Semiconductor Workforce & Talent Assessment

Prepared by ECOnorthwest and Dr. Wilfred Pinfold

for the Oregon Higher Education Coordinating Commission

Final Report

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ECOnorthwest

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Executive Summary

Study Background and Purpose

The passage of the CHIPS and Science Act (CHIPS Act) initiated a historic investment in U.S. semiconductor manufacturing, research and development (R&D), and sourcing, providing much-needed support for the development of domestic manufacturing capacity. The $52.7 billion investment is expected to drive demand for highly trained workers throughout the industry's complex production processes.

State lawmakers passed the Oregon CHIPS Act in April 2023, allocating $240 million to 15 companies planning expansions and CHIPS funding applications, with a goal of cementing Oregon's position as a global center of the semiconductor industry. Oregon officials expect $40 billion in new semiconductor investment in the coming years, which they anticipate will create 6,300 direct new jobs and 1,000 construction jobs in the state. This economic activity will spur opportunities for upskilling Oregon's workforce and provide high-quality and high-wage employment for Oregon residents.

Current educational pathways leading to the semiconductor workforce must expand to meet the scale of the CHIPS Act investments. High schools, workforce training providers, community colleges, universities, and the semiconductor industry will each play a role in supplying the workforce the CHIPS Act investments will support. This assessment of Oregon's semiconductor-related education programming serves as the first step in informing stakeholders of gaps and assets in semiconductor talent development pathways.

The report provides an overview of Oregon's semiconductor industry and workforce; a summary of engagement with interested parties across Oregon, including industry, education, and workforce development representatives; an analysis of student-level data, provided by the Oregon Higher Education Coordinating Commission (HECC), regarding enrollment in selected education pathways in Oregon's public postsecondary institutions and employment outcomes for completers of these programs; and recommendations focused on strengthening education pathways and diversifying the semiconductor workforce.

Findings

Oregon's Semiconductor Industry and Workforce

Semiconductor economic activity in Oregon, concentrated in the Portland metro area, creates demand across dozens of occupations—including engineers, technologists, assemblers, and technicians—with educational pathways ranging from high school diplomas to PhDs. Compared to the national average, the Portland-Vancouver-Hillsboro region has a high concentration of semiconductor processing technicians, computer hardware engineers, and industrial engineering technologists.

The Oregon semiconductor and related device manufacturing industry employs nearly 31,000 workers, with an average annual wage that's approximately two and a half times the average statewide wage. The Oregon Employment Department (OED) forecasts strong employment growth in the occupations most closely related to the semiconductor manufacturing industry.

Oregon's semiconductor workforce has a higher share of workers of color than does the statewide workforce, although race/ethnicity distributions vary across occupations within the industry. Only 12 percent of semiconductor workers are of historically underrepresented races or ethnicities—Hispanic or Latino, Black, Native Hawaiian and Pacific Islander, and Indigenous—a few percentage points less than the Oregon workforce overall.[1] Women are also underrepresented in Oregon's semiconductor workforce, at 25 percent of the total compared to 47 percent for Oregon's overall workforce. Historically underrepresented workers and female workers comprise higher shares of lower wage occupations than of the workforce overall, demonstrating the need for more-equitable access to educational pathways for higher wage occupations.

Core Semiconductor-Related Credential Completions

A "core" group of postsecondary programs related to the semiconductor industry workforce forms the basis for the analyses throughout this study. Credential completions in core semiconductor-related programs at public and private postsecondary institutions totaled nearly 2,000 in Oregon in 2021—3.7 percent of all completions.

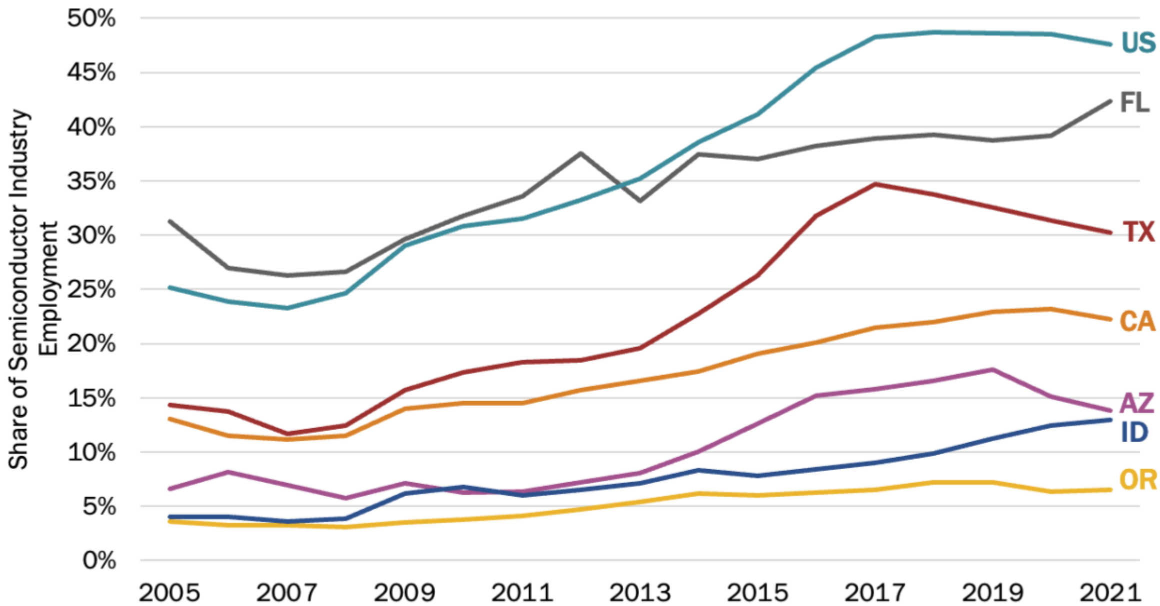
Interstate Comparison

Over the past 15 years, core semiconductor-related completions have increased as a share of all postsecondary completions at a faster rate in Oregon than the national average and faster than in four of the five other states with the largest semiconductor workforce, improving Oregon's ability to support industry needs. However, comparing semiconductor-related completions to semiconductor industry employment in each state presents a different picture, as illustrated in the chart below. Semiconductor-related completions as a share of annual industry employment in Oregon was 6 percent in 2021, the lowest among the five other states with the largest semiconductor workforce.

As the state with the 4th largest semiconductor manufacturing employment, Oregon accounted for 15 percent of industry employment in 2022, a share about equal to that of Texas (16 percent), a state with seven times the population of Oregon. Without a focus on specific credentials most acutely needed by the industry or that Oregon has relative advantages in producing, the relatively smaller size of the state's population postsecondary system could present challenges to staffing the industry with Oregon-developed talent as the state's industry grows.

[1] Throughout this summary and report, *historically underrepresented* refers to race and ethnicity.

Core Semiconductor-Related Completions Relative to Industry Employment



Data sources: Integrated Postsecondary Education Data System; Bureau of Labor Statistics, Quarterly Census of Employment and Wages

Semiconductor Pathways in Oregon's Public Postsecondary Institutions

Core Semiconductor-Related Credential Completers

This study's analysis of student-level HECC data begins to describe the paths Oregon students take from high school, through postsecondary education at Oregon's public postsecondary institutions, and into the semiconductor workforce. Due to the nature of the data and scope of this project, the picture is far from complete, but findings lay a foundation for more-comprehensive analysis in the future.

The share of historically underrepresented students in core programs has increased over time, reaching 6 percent of core program completions in 2021-22. Historically underrepresented groups are most represented among graduate core-program completers; however, representation at the undergraduate level (both university and community college) remains far below prevalence in the statewide population (21 percent), even after adjusting for students whose race and ethnicity is unknown. At the graduate level, women comprise 33 percent of core program completers, more than double the shares at the undergraduate and community college levels.

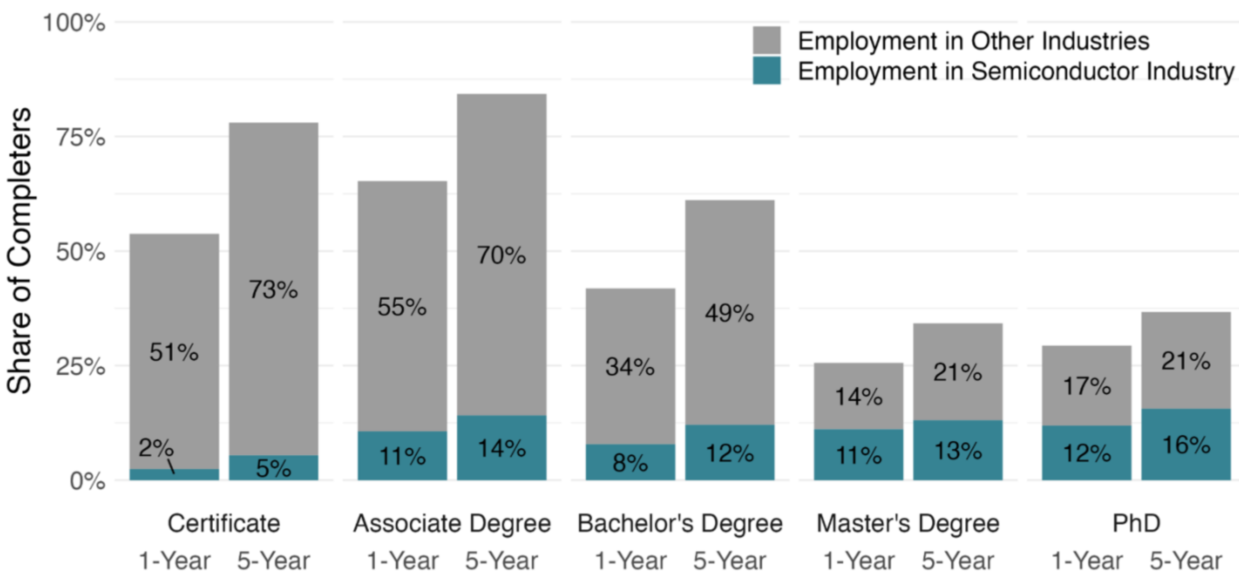
Dual-Credit Enrollees

The analysis also indicates that dual-credit courses available to Oregon high school students already serve as a stepping-stone to semiconductor-related postsecondary programs. Over the analysis period, 40 percent of students who took a semiconductor-related dual credit course in high school earned a postsecondary credential from an Oregon public postsecondary institution within five years after taking the dual credit course; 14 percent had earned a core semiconductor-related credential. In the future, this pool could serve as a focal point for efforts to raise awareness of the benefits of semiconductor pathways and to diversify the semiconductor workforce.

Post-Graduation Outcomes for Core Semiconductor-Related Program Completers

Within one year of graduation, 6 percent of community college completers gained employment in the semiconductor industry compared to 9 percent of university completers. Within five years of graduation, these employment rates increased to 9 percent and 13 percent, respectively. Semiconductor employment rates vary by credential type and completer demographics, with associate degree, master's degree, and PhD completers gaining employment in the semiconductor industry at higher rates compared to other credential types.

Post-Graduation Employment Outcomes (1-Year and 5-Year) for Core Semiconductor-Related Program Completers, Oregon



Data source: Oregon Higher Education Coordinating Commission

The analysis indicates that women and underrepresented races/ethnicities are relatively over-represented among completers who gained employment in the semiconductor industry. Historically underrepresented individuals comprised 3 percent of university completers but 5 percent of those employed in the semiconductor industry five years post-graduation, and 9 percent of community college completers but 11 percent of those with employment. Similarly, women comprised 15 percent of university-level completers but 17 percent of those employed in the semiconductor industry five years post-graduation, and 11 percent of community college completers but 18 percent of those employed in the industry.

Semiconductor employees also earn wage premiums compared to employees in other industries who completed a credential in one of the core programs. For example, historically underrepresented university completers earned 26 percent more in the semiconductor industry compared to other industries while community college completers earned 40 percent more. The semiconductor-industry wage premium for women university completers was relatively small (1 percent) compared to that for women community college completers (23 percent).

Implications of CHIPS Act Investments for Oregon's Postsecondary System

A brief scenario analysis provides context, grounded in data, for the response needed from Oregon's public postsecondary institutions to meet the additional industry growth within a state and national environment already expected to fall short. Modeling suggests the need for an increase in semiconductor-related credential production of 24 percent over 2022 levels (7 percent over 2019 levels). Accommodating the anticipated increase in Oregon's semiconductor industry in the coming years may pose challenges to the state's higher education institutions, particularly in light of very recent declines in production of industry-relevant credentials. The size of the industry in Oregon suggests the state should not aspire to meet all anticipated demand but should focus on systems and structures that strengthen existing pathways that address the most critical industry needs.

Interested Parties Engagement

The study team conducted formal interviews, informal conversations, site tours, and working sessions to ensure a well-rounded and current picture of the state of practice in postsecondary education across the state. The key findings of the engagement can be summarized in two high-level categories, which formed the basis for the recommendations summarized below and detailed in full in the report.

- Oregon's semiconductor-related programs and curricula are well established and on par with programs and curricula in other states. However, accredited programs in particular are not designed to adapt swiftly to the rapidly changing demands of the semiconductor industry.
- Educators (high school, community college, and university) and industry representatives cite many needs, which can be categorized under workforce entry, lifelong learning, and innovation.

Recommendations

The recommendations described below are based on the findings of this assessment and focus on meeting the semiconductor industry's workforce needs and increasing opportunities for Oregonians from all backgrounds and communities to gain employment in the industry. Improved access to education, training, and employment opportunities and pathways are essential to increasing gender, racial, ethnic, and other types of diversity in the industry. The state has an opportunity to support industry growth and increase semiconductor workforce diversity through investments and long-term tracking of workforce and talent metrics.

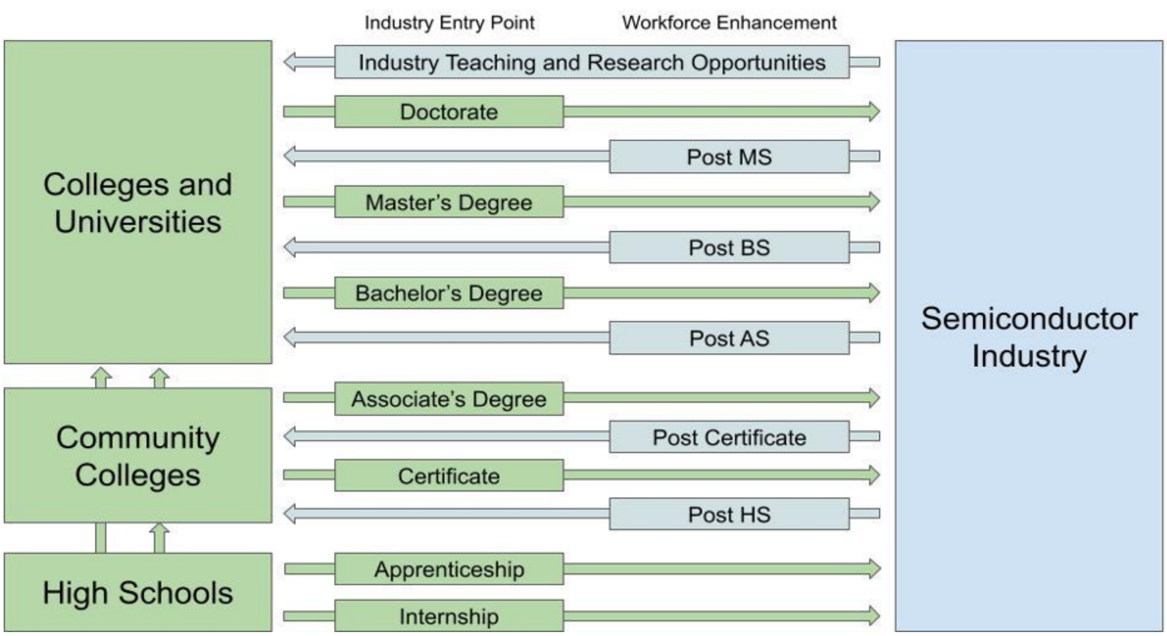
Apply an Educational Ladder Framework to Clarify Pathways

Interviewees identified successful programs—often led by innovative educators or supported by industry funding—bridging postsecondary education and Oregon's semiconductor industry. These initiatives address specific needs, adapt to evolving requirements, and have the potential to become enduring resources with coordinated support. Strategic coordination and backing can transform these programs into valuable assets for the local industry, positioning Oregon as a hub for new partnerships and retaining existing ones.

A well-functioning system should enable students to enter the industry early, gain essential skills, and receive income. Clear incentives, such as financial rewards and increased responsibility, should encourage individuals to transition from industry to postsecondary education for further qualifications. Strengthening "return pathways" through explicit incentives promotes lifelong learning.

