-day manufacturing. Through its experiential learning structure CDME embeds these students on real customer projects for extended durations with direct staff mentorship. Such experiential learning programs could also be a great asset to existing traditional industrial or manufacturing engineering programs and help connect student's classroom learning to the tangible results of their education.

Future Work

While each testimonial or year of survey results could itself be the topic of an additional paper, the broad picture painted by both quantitative data and qualitative testimonials is one of students who are well prepared and confident for careers in manufacturing. They are leveraging existing relationships with CDME customers and already have extended experience working with that organization through previous projects. Although these students are academically successful, they still point to the valuable experiential training they received at CDME as vital to setting their careers up for even greater achievement.

Future work is required to continue both the growth of CDME and the analysis of its impact on students. The data presented in this paper was collected as an internal improvement tool rather than with a focus on showing specific learning outcomes with academic rigor. Developing and executing a program to quantitatively connect student learning objectives and outcomes to the work completed at CDME would provide an excellent next step to confirm the validity of CDME's positive qualitative student experiences. Similarly, CDME is interested in what impact work at the center impacts a student's academic performance and how this work compares to other research activities both at Ohio State as well as at other research institutions across the nation. Finally, CDME is interested in more comprehensive post-graduation investigations to determine if the hypothesized positive career impact can be measured once a student enters the workforce.

Looking forward, CDME is committed to improving its own mentorship and student outcomes. The MELD Division is actively developing a program to more rigorously document student's mentorship activities and connecting those activities to accepted student learning objectives. Data collected from this revamped mentorship model should provide greater insight into how CDME's staff members are providing mentorship as well as in what areas mentorship activities should be improved.

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Appendix

Table 3 - Research Majors for Spring 2025

CDME Undergraduate Researcher Majors - Spring 2025								
	PM	MELD	M4	M&P	AM	CS	AIMS	Total # Students
Aerospace Engineering	1	0	1	1	10	0	0	13
Agriscience Education	0	0	0	0	0	0	1	1
Biomedical Engineering	0	0	6	0	0	0	0	6
Business (Operations Mgmt)	1	0	0	0	0	0	0	1
Chemistry	0	0	0	1	0	0	0	1
Computer & Information Science	0	0	0	0	0	1	2	3
Computer Science & Engineering	3	0	0	0	1	5	5	14
Computer Science & Engineering; Stats	0	0	0	0	0	1	0	1
CSCC Engineering Student	0	2	0	0	0	0	0	2
Electrical & Comp. Engineering	1	1	0	1	0	7	1	11
Electrical Engineering	0	0	0	1	0	0	0	1
Engineering Education	0	0	0	0	0	1	0	1
Engineering Physics	1	0	0	0	1	0	0	2
Finance	1	0	0	0	0	0	0	1
Industrial & Systems Engineering	1	1	1	2	1	0	1	7
Industrial Design	0	0	2	0	0	0	0	2
Marketing	1	0	0	0	0	0	0	1
Marketing & Strategic Communication	1	0	0	0	0	0	0	1
Materials Sci & Engineering	0	0	0	1	4	1	0	6
Mathematics	1	0	0	0	0	0	0	1
Mechanical Engineering	0	1	2	4	10	1	3	21
Mechanical Engineering & Applied Math	0	0	0	0	0	0	1	1
Pre-CSE	0	0	0	0	0	0	1	1
Psychology & Comms Technology	0	0	0	0	0	1	0	1
Welding Engineering	0	0	0	1	0	0	0	1
Total CDME Undergraduate Student Employees - Spring 2025								101