The following visual representation of an educational ladder—while not comprehensive—illustrates pathways from postsecondary education to the semiconductor industry (green items) and routes from the industry back to education (blue items). Such pathways can bridge the gaps between postsecondary programs and industry employment in ways that further industry-specific job skills and broader essential skills and benefit both recent program graduates and seasoned professionals. The success of the educational ladder concept in practice will depend on well-defined pathways, the support and engagement of interested and affected parties, and ongoing evaluation efforts. The recommendations below suggest ways to enact and apply the framework.

Educational Ladder Framework



Strengthen Entries to Semiconductor Workforce Pathways and Employment

- Promote the Oregon semiconductor industry and reduce the size of awareness gaps
- Strengthen project-based learning and essential skills in earlier grades/levels
- Address the postsecondary education debt barrier and expand wraparound services for students from economically disadvantaged backgrounds, people of color, and other historically underrepresented populations
- Use remote learning and AI technologies to reduce the need for on-premise learning
- Develop and support programs that bridge education and industry

Create Lifelong Learning Opportunities for the Semiconductor Workforce

- Unveil hidden career advancement pathways through collaboration of educational institutions, government, and employers
- Encourage industry-educator collaborative learning through semiconductor employees leading project-based learning initiatives
- Grow the use of online learning to leverage Oregon's existing, robust online-education programs
- Incorporate new technology to analyze individual learning patterns, identify strengths and weaknesses, and tailor educational materials to meet the specific needs of each learner
- Implement industry-provided incentives for semiconductor industry workers to upskill while in mid-career
- Eliminate disincentives for semiconductor industry workers to complete additional training, facilitating the transition to more-rewarding work environments and higher compensation
- Leverage industry leaders as exemplars to inspire students and professional to envision a similar trajectory, promoting long-term commitment to the industry

Strengthen Education Programs through Research

- Overcome high equipment costs through collaboration between industry employers and educational institutions
- Remove barriers for industry professionals to engage in research, teaching, and leadership in academic settings
- Incentivize highly qualified industry employees to actively participate in educational programs during active employment and post-retirement

Further Quantitative Analyses to Inform Semiconductor Workforce Pathways

- Use data and analysis—such as pathways analysis—to inform workforce diversity strategies
- Focus on high school students and enrollees in dual-credit courses and their paths into semiconductor-related programs
- Focus on critical shortages in credential production and existing advantages

- Be realistic about meeting anticipated workforce demand by focusing on strengthening pathways, both explicit and less-recognized
- Further the analysis included in this study to quantify the roles of specific dual-credit and postsecondary courses and further analyze employment outcomes in other industries for core semiconductor-related program completers

Next Steps: Create a Semiconductor Workforce and Talent Working Group or Consortium

We recommend the creation of a working group or consortium to continue researching and addressing semiconductor workforce questions and needs in Oregon, followed by a permanent intermediary organization to support lifelong learning and strengthen the semiconductor talent pool. The intermediary organization could initially be a loose structure around existing programs, expanding and formalizing over time, with governance and accountability as crucial considerations. The recommendations outlined above and described in more detail in the full report provide a starting place for the working group or consortium and other entities across Oregon that are preparing for the workforce needs of the semiconductor industry.

We further recommend the working group or consortium have three teams—Workforce Entry, Lifelong Learning, and Research—each with representatives from four stakeholder groups—Government, Industry, Education, and Community/Workforce. This organizational structure will allow for deep discussion of the needs in each of the three areas: the left-to-right pathway of workforce entry, the back-and-forth pathways between industry and education, and the increased collaboration between industry and universities required to support innovation and industry growth. Organization and governance of the working group could follow the pattern of industry consortia established by Future Ready Oregon.

Collaboration will be instrumental in tracking metrics and other approaches to measure the success of ongoing initiatives. Regular assessments and data collection can ensure the continuous improvement and adaptability of programs, fostering innovation, workforce diversity, and sustained growth in the semiconductor industry.

1. Purpose of the Study

The passage of the CHIPS and Science Act (CHIPS Act) initiated a historic investment in U.S. semiconductor manufacturing, research and development (R&D), and sourcing, providing much-needed support for the development of domestic manufacturing capacity. The investment is expected to drive demand for highly trained workers throughout the industry's complex production processes.

The CHIPS Act allocates $39 billion to build, expand, or modernize domestic semiconductor manufacturing facilities; $11 billion to support chip R&D through both public-private and federal programs; $2 billion to the Department of Defense and the Department of State; $500 million to the International Technology Security and Innovation Fund; and $200 million to develop the domestic semiconductor workforce.[1]

As of July 2023, 50 projects had been announced in anticipation of CHIPS Act funding, which would create 44,000 new semiconductor jobs across the nation by 2030.[2] With the passage of the CHIPS Act, the Semiconductor Industry Association (SIA) estimates that the semiconductor industry workforce will add 115,000 direct jobs by 2030, representing a 33 percent growth rate over 2023 employment levels.[3]

Oregon is a global center of the semiconductor industry and is home to activities that span multiple stages of production, including fabless chip design, electronic design automation, tool manufacturing, and chip manufacturing and packaging. Anticipating the $52.7 billion in federal dollars to be distributed across the country, Oregon's semiconductor industry can leverage these dollars to expand and strengthen production, research, and supply chain activities.[4] State lawmakers passed the Oregon CHIPS Act (Senate Bill 4) in April 2023, allocating $240 million to 15 companies planning expansions and CHIPS funding applications.[5] Oregon economic officials expect $40 billion in new semiconductor investment in the coming years, which they anticipate will create 6,300 direct new jobs and 1,000 construction jobs in the state. This will be a gradual

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[1] U.S. Senate Committee on Commerce, Science, and Transportation (2022). *CHIPS and Science Act of 2022 Section-by-Section Summary*. Accessed at: https://www.commerce.senate.gov/2022/8/view-the-chips-legislation

[2] Semiconductor Industry Association (2022). *The CHIPS Act Has Already Sparked $200 Billion in Private Investments for U.S. Semiconductor Production*. Accessed at: https://www.semiconductors.org/the-chips-act-has-already-sparked-200-billion-in-private-investments-for-u-s-semiconductor-production/; U.S. Senate Committee on Commerce, Science, and Transportation (2023). *On One Year Anniversary, Cantwell Says CHIPS and Science Act Seeding US Manufacturing, Innovation Resurgence*. Accessed at: https://www.commerce.senate.gov/2023/8/on-one-year-anniversary-cantwell-says-chips-and-science-act-seeding-us-manufacturing-innovation-resurgence

[3] Semiconductor Industry Association and Oxford Economics (2023). *Chipping Away: Assessing and Addressing the Labor Market Gap Facing the U.S. Semiconductor Industry.* Accessed at: https://www.semiconductors.org/chipping-away-assessing-and-addressing-the-labor-market-gap-facing-the-u-s-semiconductor-industry/

[4] The White House (2022). *FACT SHEET: CHIPS and Science Act Will Lower Costs, Create Jobs, Strengthen Supply Chains, and Counter China*. Accessed at: https://www.whitehouse.gov/briefing-room/statements-releases/2022/08/09/fact-sheet-chips-and-science-act-will-lower-costs-create-jobs-strengthen-supply-chains-and-counter-china/

[5] Rogoway, Mike. "Oregon forecasts $40 billion semiconductor windfall, more than 6,000 new jobs" (2023). Accessed at https://www.oregonlive.com/silicon-forest/2023/09/oregon-forecasts-40-billion-semiconductor-windfall-more-than-6000-new-jobs.html

increase in the demand for a highly trained workforce to support the semiconductor industry expansion, which can continue to spur opportunities for upskilling Oregon's workforce and provide high-quality and high-wage employment for Oregon residents.[6]

Current educational pathways leading to the semiconductor workforce must expand to meet the scale of the CHIPS Act investment. High schools, workforce training providers, community colleges, universities, and the semiconductor industry each play a unique role in creating and maintaining workforce development pathways that will ultimately advance Oregon's semiconductor economic activity and growth across the state. This assessment of Oregon's semiconductor-related education programming provides the first step in informing stakeholders of gaps and assets in the semiconductor development pathway.

An understanding of the pathways leading to the semiconductor industry helps position Oregon to meet the needs brought on by the anticipated growth in semiconductor workforce hiring. Hence, this report includes a characterization of the occupations and associated skills that are concentrated in the semiconductor industry and considers whether and how these skills are supplied from Oregon institutions. Our analysis of credential production for pertinent semiconductor-related occupations offers insight into where Oregon's postsecondary education system stands out and where additional efforts should be focused to increase credential production.

However, the identified trends—although important—cannot answer crucial questions such as: why do some students with demonstrated competencies gain employment in the semiconductor industry while others do not, what are the socioeconomic characteristics and academic profiles of those who enroll in a relevant pathway, and what are the characteristics of students who complete a given program (certificate or degree) and gain employment in the industry? An analysis of students' progressions from postsecondary programs into the workforce addresses these questions. This pathways analysis considers student characteristics and transitions from education to the workforce separately for community college students and university students

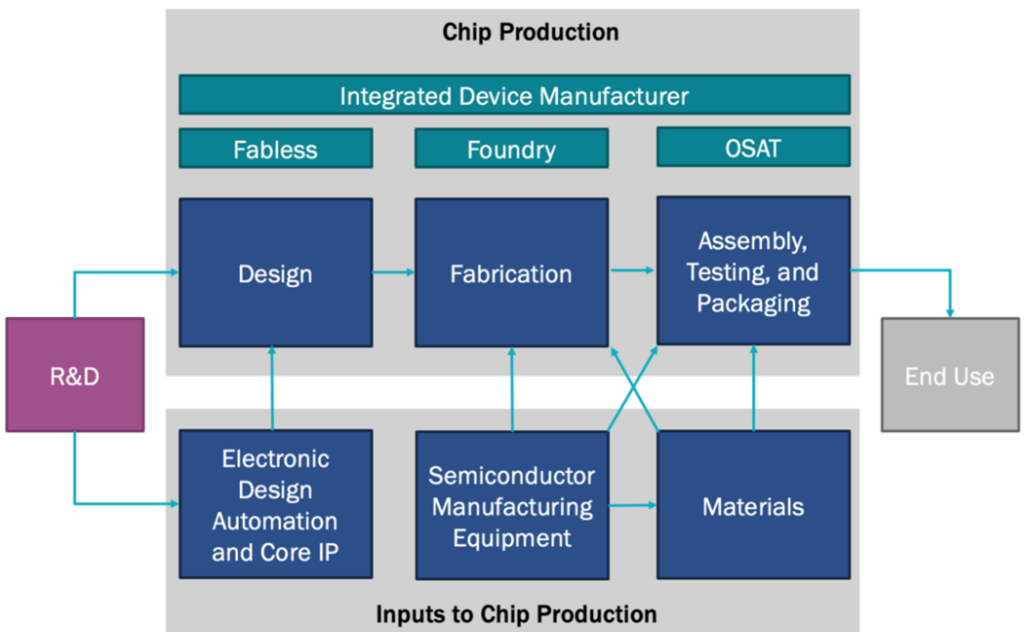
[6] See also Oregon Legislature (2023). *Oregon CHIPS Act Update*. Accessed at: https://olis.oregonlegislature.gov/liz/2023I1/Downloads/CommitteeMeetingDocument/277234; Oregon Semiconductor Competitiveness Task Force (2022). *Seizing the Opportunity*. Accessed at: http://oregonbusinessplan.org/wp-content/uploads/2022/08/Semiconductor-Task-Force-Report-for-Release1.pdf; The Oregonian. (2023) "Oregon Economists Forecast Thousands of New Semiconductor Jobs, 'Tens of Billions' in New Investment." Accessed at: https://www.oregonlive.com/silicon-forest/2023/08/oregon-economists-forecast-thousands-of-new-semiconductor-jobs-tens-of-billions-in-new-investment.html&subscribed=google-oauth2%7C111972355343984639186

2. Overview of the Semiconductor Industry and Workforce

Industry Activities

The semiconductor supply chain consists of research and development (R&D), chip production, chip production inputs, and distribution (see Exhibit 1). R&D informs each part of the semiconductor supply chain by advancing foundational technologies. Chip production operations can be categorized under the following business models: integrated device manufacturers (IDMs), fabless facilities, foundry facilities, and outsourced semiconductor assembly and test (OSAT) providers. An IDM integrates chip design, fabrication, and assembly, testing, and packaging (ATP) into one firm and sells the chip. However, most U.S. firms specialize in one part of the chip production process. Fabless facilities sell chips and conduct chip design, while purchasing fabrication services from foundry facilities and ATP services from OSAT facilities.

Exhibit 1. Semiconductor Supply Chain



Notes: Blue indicates supply chain segment; Teal indicates business model for production
Data source: The Semiconductor Supply Chain: Assessing National Competitiveness, 2021

Inputs to chip production include electronic design automation (EDA) and core intellectual property (IP), semiconductor manufacturing equipment (SME), and materials. In the design phase of production, engineers and technologists use EDA software to create the specifications, logic design, and physical design of the chip. Fabrication uses SME, a highly specialized and complex set of machinery, to create wafers. This phase of production generally requires workers with less postsecondary education and more on-the-job training. ATP consists of cutting the wafers into individual chips and packaging chips into their usable final form. The ATP process requires SME and uses labor with skills similar to those needed for fabrication.

The U.S. and its allies are the global leaders across all production phases.[8] Most notably, the U.S. has the largest global market share of EDA software and design. In Oregon, most facilities are classified by SIA as either IDMs (39 percent) that design, manufacture, and sell chips; or fabless facilities (21 percent) that design and sell hardware and chips, but do not manufacture wafers (see Exhibit 2). Oregon has a higher portion of IDM, fabless, and equipment facilities than does the U.S. overall, and a lower share of university R&D partners and EDA facilities than does the U.S.[9] Note that the scale of facility operations is unknown in these data, suggesting the need for caution in interpreting the meaning of differences between Oregon and U.S. shares at the industry segment level.

Exhibit 2. Oregon Semiconductor Facilities by Industry Segment, 2023

Industry Segment	Oregon Facilities	Industry Segment Share in Oregon	Industry Segment Share in U.S.
IDM	11	39%	36%
Fabless	6	21%	15%
University R&D Partner	3	11%	20%
Equipment	3	11%	7%
Materials	2	7%	11%
Foundry	1	4%	4%
IP & EDA	1	4%	5%
Foundry, IDM	1	4%	2%
Total	28	100%	99%

Notes: The U.S. shares do not sum to 100% because one industry segment—outsourced assembly and test services—is present in the U.S. but not in Oregon.
Data source: Semiconductor Industry Association, Semiconductor Ecosystem Map, 2023

Each facility can conduct one or multiple activities (R&D, chip design, manufacturing, and/or IP & EDA). Exhibit 3 shows the number of Oregon facilities by major activity type defined by SIA and the share of facilities conducting each activity type in Oregon compared to the U.S. (again, the number of facilities does not translate to the scale of activities in a facility). Oregon is above the national average in its concentration of facilities conducting chip design and/or manufacturing. Chip design work generally involves electrical, electronic, and computer engineers and scientists, while manufacturing work involves a wide range of technicians, technologists, and assemblers. Because each facility can conduct multiple activities, facilities in the table can be counted in more than one row. For example, facilities that conduct chip design and R&D are counted once in chip design and once in R&D.

[8] Khan, Saif M. (2021). *The Semiconductor Supply Chain: Assessing National Competitiveness*. Accessed at: https://cset.georgetown.edu/publication/the-semiconductor-supply-chain/
[9] R&D partners are defined as "Universities with semiconductor programs and are partner institutions of the Semiconductor Research Corporation (SRC) or the National Nanotechnology Coordinated Infrastructure (NNCI)." See the U.S. Semiconductor Ecosystem Map at https://www.semiconductors.org/u-s-semiconductor-ecosystem-map/

Exhibit 3. Oregon Semiconductor Facilities by Activity Type, 2023

Facility Activity	Oregon Facilities	Activity Conducted Share in Oregon	Activity Conducted Share in U.S.
R&D	19	42%	49%
Chip Design	13	29%	22%
Manufacturing	12	27%	25%
IP & EDA	1	2%	3%

Data source: Semiconductor Industry Association, U.S. Semiconductor Ecosystem Map, 2023

Semiconductor Occupations

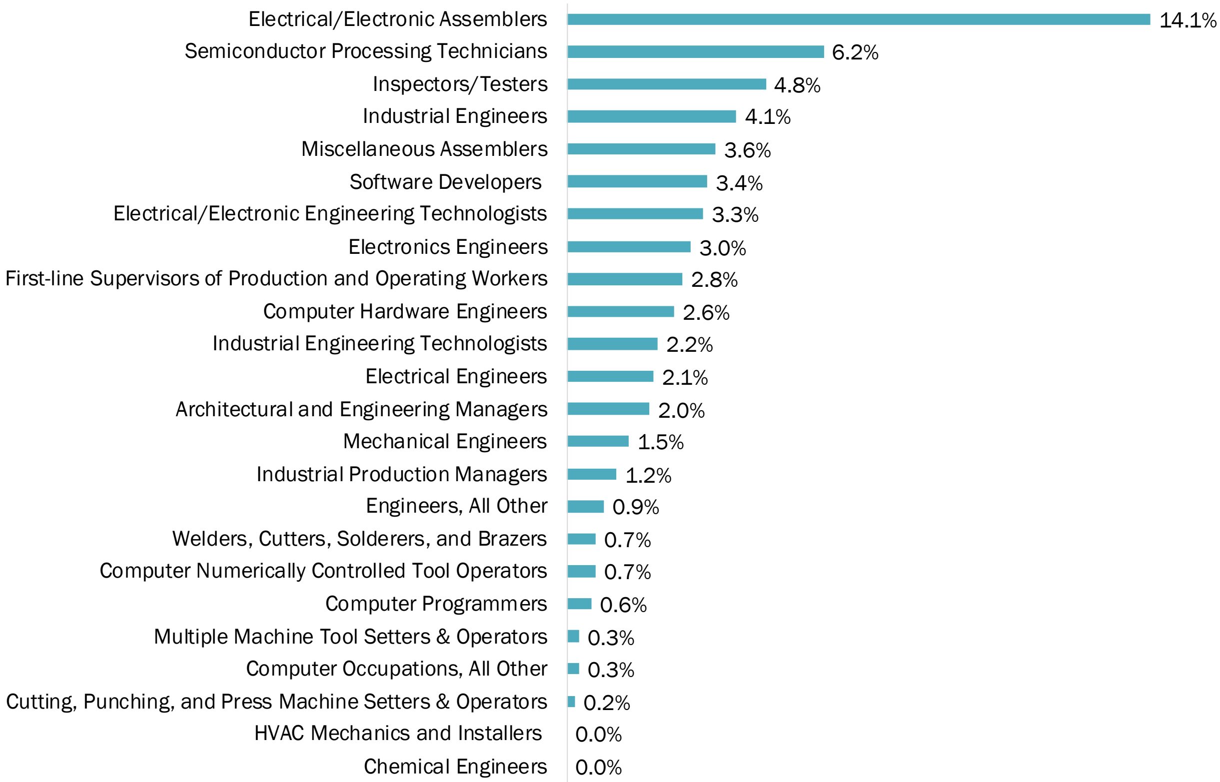
The semiconductor industry encompasses more than 150 occupations across a wide range of skill sets. Some of these occupations, such as lawyers, accountants, and sales representatives, are common in many industries, while others are more specific to the semiconductor manufacturing industry.

Semiconductor economic activity in Oregon, concentrated in the Portland metro area, creates demand for engineers, technologists, assemblers, and technicians. The educational pathways for these specialized occupations range from high school diplomas to PhDs. Across the U.S., semiconductor and other electronic component manufacturing, the industry subsector defined by the North American Industry Classification System (NAICS) features a mix of highly technical R&D and design occupations as well as less-technical occupations involved in assembly, processing, and production.[10] Additionally, industry activities are supported by management, administration, financial, and sales occupations. Although professional services serve necessary functions within the industry, these occupations are not directly employed in the production phase, and thus are not a focus of this study.

Exhibit 4 identifies the most common occupations in semiconductor and other electronic component manufacturing in the U.S. These occupations accounted for 61 percent of the industry's employment in 2021. Of the top occupations, fabrication occupations accounted for 29 percent of industry employment, engineering and design occupations accounted for 20 percent, and management occupations accounted for 5 percent. This national distribution of occupations serves as a necessary proxy for the occupational composition of Oregon's semiconductor industry because state occupational data suppress information about several occupations important to the industry. For example, there is no available Oregon-level data on employment of electrical/electronic assemblers, chemical engineers, or semiconductor processing technicians.

[10] NAICS 3344, Semiconductor and Other Electronic Component Manufacturing, is the industry group most relevant to semiconductor manufacturing in publicly available data.

Exhibit 4. Top Occupations by Employment Share in U.S. Semiconductor and Other Electronic Component Manufacturing



Data source: Bureau of Labor Statistics, National Employment Matrix for NAICS 3344, Semiconductor and Other Electronic Component Manufacturing, 2021

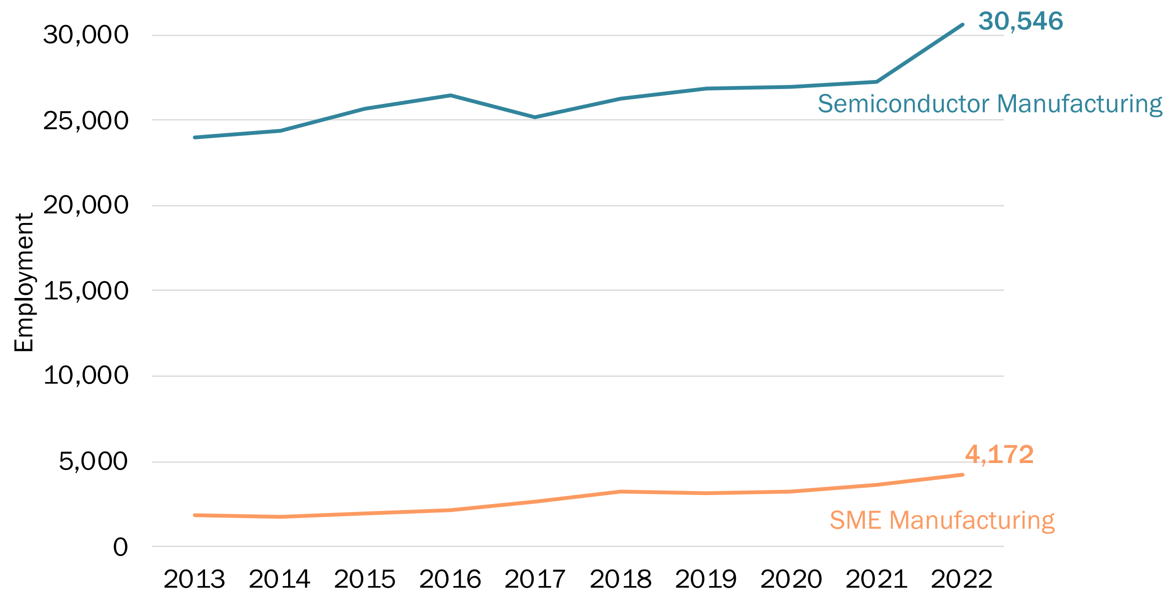
In 2022, the Oregon semiconductor and related device manufacturing industry employed 30,546 workers, with an average annual wage of $171,750, approximately two and a half times the average statewide wage.[11] Semiconductor industry employment increased by 13 percent between 2021 and 2022 after increasing by approximately 2 percent annually, on average, between 2013 and 2021 (see Exhibit 5). Semiconductor machinery manufacturing, which produces SME, employed 4,172 workers in 2022, with an average annual wage of $131,187.[12] Semiconductor machinery manufacturing employment increased at an average annual rate of 9 percent between 2013 and 2022.

As shown in Exhibit 6, metropolitan statistical areas (MSAs) in the states with the largest semiconductor workforce generally have an employment location quotient (LQ) above 1.00 in the top semiconductor occupations, signifying that employment in an occupation is above the national average concentration.[13] The Portland-Vancouver-Hillsboro MSA has a high concentration of semiconductor processing technicians, computer hardware engineers, and industrial engineering technologists compared to the national average. San Jose, CA, and

11 Oregon Employment Department (2022). Quarterly Census of Employment and Wages, NAICS 334413.
12 Oregon Employment Department (2022). Quarterly Census of Employment and Wages, NAICS 333242.
13 Semiconductor Industry Association (2021). *Chipping In: The Positive Impact of the Semiconductor Industry on the American Workforce and How Federal Industry Incentives Will Increase Domestic Jobs*. Accessed at: https://www.semiconductors.org/chipping-in-sia-jobs-report/

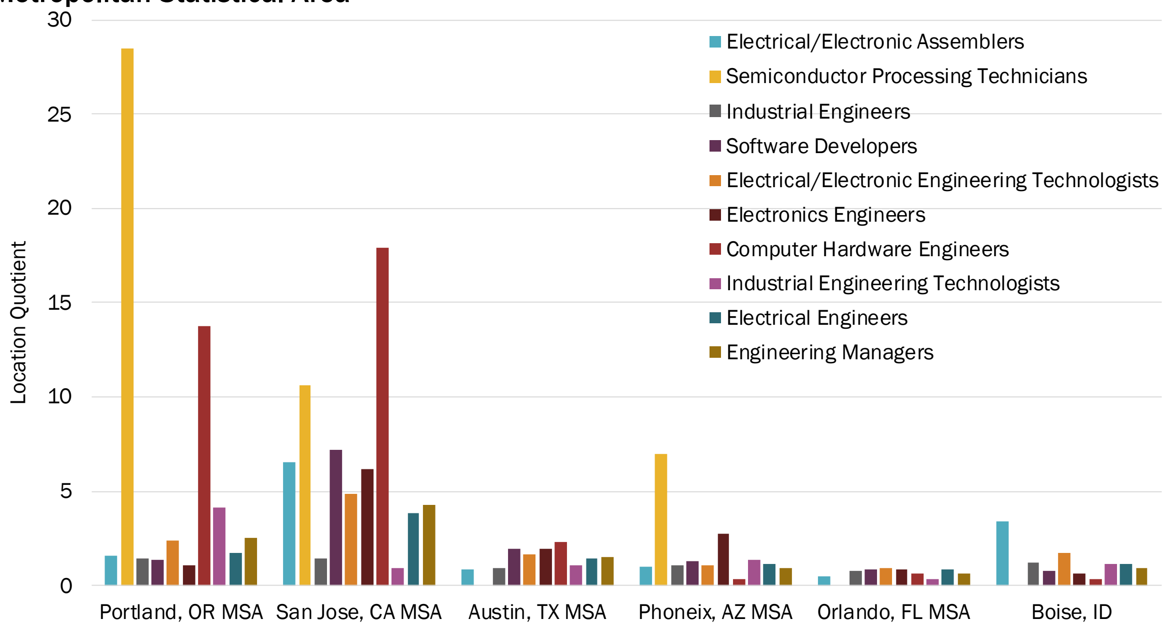
Phoenix, AZ, follow Portland in the highest concentration of semiconductor processing technicians. San Jose has the highest concentration of computer hardware engineers and electrical and electronic assemblers, while Portland has the highest concentration of semiconductor processing technicians and industrial engineering technologists across the MSAs displayed in the chart.

Exhibit 5. Oregon Semiconductor and SME Manufacturing Employment, 2013-2022



Data source: Oregon Employment Department, Quarterly Census of Employment and Wages, 2013-2022

Exhibit 6. Job Location Quotient for Se6lected Top Occupations in the Semiconductor Industry, by Metropolitan Statistical Area



Data source: Bureau of Labor Statistics, Occupational Employment and Wage Statistics, May 2022

Employment in the semiconductor manufacturing industry's top 15 occupations totaled 80,291 in the state in 2021 (see Exhibit 7).[14] Employment across these occupations is anticipated to increase by 7,555 by 2031. The occupations with the highest projected growth are software developers and testers, industrial engineers, and electrical engineers. Electrical and electronic assemblers and semiconductor processing technicians, occupations crucial to the fabrication and ATP stages of manufacturing, are anticipated to grow by 10 and 4 percent, respectively. The top semiconductor industry occupations that have anticipated negative employment growth in the state are miscellaneous assemblers and inspectors/testers. Miscellaneous assemblers are relatively more exposed to the risk of production automation, as workers are employed in various production industries besides the semiconductor industry.[15] Overall, the Oregon Employment Department (OED) forecasts strong employment growth in the occupations most closely related to the semiconductor manufacturing industry.

Exhibit 7. Employment Projections, Semiconductor Industry's Top Occupations, Oregon

Occupation	2021 Oregon Employment	2031 Oregon Employment	Percent Change	Average Annual Openings
Software Developers/Testers	18,767	23,489	25%	1,768
Miscellaneous Assemblers	10,417	10,170	-2%	1,012
First-line Supervisors of Production and Operating Workers	7,295	8,102	11%	759
Inspectors/testers	6,529	6,138	-6%	645
Electronics Engineers	5,025	5,677	13%	379
Electrical/Electronics Assemblers	4,790	5,247	10%	533
Semiconductor Processing Technicians	4,561	4,760	4%	488
Industrial Engineers	4,433	5,352	21%	381
Engineering Managers	3,978	4,517	14%	308
Heating, Air Conditioning, Refrigeration Mechanics, and Installers	3,753	4,352	16%	405
Mechanical Engineers	3,643	4,139	14%	266
Electrical Engineers	2,801	3,331	19%	233
Electrical/Electronic Engineering Technologists and Technicians	2,653	2,938	11%	261
Computer Hardware Engineers	1,343	1,396	4%	97
Chemical Engineers	303	353	17%	23
Total/Average	80,291	89,961	11%	7,555

Data source: Oregon Employment Department, 2021

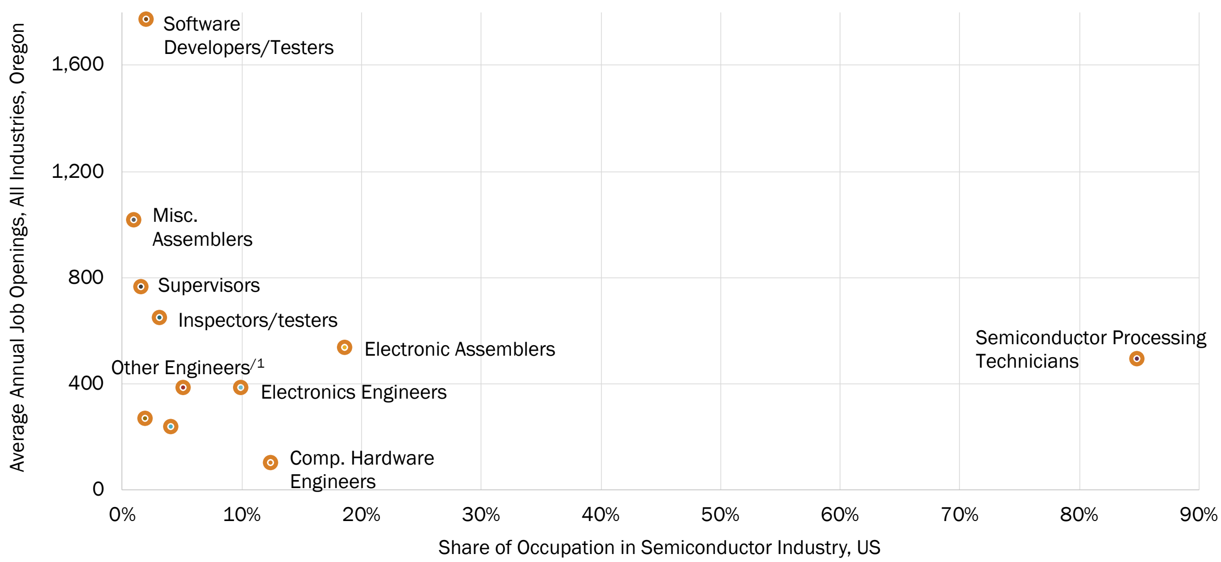
Between 2021-2031, OED projects average annual job openings for semiconductor processing technicians, electronic assemblers, and electronics engineers of between 400 and 550 each. Based on national averages, the semiconductor industry will generate approximately 85 percent of the

[14] Oregon Employment Department (2021). Occupational Employment Projections. Accessed at: https://www.qualityinfo.org/

[15] Correspondence with Oregon Employment Department Projections Economist, July 2023

projected annual job openings for semiconductor processing technicians, 19 percent of electronic assemblers, and 10 percent of electronics engineers. Exhibit 8 compares the occupational demand generated by the semiconductor industry (horizontal axis) to average annual projected job openings (vertical axis) for the top occupations in the industry. For example, 10 percent of U.S. electronics engineers work in the semiconductor industry and the occupation is projected to have 379 openings per year (across industries). In comparison, 85 percent of semiconductor processing technicians work in the industry and the occupation is projected to have 488 openings per year. The implications for pathway development and planning vary based on each occupation's concentration in the semiconductor industry.

Exhibit 8. Projected Job Openings versus Share of Occupation in Semiconductor Industry for Industry's Top Occupations, Oregon



Notes: /1: Electrical Engineers, Industrial Engineers, and Mechanical Engineers.
Data source: Oregon Employment Department, Occupation Projections, 2021-2031; Bureau of Labor Statistics, National Employment Matrix, 2021

Exhibit 9 presents the annual employment and median annual wage for the semiconductor industry's top occupations in 2022. The occupations most involved in the R&D and design phases of the semiconductor supply chain earn the highest wages, such as engineers, engineering managers, and software developers. The occupations involved in fabrication and ATP earn, on average, $40,000 to $50,000. Note that the wage estimates presented are for occupations across industries; in general, the semiconductor manufacturing industry offers higher wages compared with other industries.[16]

[16] U.S. Census Bureau. (2021). American Community Survey, 5-year Estimates.

Exhibit 9. Employment and Wages in Semiconductor Industry's Top Occupations, Oregon

Occupation	2022 Annual Employment	2022 Median Annual Wage
Software Developers	19,876	$125,882
Miscellaneous Assemblers	12,604	$39,541
First-Line Supervisors of Production and Operating Workers	8,762	$62,754
Computer Hardware Engineers	8,458	$137,030
Inspectors/Testers	6,418	$48,838
Semiconductor Processing Technicians	5,173	$51,126
Engineering Managers	4,407	$157,082
Industrial Engineers	4,233	$103,501
Electrical and Electronic Assemblers	4,061	$40,456
Heating, Air Conditioning, Refrigeration Mechanics, and Installers	3,623	$63,710
Mechanical Engineers	3,488	$102,877
Software Quality Assurance Analysts and Testers	2,643	$84,594
Electrical Engineers	2,407	$106,288
Electrical and Electronic Engineering Technologists and Technicians	2,363	$65,978
Industrial Engineering Technologists and Technicians	2,205	$63,565
Electronics Engineers	1,093	$103,542
Chemical Engineers	200	$87,485
Semiconductor Industry Average Wage		$171,750
Oregon Workforce Median Wage		$49,400

Data source: Oregon Employment Department, Occupational Employment Statistics, 2022; Oregon Employment Department, Quarterly Census of Employment and Wages, 2022

Semiconductor Workforce Demographics

The semiconductor industry workforce has a higher share of workers of color than does the statewide workforce, although race/ethnicity distributions vary across occupations within the industry. In 2021, approximately 45 percent of the Oregon semiconductor industry workforce identified as Black, Indigenous, or People of Color (BIPOC), compared to the Oregon workforce average of 25 percent.[17] Between 2012 and 2021, the share of BIPOC workers in the semiconductor industry workforce increased by almost 13 percentage points (see Appendix A).

Asian workers represent approximately 27 percent of the total workforce in the Oregon semiconductor industry—more than half of the BIPOC workforce. Historically underrepresented groups in STEM fields—Hispanic or Latino, Black, Native Hawaiian and Pacific Islander, and Indigenous individuals—comprise approximately 18 percent of the Oregon

[17] U.S. Census Bureau (2021). American Community Survey, 5-year Estimates.

semiconductor workforce.[18] In 2021, the gap in employment for historically underrepresented groups between the Oregon workforce and the semiconductor industry is a couple of percentage points smaller than it was in 2012 (see Exhibit 10).[19]

Semiconductor processing technicians and supervisors of production and operating workers realized the greatest increases in the historically underrepresented share of workers (e.g., 19 percent in 2012 to 30 percent in 2021 for Other Production Workers, which includes semiconductor processing technicians). The occupations with the highest relative shares of historically underrepresented workers in 2021 were technicians, supervisors, and assemblers.

Exhibit 10. Top Semiconductor Occupations and Historically Underrepresented/1 Worker Shares, Oregon

Occupation	2012	2021
Other Production Workers/2	19%	30%
First-line Supervisors of Production and Operating Workers	14%	26%
Miscellaneous Assemblers	24%	24%
Electrical/Electronics Assemblers	25%	23%
Inspectors/Testers	14%	19%
Heating, Air conditioning, Refrigeration Mechanics and Installers	11%	12%
Engineering Technologists & Technicians/3	10%	12%
Industrial Engineers	2%	8%
Mechanical Engineers	5%	7%
Electrical/Electronics Engineers	3%	7%
Computer Hardware Engineers	9%	7%
Software Developers	4%	5%
Engineering Managers	5%	3%
Chemical Engineers	4%	0%
Semiconductor Industry Average/4	8.0%	11.9%
Oregon Workforce Average	13.1%	16.2%

Notes:
/1: Historically underrepresented populations in STEM fields include individuals who identity as Hispanic or Latino, Black or African American, Alaskan Native or American Indian, and Native Hawaiian or Pacific Islander
/2: Includes Semiconductor Processing Technicians
/3: Occupation defined as Industrial Engineering Technologists/Technicians and Electrical and Electronics Engineering Technologists/Technicians
/4: The ACS industry estimates are for Electronic Component Manufacturing which includes Semiconductor and Other Electronic Component Manufacturing and Manufacturing and Reproducing Magnetic and Optical Media
Data source: U.S. Census Bureau, ACS 5-year Estimates 2012 and 2021

Exhibit 11 presents occupation-level disaggregation by race and ethnicity in 2021. More than one quarter—27 percent—of workers in electronic component manufacturing (which includes

[18] See National Science Foundation (2023). *Diversity and STEM: Women, Minorities, and Persons with Disabilities.* Accessed at: https://ncses.nsf.gov/pubs/nsf23315/
[19] Differences between the share of historically underrepresented workers in the statewide workforce and those in the top occupations in the semiconductor industry are not necessarily statistically significant. Additionally, differences between 2012 and 2021 shares are not necessarily statistically significant.

semiconductor manufacturing) identify as Asian. Workers with these identities are more concentrated in engineer, assembler, and software developer/tester occupations than in occupations statewide. Hispanic or Latino workers are more concentrated within assembly, inspector/tester, semiconductor processing technician, and supervisor of production worker occupations, which have median annual wages that are below or at the statewide average of $49,400. Historically underrepresented workers and female workers (see below) comprise higher shares of lower wage occupations than of the workforce overall, demonstrating the need for more-equitable access to educational pathways for higher wage occupations.

Exhibit 11. Top Semiconductor Occupations and Shares of Workers by Race/Ethnicity, Oregon, 2021

Occupation	White	Asian	Black or African American	Hispanic or Latino	Other/4
Software Developers	72%	19%	1%	4%	4%
Other Production Workers/1	61%	7%	1%	27%	4%
Inspectors/Testers	68%	10%	1%	16%	5%
Miscellaneous Assemblers	60%	13%	3%	19%	5%
First-line Supervisors of Production and Operating Workers	69%	1%	1%	24%	4%
Engineering Technologists & Technicians/2	70%	10%	2%	10%	8%
Electrical/Electronics Engineers	56%	36%	2%	4%	2%
Mechanical Engineers	87%	5%	1%	6%	2%
Industrial Engineers	82%	8%	2%	5%	3%
Engineering Managers	82%	7%	1%	1%	9%
Heating, Air conditioning, Refrigeration Mechanics and Installers	78%	2%	1%	11%	8%
Electrical/Electronics Assemblers	46%	22%	2%	14%	16%
Computer Hardware Engineers	58%	32%	6%	1%	4%
Chemical Engineers	86%	12%	0%	0%	2%
Semiconductor Industry/3	55.2%	27.2%	2.7%	7.9%	7.0%
Oregon Workforce Average	74.6%	4.9%	1.8%	13.3%	5.5%

Notes:
/1: Includes Semiconductor Processing Technicians
/2: Occupation defined as Industrial Engineering Technologists/Technicians and Electrical and Electronics Engineering Technologists/Technicians
/3: The ACS industry estimates are for Electronic Component Manufacturing which includes Semiconductor and Other Electronic Component Manufacturing and Manufacturing and Reproducing Magnetic and Optical Media.
/4: Includes non-specified racial groups and those that account for less than 2.7% of the total.
Data source: U.S. Census Bureau, ACS 5-year Estimates 2021

The semiconductor industry workforce is composed of 25 percent women whereas Oregon's overall workforce is composed of 47 percent women. Workers that identify as female account for a higher share of assemblers, inspectors/testers, and technicians relative to other top occupations (see Exhibit 12). Female workers comprise a lower share of most engineering and computer-related occupations relative to the average across occupations. In the semiconductor industry, the share of female workers decreased between 2012 and 2021, from 27 percent to 25 percent.

Exhibit 12. Top Semiconductor Occupations and Female Worker Shares, Oregon

Occupation	2012	2021
Software Developers	17%	18%
Other Production Workers/1	25%	27%
Inspectors/testers	38%	34%
Miscellaneous Assemblers	36%	31%
First-line Supervisors of Production and Operating Workers	19%	16%
Engineering Technologists & Technicians/2	23%	20%
Electrical/Electronics Engineers	13%	9%
Mechanical Engineers	8%	7%
Industrial Engineers	18%	25%
Engineering Managers	12%	8%
Heating, Air Conditioning, Refrigeration Mechanics, and Installers	1%	4%
Electrical/Electronics Assemblers	47%	39%
Computer Hardware Engineers	7%	8%
Chemical Engineers	15%	21%
Semiconductor Industry Average/3	27.4%	25.1%
Oregon Workforce Average	47.9%	47.3%

Notes:
/1: Includes Semiconductor Processing Technicians
/2: Occupation defined as Industrial Engineering Technologists/Technicians and Electrical and Electronics Engineering Technologists/Technicians
/3: The ACS industry estimates are for Electronic Component Manufacturing which includes Semiconductor and Other Electronic Component Manufacturing and Manufacturing and Reproducing Magnetic and Optical Media. /4: Includes non-specified racial groups and those that account for less than 2.7% of the total.
Data source: U.S. Census Bureau, ACS 5-year Estimates 2021

Finally, the semiconductor workforce has relatively high educational attainment and wages. A higher share of workers (65 percent) in semiconductor manufacturing hold a bachelor's degree or higher, compared to the Oregon workforce average (37 percent).[20] And workers in Oregon semiconductor manufacturing—in low-, middle-, and high-wage jobs—earn more than their peers in other industries. Higher-than-average wages are present across all genders, races, ethnicities, and levels of educational attainment.[21]

[20] U.S. Census Bureau (2021). American Community Survey, 5-year Estimates.
[21] Oregon Business Council (2023). *Economic and Fiscal Impact of Semiconductor Industry Expansion in Oregon*. Accessed at: https://cdn.orbusinesscouncil.org/docs/policy/Oregon_Semiconductor_Industry_Report.pdf

Semiconductor Credential Attainment

Postsecondary credential programs at institutions that help train the semiconductor workforce can be matched to each occupation within the industry via a crosswalk provided by the National Center of Education Statistics (NCES), which matches postsecondary programs to occupations based on specific skills and knowledge needed to be successful in an occupation.[22] Not all of the top occupations in the semiconductor industry are matched with programs in Oregon; for example, semiconductor processing technicians, electrical/electronic assemblers, and miscellaneous assemblers generally do not require postsecondary training, and therefore are not included in the NCES mapping. NCES assigns Classification of Instructional Programs (CIP) codes to fields of study and groups them into categories. For example, the fields of study matched to the mechanical engineer occupation—Electromechanical Engineering, Engineering Mechanics, and Mechanical Engineering—are each assigned a CIP code and included in the engineering category. For a complete summary of the mapping of Oregon's relevant postsecondary programs to occupations, see Exhibit A-2 in Appendix A.

A total of 47 CIP codes, or NCES-classified fields of study, relate to the semiconductor industry workforce and are grouped within five categories: engineering, engineering technologies and technicians, computer and information science, precision production, and mechanic and repair technologies and technicians. Specifically, there are 20 fields of study in engineering, 12 in engineering technologies and technicians, 9 in computer and information science, 5 in precision production, and 1 in mechanic and repair technologies and technicians. A "broad" definition of semiconductor-related credential programs encompasses all 47 fields of study. The inclusion of computer and information science programs, however, may lead to spurious conclusions about the talent supply available to the industry, due to a rapid increase in completions in this category in the last decade. We thus developed a "core" program list to exclude computer and information science and other peripheral programs. See Appendix A: Supplemental Data for more information about the program categories, including Exhibit A-3.

Total Semiconductor-Related Completions

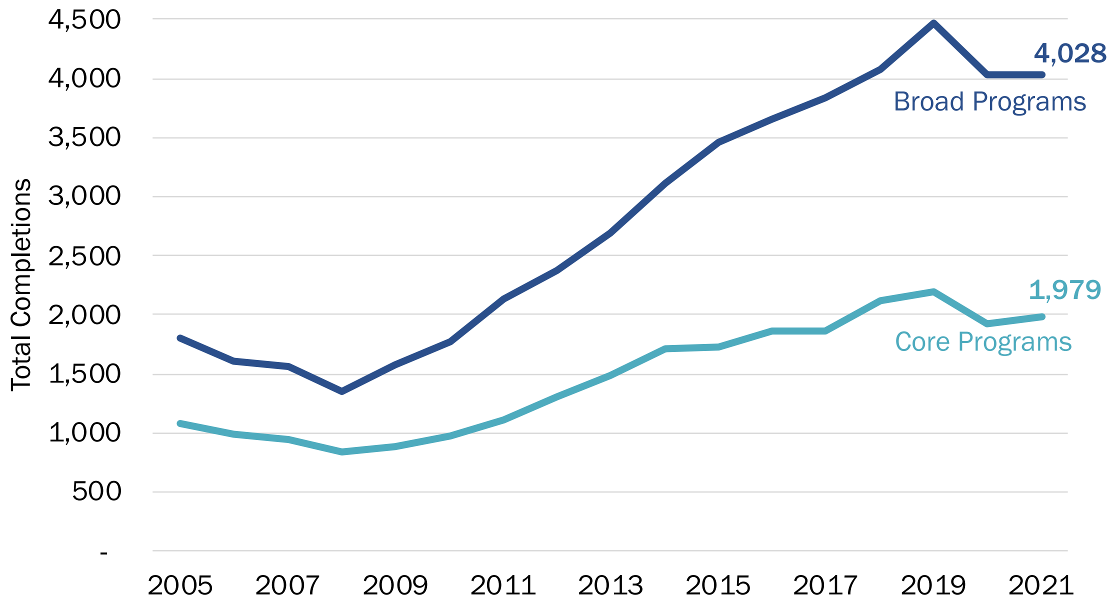
Across the broad definition of NCES-classified programs supporting the semiconductor workforce, credential completions totaled approximately 4,000 in 2021 (see Exhibit 13; data for 2022 were not yet available at the time of analysis). The annual total has trended upward since the early 2000s, increasing by 123 percent between 2005 and 2021 (or 5.6 percent annually), compared to a 32 percent increase for all programs in Oregon. The above-average increase in semiconductor-related completions has, however, been largely driven by computer and information science programs. Removing those programs, completions in the core group of semiconductor-related programs follow a more muted trend, with average annual growth of 4 percent. Between 2010 and 2015, the growth rate averaged 12 percent annually; between 2015

[22] National Center for Education Statistics (2023). CIP SOC Crosswalk. Accessed at: https://nces.ed.gov/ipeds/cipcode/post3.aspx?y=56

and 2021, it slowed to an annual average of 3 percent. Overall, core semiconductor-related program completions grew by 15 percent between 2015 and 2021, from 1,730 to 1,979.

The COVID-19 pandemic broke the trend of growth in completions across programs and geographies, in part due to decreased enrollment.[23] Within semiconductor-related programs, completions fell by 9.7 percent between 2019 and 2020, with reductions in certificate and associate-degree completions driving the trend. Across all programs in Oregon, completions fell by 8.9 percent. In 2021, completions increased just slightly relative to 2020—by 0.3 percent for semiconductor-related programs and by 0.1 percent across all programs.

Exhibit 13. Semiconductor-Related Completions, Oregon



Data source: Integrated Postsecondary Education Data System

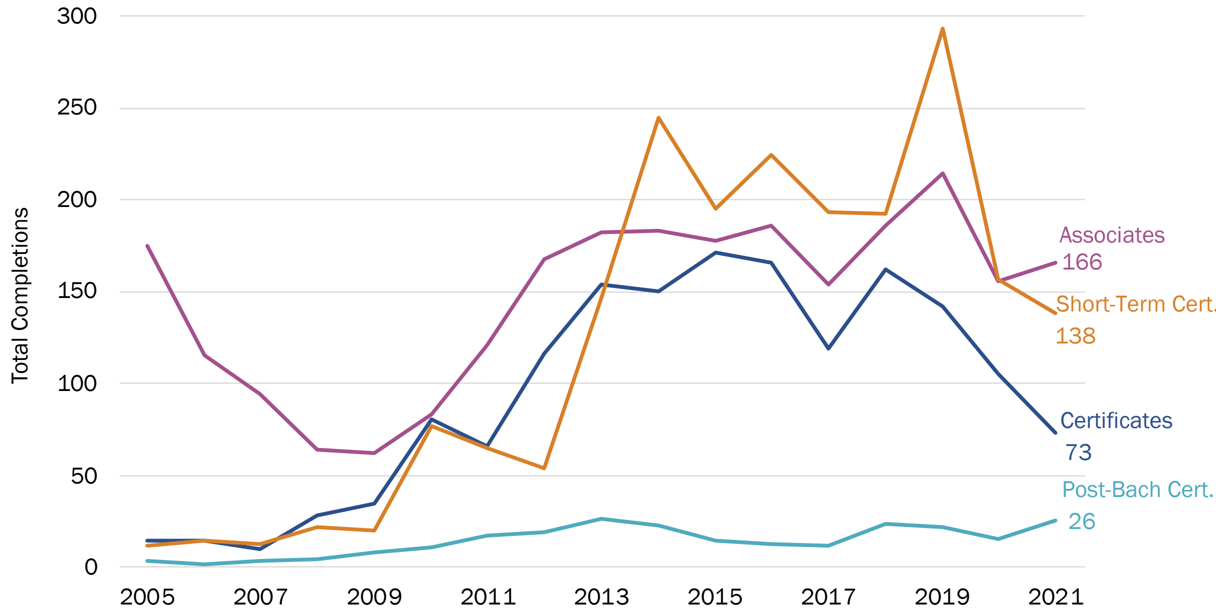
Semiconductor-Related Completions by Award Level

In Oregon's core programs related to the semiconductor workforce, completions of short-term certificates, certificates, and associate degrees more than doubled between 2010 and 2015 (see Exhibit 14).[24] The sharp increase in short-term certificate completions after 2012 was mostly driven by completions in two core semiconductor-related fields of study: Machine Shop Technology and Manufacturing Engineering Technologies and Technicians. Associate degree completions in Manufacturing Engineering Technologies and Technicians drove the increase between 2010 to 2015, together with Machinist completions. Short-term certificate, certificate, and associate degree completions have declined since 2015, with certificates showing the largest decrease.

[23] Oregon Higher Education Coordinating Commission (HECC) (2020). *Impact of COVID-19 on Public Postsecondary Institutions*. Accessed at: https://www.oregon.gov/highered/research/Documents/Student/COVID-19-Impact-PreliminaryFindings-Enrollment.pdf

[24] Short-term certificate programs are less than 2 years, or less than 60 semester credit hours or 90 quarter hours. Certificate programs are more than 2 years, but less than 4 years.

Exhibit 14. Core Semiconductor-Related Completions by Award Level, Certificates and Associate Degrees, Oregon

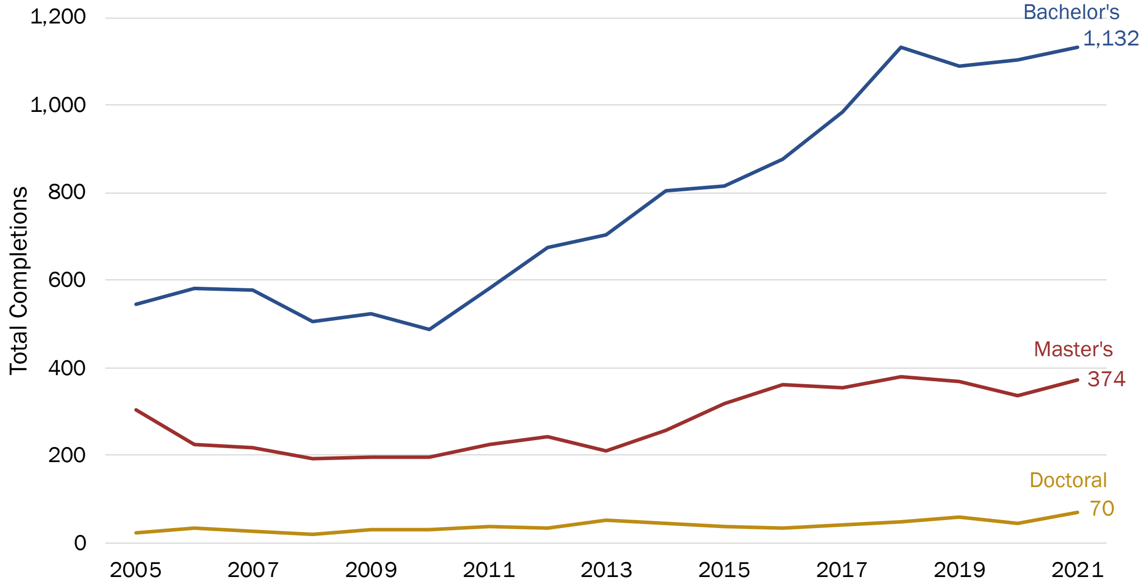


Data source: Integrated Postsecondary Education Data System

Core semiconductor-related bachelor's and graduate degree completions have generally increased since 2005 (see Exhibit 15). Bachelor's completions increased by an average of 5 percent per year, with the fastest growth after 2010. This increase was driven by Mechanical Engineering completions, which accounted for 560 of the 1,132 bachelor's completions in 2021.

Core semiconductor-related master's degree completions increased by an average of 2 percent per year, while doctoral degree completions increased by an average of 10 percent per year. Master's and doctoral completions combined totaled 444 in 2021. Electrical and Electronics Engineering completions account for most of the increase in master's and doctoral completions since 2010. In contrast to sub-baccalaureate completions, bachelor's and more-advanced completions exceeded pre-COVID completions in 2021.

Exhibit 15. Core Semiconductor-Related Completions by Award Level, Bachelor's and Graduate Degrees, Oregon



Data source: Integrated Postsecondary Education Data System

Demographics of Core Semiconductor-Related Credential Completers

In 2021, students who identify as female comprised 19 percent of completers in core semiconductor-related programs, compared to 62 percent across all programs (see Exhibit 16). In comparison, 47 percent of the Oregon workforce and 25 percent of the semiconductor industry workforce identifies as female.[25] Between 2005 and 2021, the share of female completers in core semiconductor-related programs increased by 5 percentage points, from 14 to 19 percent. Female completers comprise relatively higher percentages within post-bachelor's certificate, master's, and doctoral award levels, and lower percentages within associate and bachelor's degree award levels.

In 2021, students identifying as BIPOC comprised 31 percent of core semiconductor-related completers, nearly identical to the share of BIPOC completers across all programs (30 percent) (see Exhibit 17). The semiconductor share is a 14-percentage point increase from 2005, when 17 percent of completers were BIPOC. In comparison, 25 percent of the Oregon workforce and 45 percent of the semiconductor industry workforce identifies as BIPOC.[26] BIPOC students account for a relatively higher share of short-term certificate, certificate, and associate degree completers.

Approximately 490 BIPOC students completed a core semiconductor-related credential in 2021, compared to 150 in 2005 and 160 in 2010. Since 2005, completers identifying as Asian, Native Hawaiian, or Other Pacific Islander have represented the highest share of BIPOC completions (see Exhibit 18). Completers identifying as Hispanic or Latino or Two or More Races comprised

[25] U.S. Census Bureau. (2021) American Community Survey, 5-year Estimates.
[26] Ibid.

10 and 6 percent of completions, respectively, in 2021. The share of completions earned by these groups increased from 5 and 4 percent, respectively, in 2010. The shares of Black or African American, and American Indian or Alaska Native completers have increased less dramatically over the period and represent a small portion of total completions.

Exhibit 16. Female Completers in Core Semiconductor-Related and All Programs, by Award Level, Oregon

Award Level	2005		2021	
	All Programs	Core Semiconductor Programs	All Programs	Core Semiconductor Programs
Short-term Certificates	84%	0%	66%	15%
Certificates	81%	0%	76%	18%
Post-bachelor's Certificates	67%	25%	70%	38%
Associates	58%	13%	61%	19%
Bachelor's	57%	10%	56%	14%
Master's	58%	21%	62%	31%
Doctoral	51%	13%	58%	29%
Total	62%	14%	62%	19%

Note: Calculations exclude students identified as non-residents.
Data source: Integrated Postsecondary Education Data System

Exhibit 17. BIPOC Completers in Core Semiconductor-Related and All Programs, by Award Level, Oregon

Award Level	2005		2021	
	All Programs	Core Semiconductor Programs	All Programs	Core Semiconductor Programs
Short-term Certificates	13%	0%	30%	44%
Certificates	12%	20%	32%	41%
Post-bachelor's Certificates	11%	25%	23%	15%
Associates	13%	17%	29%	35%
Bachelor's	12%	16%	32%	30%
Master's	11%	24%	24%	27%
Doctoral	12%	0%	27%	17%
Total	12%	17%	30%	31%

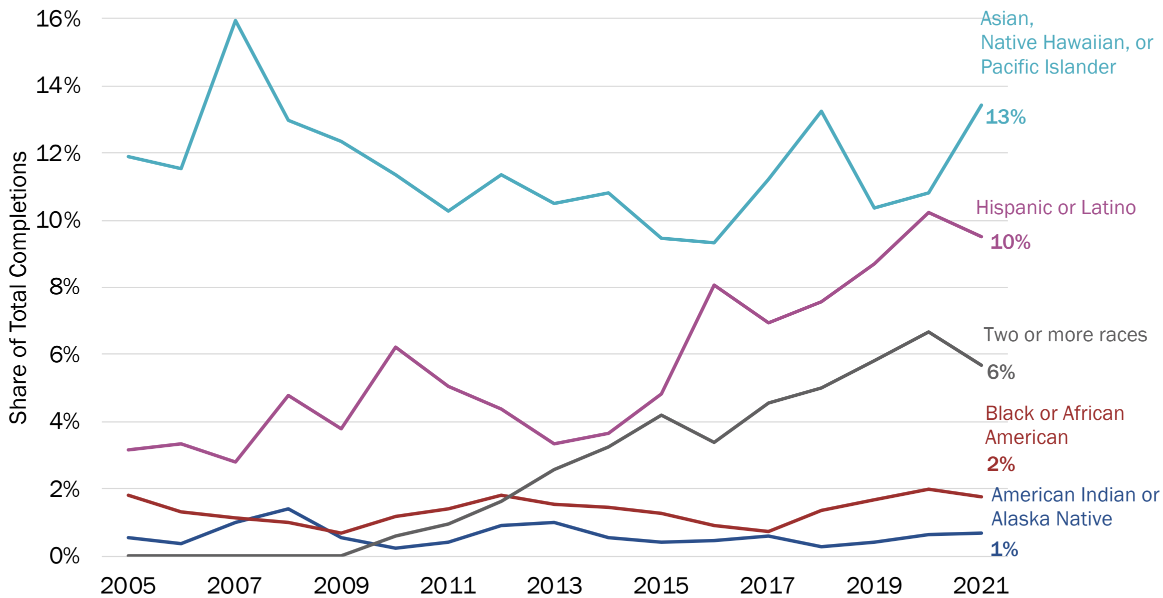
Note: Calculations exclude students identified as non-residents.
Data source: Integrated Postsecondary Education Data System

Core semiconductor-related programs have a higher proportion of non-resident completers compared to all programs (see Exhibit 19). Since 2005, the share of non-resident completers in core semiconductor-related programs has been 10-15 percentage points higher than the share across all programs. In 2021, non-resident completers accounted for more than half of all master's and doctoral degrees.[27] However, approximately 80 percent of master's and 25 percent

[27] National Center for Education Statistics (2021). Integrated Postsecondary Education Data System.

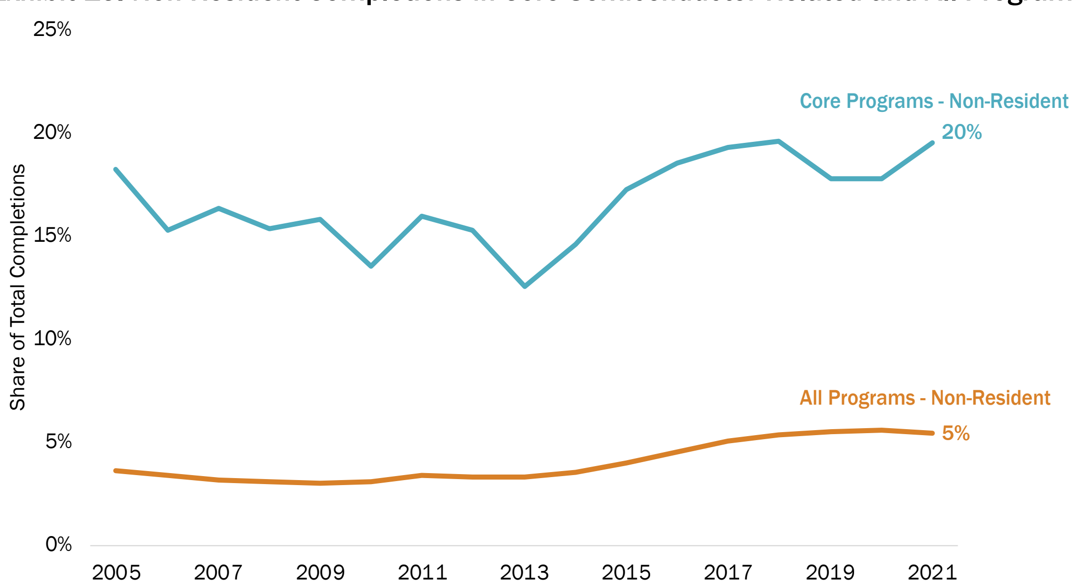
of doctoral non-resident STEM graduates in the U.S. leave the country after graduation, implying a smaller talent pool for the U.S. semiconductor industry relative to the number of credentials awarded.[28] Analysis described in Chapter 4 (see Exhibit 45) suggests that a high share of non-resident graduates of core semiconductor-related programs in Oregon leave the state following graduation.

Exhibit 18. Percent of Completions in Core Semiconductor-Related Programs, by Race and Ethnicity, Oregon



Data source: Integrated Postsecondary Education Data System

Exhibit 19. Non-Resident Completions in Core Semiconductor-Related and All Programs, Oregon



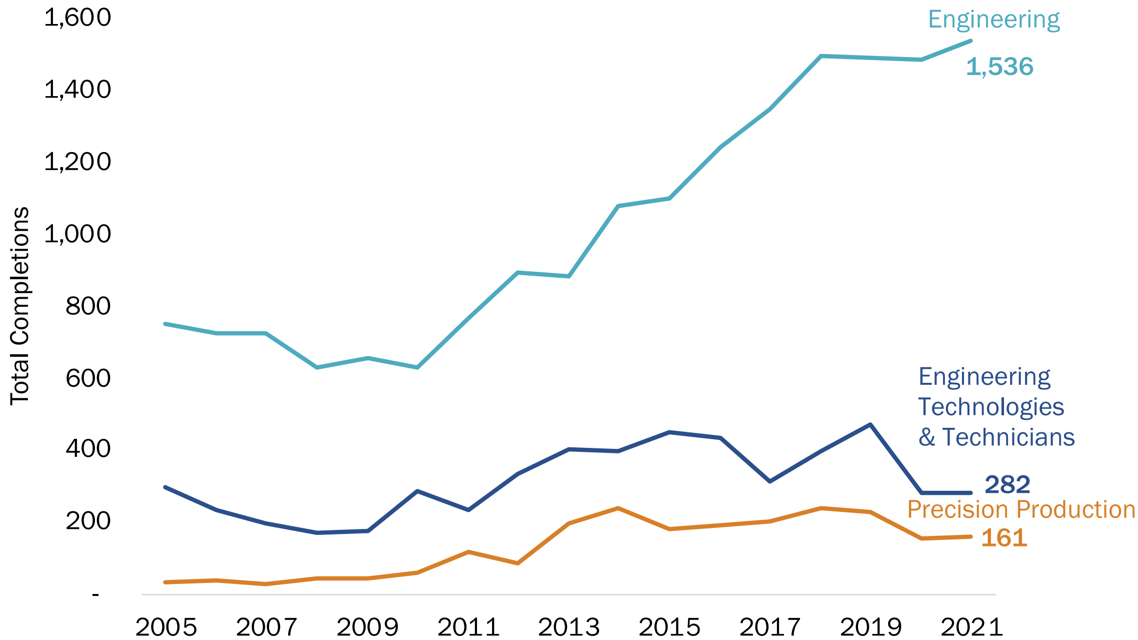
Data source: Integrated Postsecondary Education Data System

[28] Semiconductor Industry Association and Oxford Economics (2023). *Chipping Away: Assessing and Addressing the Labor Market Gap Facing the U.S. Semiconductor Industry*.

Semiconductor-Related Completions by Category

Within the core semiconductor-related categories, engineering accounts for 77 percent of completions, totaling 1,536 in 2021 (see Exhibit 20).[29] Completions in the engineering and precision production categories have more than doubled since 2005, while engineering technologies and technicians completions have decreased slightly. Exhibit 21 details the completions associated with semiconductor occupations mapped to the core semiconductor-related programs. Core completions related to nearly all semiconductor occupations have increased considerably since 2005: by more than 100 percent in Mechanical, Chemical, and General Engineering programs; and by more than 300 percent in Machinist programs.[30]

Exhibit 20. Completions by Core Program Category, Oregon



Data source: Integrated Postsecondary Education Data System

Completions in the fields of study most related to occupations involved in EDA, research, and design processes of the semiconductor industry—such as engineers, computer programmers, and computer analysts—are concentrated in bachelor's, master's, and doctoral award levels. Bachelor's degrees account for 70 percent of completions in engineering (see Exhibit 22). Engineering technologies and technicians completions—held by electrical, electronic, and industrial engineering technologists and technicians—are more evenly distributed across credential types, with most completions in certificates (including short-term) and associate degrees. Certificates and associate degrees account for all completions in precision production, which is best suited to train workers such as machinists, operators, and tenders.

[29] See the Appendix A for additional information about broad and core program categories.
[30] Data on credential completions for many of the occupations required for fabrication and ATP processes are limited because these occupations require on-the-job training rather than a postsecondary credential.

Exhibit 21. Core Semiconductor Completions by Corresponding Occupation, Oregon

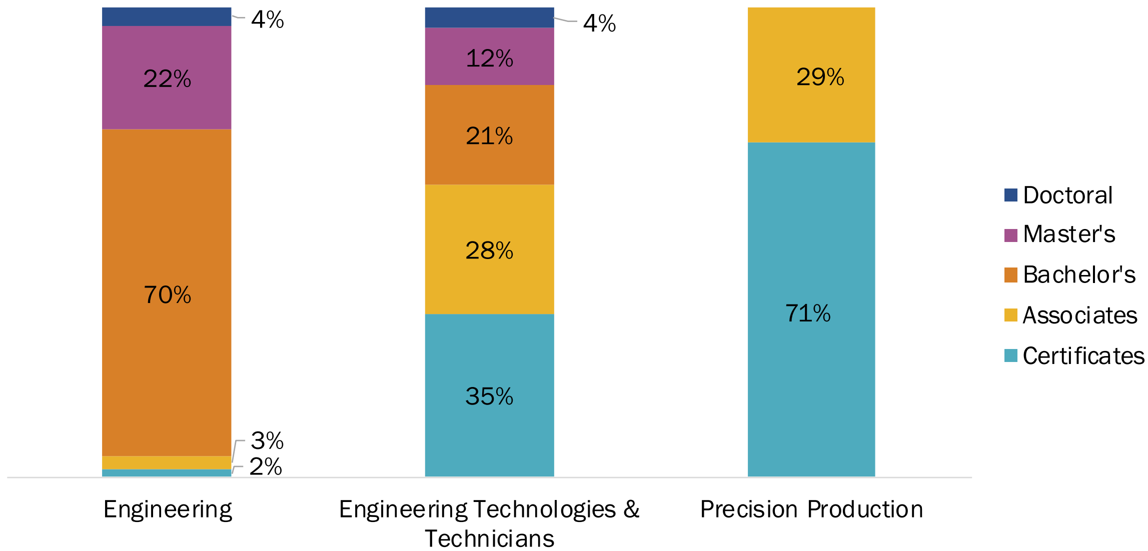
Occupation Title	2005	2010	2015	2021
Engineering Managers	659	613	1,016	1,388
Computer Hardware Engineers	395	239	410	512
Electrical Engineers	304	223	389	470
Electronics Engineers	304	223	389	356
Mechanical Engineers	212	221	354	643
Electrical/Electronic Engineering Technologists and Technicians	138	21	27	17
Industrial Production Managers	89	112	132	131
Industrial Engineers	69	69	105	110
Engineers, All Other	59	56	143	260
Computer Programmers/1	57	28	59	75
Industrial Engineering Technologists and Technicians	50	171	303	141
Chemical Engineers	44	60	111	139
Cutting, Punching, and Press Machine Setters, Operators, and Tenders, Metal and Plastic	32	28	78	90
Machinists	31	55	182	125
Inspectors/Testers	-	-	8	-
Computer Numerically Controlled Tool Operators	-	-	-	36

Note: Some completions are counted for more than one occupation thus, completions should not be summed by year to arrive at annual total completions.
/1: Computer Programmers can be trained through the Computer Software Technology/Technician field of study that falls within the Engineering Technologists and Technician category.
Data source: Integrated Postsecondary Education Data System, Completions

Precision production has the highest share of BIPOC completers of the three categories, with 52 percent of total completers identifying as BIPOC in 2021. Between 2005 and 2007, BIPOC completers comprised approximately 15 percent of completions in each category; after 2008, the gap between precision production and engineering widened. Engineering and engineering technologies and technicians have seen a recent increase in BIPOC completer shares, with BIPOC students accounting for 22 percent of engineering completions and 26 percent of engineering technologies and technicians completions in 2021.

In 2021, female students comprised 18 percent of completers in engineering and 24 percent in engineering technologies, compared to 14 percent in both program categories in 2005. Precision production has the lowest share of completions by female students, although between 2015 and 2021, that share increased from 4 percent to 10 percent.

Exhibit 22. Completions by Category and Award Level, Oregon, 2021



Data source: Integrated Postsecondary Education Data System, Completions

Interstate Comparisons

States with semiconductor educational pathways that align with local industry needs are best positioned to support the expansion of the industry. In Oregon, core semiconductor-related completions have increased as a share of all program completions at a faster rate than the national average and four of the five states with the largest semiconductor workforce other than Oregon (see Exhibit 23).[31] Between 2005 and 2021, Oregon's share of core semiconductor-related completions had an average annual growth rate of 2.4 percent, followed by Arizona at 1.9 percent and Idaho at 1.8 percent. Texas and the U.S. had an average annual growth rate of less than 1 percent while California and Florida saw a negative average annual growth rate. In 2021, core semiconductor-related completions accounted for 3.7 percent of all completions in Oregon, topped only by Idaho at 3.8 percent. These two states lie above the national average of 3.3 percent while Arizona, Florida, California, and Texas lie below.

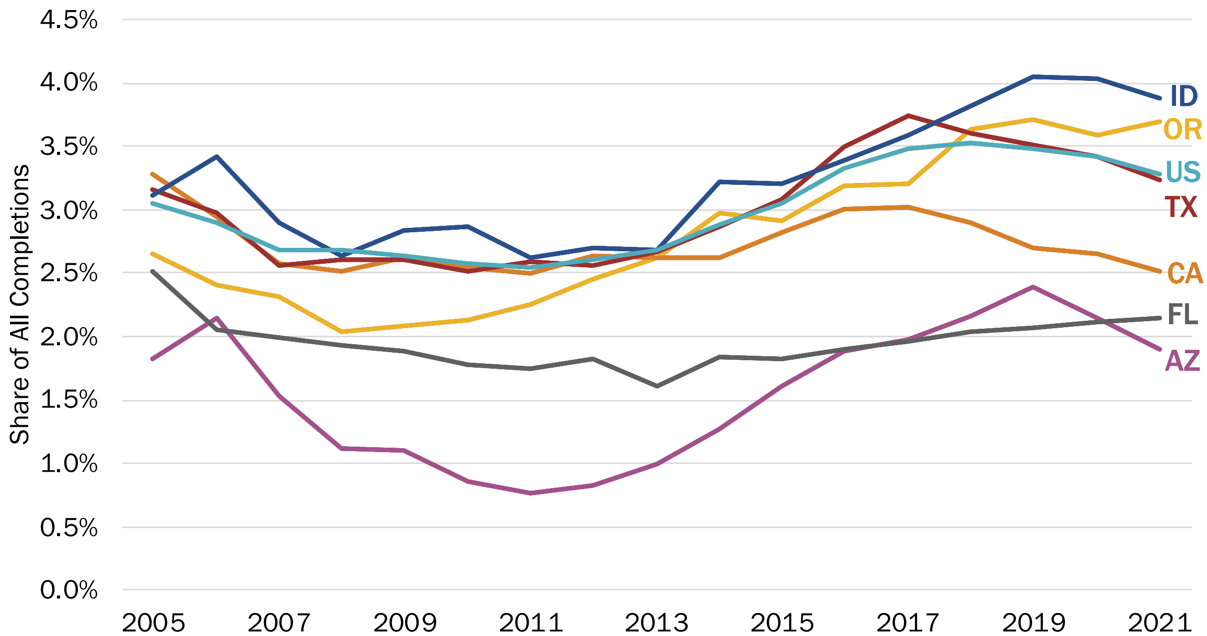
However, comparing core semiconductor-related completions to semiconductor industry employment in each state presents a different picture, as illustrated in Exhibit 24. This metric suggests the strength of a state's semiconductor educational pathways relative to industry need as proxied by employment. Core semiconductor-related completions as a share of annual industry employment in Oregon was 6 percent in 2021, the lowest compared to the five other states with the largest semiconductor workforce. Florida and Texas have the highest share of core semiconductor-related completions relative to industry employment: 42 percent and 30 percent, respectively.

[31] Semiconductor Industry Association (2021). *Chipping In: The Positive Impact of the Semiconductor Industry on the American Workforce and How Federal Industry Incentives Will Increase Domestic Jobs*. Accessed at: https://www.semiconductors.org/chipping-in-sia-jobs-report/

In Oregon, the size of these pathways is relatively small compared to other states with large semiconductor industries. This is not surprising given the relative overrepresentation of the industry in Oregon. As the state with the 4th largest semiconductor manufacturing employment, Oregon accounted for 15 percent of industry employment in 2022, a share about equal to that of Texas (16 percent), a state with seven times the population of Oregon. However, without a focus on specific credentials most acutely needed by the industry or that Oregon has relative advantages in producing, the smaller size of the state's population and correspondingly smaller size of the public postsecondary system could present challenges to staffing the industry with Oregon-developed talent as the state's industry grows in response to the large, anticipated state and federal investments.

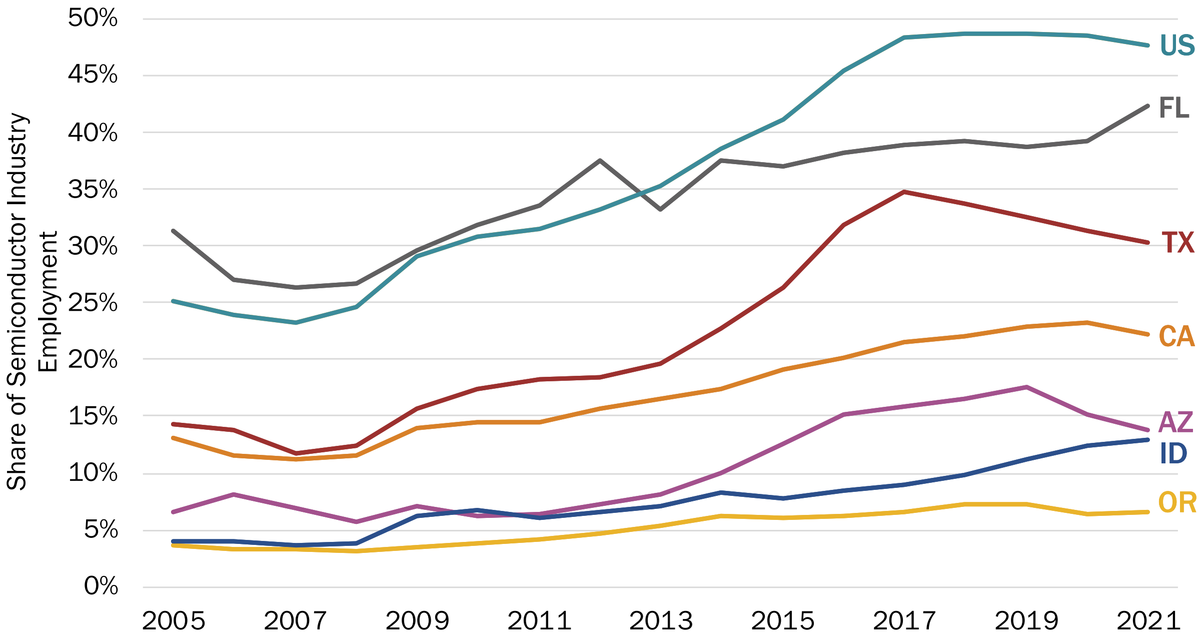
As shown in Exhibit 25, Oregon and Idaho have higher shares of completions in engineering technologies and technicians and precision production than do other comparison states, which have higher shares of completions in engineering. Oregon's distribution of core semiconductor-related completions across categories is most closely aligned with the national average, compared to other states.

Exhibit 23. Share of Postsecondary Completions that are Semiconductor-Related



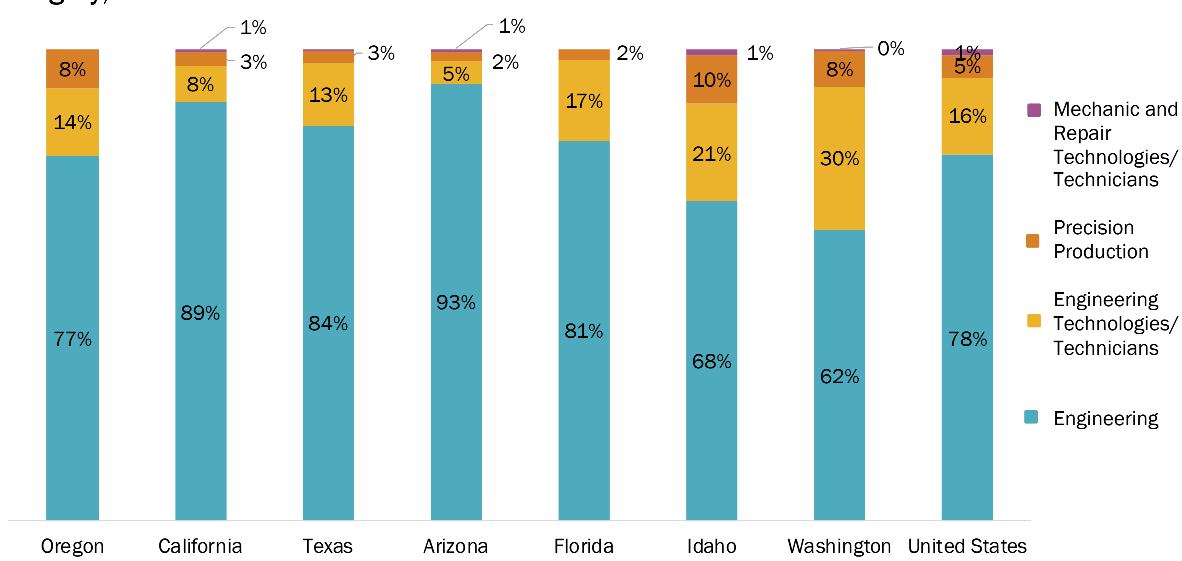
Data source: Integrated Postsecondary Education Data System, Completions

Exhibit 24. Semiconductor-Related Completions Relative to Industry Employment



Data source: Integrated Postsecondary Education Data System, Completions; Bureau of Labor Statistics, Quarterly Census of Employment and Wages.

Exhibit 25. Percent of Semiconductor-Related Program Completions, by State and Program Category, 2021



Note: The mechanic and repair technologies & technicians category includes one semiconductor-related field of study, Industrial Electronics Technology and Technician. Programs in this field of study train semiconductor processing technicians and are not currently offered in Oregon.
Data source: Integrated Postsecondary Education Data System, Completions

3. Interested Parties Engagement

Assessing Oregon's Semiconductor-Related Talent Pathways

The foundation for our high-level assessment of the talent pathways for semiconductor occupations in the state of Oregon is work completed by the American Semiconductor Association (ASA) and summarized in their vision paper *Fueling American Innovation & Growth*.[32] This document provides a roadmap for advancing microelectronics education and workforce development on a national scale. Building on insights from ASA's paper, we aim to develop recommendations for Oregon's educational programming within the national context, industry best practices, and emerging cross-industry educational frameworks.

Furthermore, we acknowledge the crucial contributions of Oregon's Semiconductor Competitiveness Task Force and their report titled *Seizing Opportunity*.[33] This report illuminates key aspects of semiconductor talent development and the need to address challenges and opportunities to maintain competitiveness in the global market. By integrating the lessons learned from the Task Force's report, our evaluation will encompass a broader perspective on semiconductor industry growth and competitiveness.

Our approach to this work involved conducting a high-level analysis of program offerings across Oregon's postsecondary institutions. We explored course summaries, conducted interviews with administrators and faculty members from universities and colleges and held discussions with talent recruiters to gain insights into the state's educational programming.

The assessment focuses on both the quantity of available courses and their quality with regard to meeting the current and future needs of the semiconductor industry. Interviewee reflections on curriculum strength, facility conditions, and the availability of hands-on training are considered as part of the development of a holistic understanding of the educational landscape.

Additionally, our evaluation explores the optimal scale of local educational programming and discusses the potential benefits and drawbacks of collaborating with other states or international providers to enhance Oregon's talent development initiatives.

This assessment of educational offerings will assist stakeholders in making informed decisions about advancing Oregon's semiconductor talent pathways. Leveraging and considering the insights from our engagement process, ASA's vision paper, and the Semiconductor Competitiveness Task Force's report, we deliver actionable recommendations to strengthen the state's semiconductor ecosystem and drive its continued growth and success.

[32] American Semiconductor Academy (ASA) Initiative & SEMI. *Fueling American Innovation & Growth*. 2022, https://www.semi.org/sites/semi.org/files/2022-08/SEMI_ASA_Vision_Paper_Version1.pdf

[33] Oregon Semiconductor Competitiveness Task Force (2022). *Seizing Opportunity*. http://oregonbusinessplan.org/wp-content/uploads/2022/08/Semiconductor-Task-Force-Report-for-Release.pdf

Defining semiconductor-related pathways:

Semiconductors have become an integral part of modern life, permeating a myriad of industries and applications. From the devices we use daily, such as smartphones and computers, to critical technologies like medical devices and renewable energy systems, semiconductors underpin innovations of every kind. As a result, the semiconductor industry has evolved into a multifaceted sector that employs a diverse range of professionals spanning the arts and sciences. This report, however, seeks to provide a more-focused perspective within the vast landscape of semiconductor-related professions.

In this study, *semiconductor-related pathways* refer to the many different pathways that exist for students working toward, and employees in, the semiconductor industry. For the purpose of this report, we define "semiconductor-related" as encompassing a spectrum of hard skills, including expertise in disciplines such as chemistry, physics, material science, mechanical engineering, and computer science, which are foundational to understanding semiconductor materials and processes.

Additionally, the term encompasses core/essential competencies like problem-solving and teamwork, which are essential for addressing complex challenges in semiconductor research, development, and manufacturing. Furthermore, it encompasses job-specific skills, such as proficiency in semiconductor fabrication tool operation and maintenance, which are critical for the effective production and optimization of semiconductor devices and technologies.

Assessment Process

Our approach to this work involved a combination of formal interviews, informal conversations, site tours, and working sessions to ensure a well-rounded and current picture of the state of practice in postsecondary education across the state. We interviewed and collected the perspectives of industry representatives and recruiters, high school and postsecondary educators, workforce program leaders, and a student. Additionally, we considered our findings relative to reported conditions in comparable states that are known for their strength in semiconductor-related education, such as Arizona and Indiana, to draw insights and identify areas of strength and improvement.

Formal Interviews with Educators

We conducted 14 formal interviews with a diverse group of high school, community college, and university educators involved in semiconductor-related programming. The interviews were designed to delve into perspectives on the curriculum, course offerings, and hands-on training opportunities available to students (see Appendix B for the interview question set). By engaging with educators from various levels of education, we obtained a comprehensive view of educational pathways leading toward semiconductor occupations and identified potential areas of collaboration and alignment.

Formal Interviews with Recruiters and Employers

To complement the perspectives of educators, we conducted four formal interviews with recruiters from different companies operating in the semiconductor industry. These interviews focused on understanding the specific skill sets and competencies they seek in potential candidates. Insights from recruiters provided valuable context for evaluating the effectiveness of the existing educational programming and identifying potential gaps between industry needs and available talent.

Informal Conversations and Working Sessions

Recognizing the significance of informal insights, we engaged in dozens of informal conversations with stakeholders across the semiconductor pathways ecosystem. These conversations spanned educators, industry professionals, researchers, and students. Additionally, we participated in working sessions with relevant stakeholders to collaboratively identify challenges and opportunities within talent pathways. These interactions contributed to a nuanced understanding of the factors influencing the success of semiconductor-related education in Oregon.

Site Tours and Observations

Site tours of educational institutions and industry facilities allowed us to gain firsthand knowledge of the facilities, resources, and equipment available to students. Through observations, we assessed the practicality and alignment of the learning environment with industry demands. These site visits also enabled us to gauge the level of investment in semiconductor-related education and the degree of industry-academic collaboration.

Benchmarking with Other States

To position Oregon's talent pathways within a broader context, we conducted a comparative analysis with similar states, such as Arizona and Indiana. In so doing, we identified both areas of excellence and potential opportunities for improvement. This analysis provided valuable insights into best practices and potential strategies for advancing Oregon's talent pathways.

Our approach allowed us to triangulate information from multiple sources, providing a robust and reliable basis for our conclusions and recommendations. The combination of formal interviews, informal conversations, site tours, and benchmarking with other states enriched our evaluation and ensured that the report reflects the current state of practice in Oregon's postsecondary semiconductor-related programming.

Findings of the Assessment

In this section we highlight key observations, activities, and identified needs throughout Oregon's semiconductor-related talent pathways. These findings, in turn, inform the recommendations provided in Chapter 5, which aim to strengthen talent pathways, foster collaboration between education and industry, and propel Oregon's semiconductor-related ecosystem toward continued growth and competitiveness.

Summary of Findings

The findings of the assessment can be summarized in two high-level categories:

Semiconductor-related programs and curricula are well established in Oregon. As accredited programs they are not designed to adapt swiftly to the rapidly changing demands of the industry. While these programs provide a solid foundation of valuable skills applicable throughout one's career, the fast-paced nature of the semiconductor sector highlights a gap in more-immediate, industry-specific job skills. Additionally, the emphasis on core competencies, particularly problem-solving abilities, could be further reinforced. This situation underscores the need for an intermediary entity that bridges the gap between universities, which focus on enduring skills, and industry, which demands quickly evolving competencies. The intermediary entity can serve as a resource for updating industry-specific job skills, benefiting both recent graduates and seasoned professionals in the semiconductor field.

Educators and industry representatives cite many needs with regard to supporting workforce entry, lifelong learning, and innovation. The described needs include the following, which are described more fully in the following sections:

- More awareness of the industry and earlier exposure (in middle/high school) to career-connected learning for students across the state
- More access to STEM education for K-12 learners to prepare students with the skills and awareness of meaningful, in-demand careers
- More organizational collaboration in multiple dimensions (among education, training, industry, community leaders, and HECC)
- More-robust funding of grants, scholarships, and training incentives
- More/expanded career and technical education (CTE) and STEM programming
- Enhanced/expanded/systemized continuing education, including more hands-on training with state-of-the-art facilities at all levels of training/education
- Flexible training options and wraparound services to support students and increase diversity
- Metrics and other approaches to tracking the success of efforts and initiatives
- Strategies to overcome "the math barrier"

The following sections expand upon these findings and describe the nature of semiconductor-related activities and needs at the high school, community college, university, and industry levels.

High School Activities and Needs

STEM education at the high school level in Oregon, particularly in the Hillsboro area, provides programs that prepare students for careers in the semiconductor industry. The region's close proximity to major semiconductor companies like Intel has led to a significant emphasis on cultivating a skilled and competent workforce that can contribute to the industry's growth and development. Oregon high school STEM education curriculums, both in and out of the Hillsboro area, can be tailored to meet industry needs by leading students toward jobs in the semiconductor industry in the following ways:

Early Exposure to the Semiconductor Industry:

Exhibit 26 depicts shares of Oregon high school survey respondents with aptitude versus interest in different career areas. Semiconductor-related areas like Computers & Technology and Advanced Manufacturing have large gaps, with more students demonstrating aptitude than interest. With awareness of these gaps, interviewees described the importance of introducing students to the semiconductor industry at an early stage. Schools in Hillsboro in particular offer specialized STEM programs, youth-friendly assessments (e.g., YouScience), workshops, and events that provide students with exposure to the field's concepts, technologies, and career opportunities. This early exposure helps generate interest and passion for the semiconductor industry among young students, including tactile and visual learners, and some students go directly into the industry from high school.

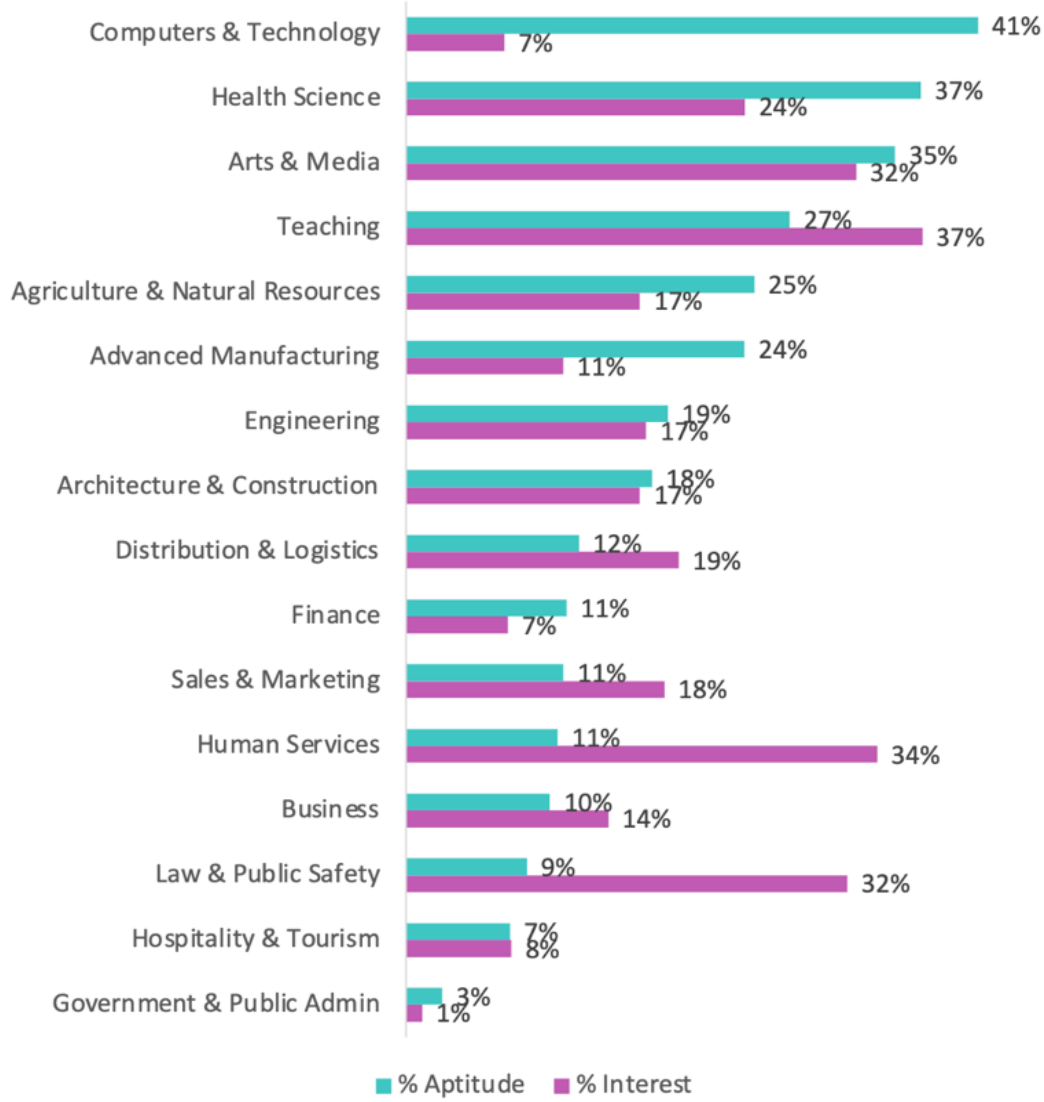
"Pitch semiconductor before high school. Let people know that these programs exist. Start early so you don't have to rely on catching everybody by accident." – High School Faculty

"Working with students and companies is the easiest part, as students feel proud that they are working in a company." – High School Apprenticeship Lead

"Someone needs to better explain what mechatronics are, especially for educating high schoolers. How would you describe mechatronics and this work to a layperson? How are we going to get students to do it, if they don't understand what it is?" – Community College Representative

"Sign [high school] students up for a 5-year contract that is like a 'we-got-you' bonus. Do something like the military. Allow seniors to commit to 5 years, go through a STEM program, work 20 hours a week, and sign a contract." - High School Faculty

Exhibit 26. Percentage of Oregon high school survey respondents with each cluster in their Top 3 Career Cluster recommendations



Data Source: Oregon Career Cluster Alignment Report, AY 2022-23

Mechatronics: Forest Grove High School offers mechatronics courses, giving students hands-on experience in electronics, mechanics, and programming. The program also teaches problem solving and troubleshooting skills, making students employable in technician jobs straight out of high school.

> "The high school [mechatronics] program includes hands-on experience so students can learn troubleshooting skills with a full year of robots, digital logic, 3-D printers, and mechatronics classes. In these classes, they build rockets, do everything, and have a good time." – High School Faculty

Partnerships with Industry: High schools in the Hillsboro area are actively fostering and seeking additional partnerships with semiconductor companies, creating avenues for real-world learning experiences for students. These partnerships include internships and apprenticeships (e.g., the Hillsboro Advanced Manufacturing Apprenticeship), mentorship programs, and site visits, allowing students to interact with industry professionals and gain practical insights into the semiconductor field.

"In order to grow [our apprenticeship program], we need more partnership with more training agents and regional employers who want to hire our skilled laborers." – Community College Apprenticeship Lead

"We are working with industry on two things: 1) paying attention to the emerging population, including those who are teaching semiconductor-related courses and 2) allowing these teachers to come in and job shadow. That way these teachers can do an externship to learn first-hand and know what it's like working in the industry and what the up-to-date trends are." – Workforce Program Lead

Focus on Core/Essential Competencies: Technical expertise is not enough for success in the semiconductor industry. Students need essential competencies such as communication, teamwork, problem-solving, and adaptability.

"The industry is looking for four qualities: Students that are dependable, who tell the truth, are interested, and can work with other people." – High School Faculty

Proximity to Industry: While many states and regions prioritize STEM education, the Hillsboro area's proximity to a semiconductor industry hub allows for more-extensive collaborations between high schools and semiconductor companies, resulting in educational programs that may be easier to align with indu6stry needs. The implications for and experiences of high schools with less proximity to the semiconductor industry hub should be considered and addressed as well.

Community College Activities and Needs

We spoke with representatives of six of Oregon's 17 community colleges.[34] This section describes steps these colleges have taken to build pathways into the semiconductor industry as well as additional supports these and other community colleges need to ensure their technical programs provide a range of credit-based, low-barrier opportunities that align with the semiconductor industry's needs:

Enhanced Awareness/Marketing: Community colleges recognize the importance of marketing to help students and parents understand semiconductor work and attract students to their semiconductor-related programs.

[34] We interviewed representatives of Portland Community College (PCC), Lane Community College (LCC), Chemeketa Community College (CCC), Clackamas Community College (CCC), Central Oregon Community College (COCC), and Mt. Hood Community College (MHCC).

"We mainly rely on word of mouth from the workforce. We don't market in the traditional sense of the word, but it's still the best kept secret." – Workforce Program Lead

"It's an advertising issue. Advertising the semiconductor industry is challenging as we are looking for a 'unicorn student' who doesn't necessarily want an engineering degree but is still interested in working with their hands." – High School Faculty

Partnerships with the Semiconductor Industry: Community colleges actively foster partnerships with semiconductor companies in their regions. These partnerships provide valuable insights into industry needs, allow for the alignment of curriculum with industry standards, and often result in internships, job placements, or apprenticeship opportunities for students.

Partnerships between Education Institutions: Community college representatives expressed a need for greater coordination between colleges, in part to lessen competition for the limited pool of students. Community colleges and education institutions would benefit from having tools in place to build out career training education programs. One example is Arizona's semiconductor technician quick start program, a ten-day, 40-hour bootcamp-style program that trains students at one of three community colleges.[35]

"It's important to know what everyone has so we're not in competition for the same students. Let's be a niche in one thing, train students in this particular thing, and let [another CC] do this other thing…so we don't all have to do the same thing." – Community College Representative

Apprenticeship Programs: Apprenticeship programs are a valuable tool for workforce training in the semiconductor industry. Community colleges actively support and offer these programs, enabling students to gain paid hands-on experience while working under the guidance of experienced professionals.

"A standard apprenticeship involves 2,000 hours on the job. However, this is nearly impossible for students going to school full time. Therefore, we use a competency-based model approach to give the program more flexibility. Students still work similar amounts of time on the job, including during summer, which is a great time for students to work full time." – High School Apprenticeship Lead

Earn and Learn Frameworks: Given Oregon's above-average tuition and fees at public two-year colleges,[36] college and apprenticeship program representatives describe the importance of earn-and-learn models in which students are compensated, and work and learning are blended. Payment structures such as stipends, hourly pay, and tuition reimbursement provide lower barrier opportunities, increasing program diversity, retention, and success. One community

[35] https://info.maricopacorporate.com/semiconductor
[36] Ma, Jennifer and Matea Pender (2022). *Trends in College Pricing and Student Aid, New* York: College Board, p. 14. Accessed at https://research.collegeboard.org/media/pdf/trends-in-college-pricing-student-aid-2022.pdf

college representative described how linking pay to a skills assessment every six months during a certificate program has improved program completion rates.

"The cost to go to college here is far more expensive than in California. Here the average cost is $140/credit, whereas the maximum is $46/credit in California. Oregon is quarterly (45 credits/year), whereas California has a semester system (30 credits/year). Cost is a major factor… Wages are lower in Portland but the cost of living is comparable to the Bay Area." – Community College Representative

"It takes time and resources to take classes for a year, pay bills, and take care of kids, families…therefore, internships or earn-to-learn kind of programs ensures you invest in the person, and give them a chance. We should pay them to go to school." – Out-of-State Community College Representative

"We need to provide ways for students to work and get paid while taking classes, while providing them opportunities to get hired or promoted as they go through the program. This would make a huge difference." – Community College Representative

Stackable Accreditation Options: Some Oregon community colleges offer stackable accreditation options in recognition of the varied career paths within the semiconductor industry. Students can earn certificates or credentials for completing specific modules or courses, which can accumulate over time to qualify for higher level technician positions or further education in the field.

Funding Support: Community colleges seek grants to help pay for equipment like personal protective equipment and clean room bunny suits. Funding comes in part from partnerships with industry and/or grants from organizations such as the Oregon Education Association (OEA) Foundation and The National Institute for Metalworking Skills (NIMS).

Mobile Learning and Flexibility: Some community colleges offer mobile courses and flexible learning options, such as course schedules aligned with industry split shifts to allow students to work while attending school. Mobile courses enable students to access, for example, welding training and certifications, without traveling.[37] Other flexible learning options include varied course times (e.g., night and weekend courses) and remote courses.

"We need to offer more classes (e.g., mechatronics) that have multiple times to enter and exit (e.g., each semester), so first or second year students could take it." – Community College Representative

Holistic Support: Community colleges often partner with local community-based organizations (CBOs) to provide additional support including mentorship, transportation, childcare, and other culturally responsive wraparound services.

[37] E.g. PCC's Mobile Welding Outreach & Skills Training Center (https://www.pcc.edu/news/2023/10/mobile-welding-center/) and MHCC's Mobile Training project (https://www.mhcc.edu/0131-2023/)

"To increase the participation of women and women of color, we've been experimenting with some particular cohorts, working with specific CBOs and recruiting from within their organization.... Also, this July we will have an all-women cohort to help counteract the declining participation of women." – Apprenticeship Program Lead

"If we want women to come in greater numbers, we need to have folks take care of their children." – Community College Representative

"We also tap into private/public partnerships, like working with community-based organizations (CBOs), to get their help with recruitment and wrap-around services our program participants need to get a job and keep a job." – Workforce Program Lead

Case Study: Quick Start, Hillsboro, Oregon

The Quick Start Semiconductor Technician Paid Training program, a partnership between WorkSource Oregon, Portland Community College, Intel, and the City of Hillsboro, is a paid, fast-paced training program that prepares workers for careers in semiconductor fabrication. The 10-day course covers theory and practical application, and a new class starts every month. The program is funded by Washington County, the City of Hillsboro, and a Strategic Innovation grant from the State of Oregon. Students who complete the program earn college credit toward an associate degree and an industry-recognized certification. They also receive a training stipend of $500 per week.

University Activities and Needs

Universities in Oregon have long prepared students for jobs in the semiconductor industry. In addition to credential-awarding programs, several universities within the Oregon University System maintain specialized cleanroom facilities essential for semiconductor research and manufacturing. These cleanrooms house a range of equipment and infrastructure, such as photolithography tools and thin-film deposition systems. There is also access to equipment for semiconductor materials research, devices research, and rapid prototyping. Rapid prototyping equipment supports high-precision fabrication and empowers researchers and students to create semiconductor components and instruments efficiently.

Oregon universities offer a combination of specialized degree programs, research opportunities, industry partnerships, and career services that contribute to preparing students for jobs in the semiconductor industry. We interviewed representatives from four Oregon universities and three universities outside of Oregon.[38] University representatives and their industry partners repeatedly raised the following priorities, needs, and concerns in our interviews and discussions:

Importance of Organizing and Collaborating: University / semiconductor industry collaborations are generally less formal than community college / industry collaborations but are still important. By fostering partnerships with local semiconductor companies and industry stakeholders, universities create opportunities for practical training (e.g., hands-on experience through internships), research collaborations, industry-driven coursework, and job placement.

[38] We interviewed representatives from Oregon State University, University of Oregon, Portland State University, Oregon Institute of Technology, Purdue University, Nuertingen-Geislingen University, and Sierra College.

Challenges to efficient collaboration include rapidly evolving industry needs and securing adequate funding for programs.

Speed of Change: Universities engage in dialogue and collaborative projects with industry partners to align their curricula with industry needs but it takes up to seven years to formally change curricula, which is too slow to meet rapidly changing needs.

> "Communication and teamwork skills are important… Several industry partners collaborate with the university, and alumni often return to hire their own interns, creating a cyclical relationship, with many interns being hired full-time after their internships." – University Representative

Hands-On Experience: Some universities in Oregon are constrained by their ability to offer hands-on experience with state-of-the-art semiconductor facilities. Collaborating with industry partners, seeking grants, and leveraging alumni support are among the strategies employed to increase access to this equipment.

The Math Barrier: Math is often seen as a barrier in transitioning between levels of education. Some individuals with good technical skills and interest in completing engineering courses hold back because they believe, based on their school experiences, that they are bad at math. Teaching applied math as a tool to complete technical tasks can help remove this barrier.

Faculty Skills and Interests: Some interviewees emphasized the importance of training faculty with the most up-to-date semiconductor technology and trends. Others described the challenge of balancing the innovation and creativity inherent in the university setting with meeting the needs of the workforce ecosystem.

Hybrid Master's Programs: University representatives highlighted the opportunity to scale semiconductor-related master's programs through hybrid and/or part-time program models. Providing creative ways for students to work while earning a master's degree can provide mutual benefits for both industry and universities.

> "The research universities in Oregon can only aspire to be a part of the solution for Intel and others in terms of producing a robust MS- and PhD workforce. Still, it is essential that the state maintain strong R1 institutions otherwise we will lose talented students at all levels (BS, MS, PhD) and faculty to other states. Part-time master's programs can be a huge win-win for industry and the universities. But it is the full-time PhD students who are the backbone for strong research enterprises." – University Representative

Importance of PhD Pathways: University representatives described the importance of maintaining top-quality semiconductor-related PhD programs. Interviewees noted the value of PhD programs that are in-person, fully funded, and full-time.

Professors of Practice: One out-of-state university emphasized the benefit of supporting professors of practice with semiconductor backgrounds to expand students' exposure to the industry and utilize the expertise of industry professionals.

Industry Activities and Needs

Like their counterparts in education, industry representatives support the state's goal of aligning educational programs with industry needs. The industry interview findings provide valuable insights into the challenges and opportunities within the semiconductor industry in Oregon. The themes and needs described below emphasize the importance of collaboration, upskilling, industry participation, and state support to foster a vibrant semiconductor ecosystem in the state:

Youth Apprenticeship Programs: The success of the Hillsboro Advanced Manufacturing Apprenticeship underscores the potential of early engagement to attract young talent to the semiconductor industry and promote education in manufacturing.

Attracting Students Amidst Industry Giants / Leveling the Playing Field: The challenge some employers have attracting students in the shadow of larger industry players like Intel highlights the need for diversified opportunities. Larger companies can sometimes overwhelm smaller companies, suggesting the need to level the playing field to some extent for smaller companies.

> "Intel helps us in many ways. But sometimes it overshadows what we are able to do." – Industry Representative
>
> "Recruitment is a challenge due to increased industry demand and partners…. Intel, for example, could hire all the students on its own." – University Representative

State-Supported Infrastructure to Support Upskilling for Rapid Technology Changes: The rapid pace of technological change necessitates continuous upskilling of the workforce. Industry representatives described the need for state-supported infrastructure and equipment (e.g., photolithography tools and thin-film deposition systems), highlighting the importance of government investment in creating a supportive environment for semiconductor education and research.

> "Anything we can do to upskill your workforce to prepare, is important. Every day the technology is changing, it's going to change more." – Industry Representative

Building Relationships between Education, Workforce, and Industry: Multiple employers emphasized the need to foster mutually beneficial relationships between education and industry, including mentoring and research roles.

Earn and Learn Programs: Like other states, Oregon is exploring "Earn and Learn" initiatives to provide low-barrier opportunities for lower income individuals and encourage a seamless integration of work and education. By providing opportunities for individuals to gain hands-on experience while pursuing their education at community colleges, Oregon can address the need for a skilled workforce and offer sustainable pathways for students to enter the semiconductor industry.

> "Earn and Learn programs are closer to apprenticeship in a more direct way as they help entry-level employees work toward a higher degree (e.g., AA degree). For instance, if semiconductor employers provided equipment in a classroom onsite, college instructors could come in and teach employees between their shifts, who could earn their college credit during work. Some courses could happen onsite (robotics, vacuum, etc.) …or, after they finish their shift, employers could pay their employees to go to college and earn credits. This, then, provides a structured approach for employees to earn the college credit and certificate." – Community College Representative

Diversifying Oregon's Talent by Lowering Barriers: Industry representatives expressed great desire to continue diversifying the employment pool of the semiconductor industry as well as the need for additional support structures to lower barriers for underrepresented individuals to enter the semiconductor industry.

Growing and Retaining Oregon's PhD Talent Pool: The need for more PhD talent in Oregon highlights the importance of promoting advanced education and research in the state. Retaining talent within the state is vital for Oregon's economic growth.

Intellectual Property Ownership: The discussion around intellectual property ownership between universities and companies underscores the importance of fostering an environment of collaboration and co-ownership.

4. Pathways Analysis

In addition to our analysis of publicly available data described in earlier chapters, we analyzed student-level data, provided by the HECC, regarding (1) students enrolled in selected education pathways in Oregon's public postsecondary institutions and (2) students' employment outcomes after completing a semiconductor-related postsecondary credential program from these institutions. Pathways assessed include postsecondary programs regardless of a student's high school experience as well as paths that start with selected dual-credit courses while a student is in high school. The student-level data, linked to employment outcomes, provides a more robust means than is possible with publicly available data for quantifying the extent to which Oregon pathways support employment in the semiconductor workforce and for identifying potential programmatic gaps associated with occupations important to the industry.

This analysis provides a first look at the extent to which Oregon's semiconductor-related education pathways directly support employment in the state's semiconductor industry by providing a flow of credentialed workers. It provides high-level benchmarks for assessing the strength of these pathways and the extent to which they appear to reinforce trends observed in aggregate toward increasing workforce diversity. And it lays a foundation for subsequent analysis of the many avenues of investigation possible with this data source. The central questions addressed by the pathways analysis include the following:

1. What are the demographic characteristics of students in semiconductor-related pathways and how do they compare to those of the adult population and semiconductor workforce?
2. What are typical labor market experiences for students earning a credential in these pathways?
3. How does the typical labor market experience of these students vary by student demographics and industry of employment (semiconductor manufacturing versus all other industries)?

This chapter describes the pathways analysis, beginning with a description of the data and important limitations of the data. It then presents demographic characteristics (age, gender, race, and ethnicity) of students included in the analysis, followed by findings regarding employment outcomes for these students. The chapter concludes with a brief assessment of how the additional need for semiconductor workers anticipated from state and federal CHIPS Act investments relates to the scale of existing education pathways.

Data Description and Definitions

The analysis presented in this chapter is based largely on student-level education and employment data provided through a data-sharing agreement with HECC. The data include student-level demographics (date of birth, race and ethnicity, gender, age), course enrollments, credential completions (date, type of award, and major or program of study), and employment information (annual hours and wages by industry of employer). The universe of students included three groups (see Appendix C for a list of included majors):

1. All students who completed a postsecondary credential at a public Oregon institution during 2013 or later in a semiconductor-related program of study.
2. All students who enrolled in a semiconductor-related course at a public Oregon institution during 2013 or later.
3. All students who enrolled in a semiconductor-related dual-credit course while in high school in Oregon during 2013 or later.

The data included additional course-taking and completion information, regardless of major, to provide a complete picture of students' experiences in Oregon's public postsecondary system, as well as employment information from 2011 to 2021 for groups 1 and 2. Credential data are aggregated by institution level: community college, undergraduate university, and graduate. This chapter relies on various subsets of these data as described in the sections below.

In this analysis, demographic information includes race and ethnicity, gender, and age group and is aggregated, in certain cases. Specifically, this analysis aggregates students who identify as Black or African American, Hispanic or Latino, Native Hawaiian or Pacific Islander, or American Indian or Alaska Native to clarify that these groups are historically underrepresented in STEM.[39]

Employment outcomes are presented for core semiconductor-related program completers and segmented into combined cohorts based on the year of completion. Combining multiple academic year cohorts allows for more reliable cohort sizes for trend analysis. This analysis investigates employment outcomes one year prior to graduation, one year post-graduation, and five years post-graduation. In order to create comparable observations, academic year cohorts were combined differently depending on employment outcome:

1. For one-year-prior-to-graduation employment outcomes, the analysis includes completers that graduated between the 2013-14 and 2020-21 academic years.
2. For one-year and five-year post-graduation employment outcomes, the analysis includes completers in the 2013-14 through 2015-16 academic years for the university level and the 2013-14 through 2016-17 academic years for the community college level.[40] These cohorts each have at least five years post-completion for which we can observe employment outcomes.

While these data can provide valuable insights into Oregon's public education pathways, they also have important limitations that affect interpretation of our findings. The available data speak directly to the connections between Oregon's public education pathways and employment in Oregon's semiconductor industry (or other Oregon industries), but not more.

[39] National Science Foundation (2023). *Diversity and STEM*. Accessed at: https://ncses.nsf.gov/pubs/nsf23315/report
[40] Combined cohorts include different year ranges for university and community college completers due to lack of data for university completers in the 2020-21 academic year.

Most importantly, they do not include postsecondary experiences in private or out-of-state institutions, and they do not include information about employment outside of Oregon or that is not covered by Oregon's unemployment insurance program. As a result, we cannot definitively identify complete educational or employment experiences of Oregon students, although the available information should provide a reasonably complete picture.

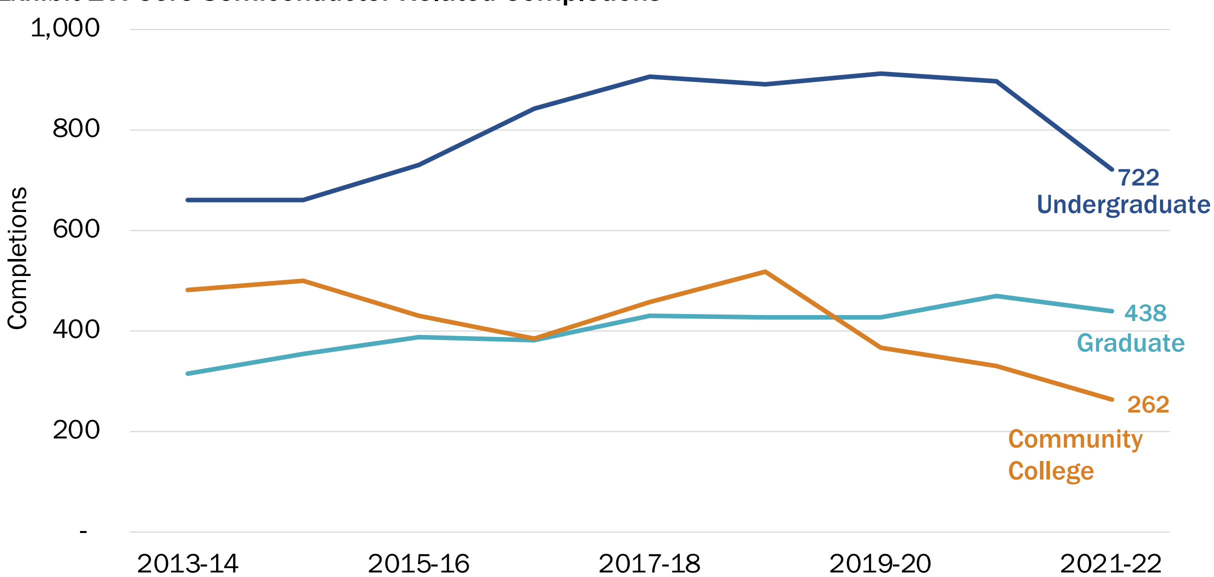
Semiconductor Pathways in Oregon's Public Postsecondary Institutions

This section describes the characteristics and employment outcomes of recent completers of core educational pathways at Oregon's public postsecondary institutions. Findings characterize the strength of the relationship between these pathways and semiconductor employment and suggest the extent to which these pathways are supporting and could further support efforts to diversify the industry's workforce.

Core Semiconductor-Related Credential Completions

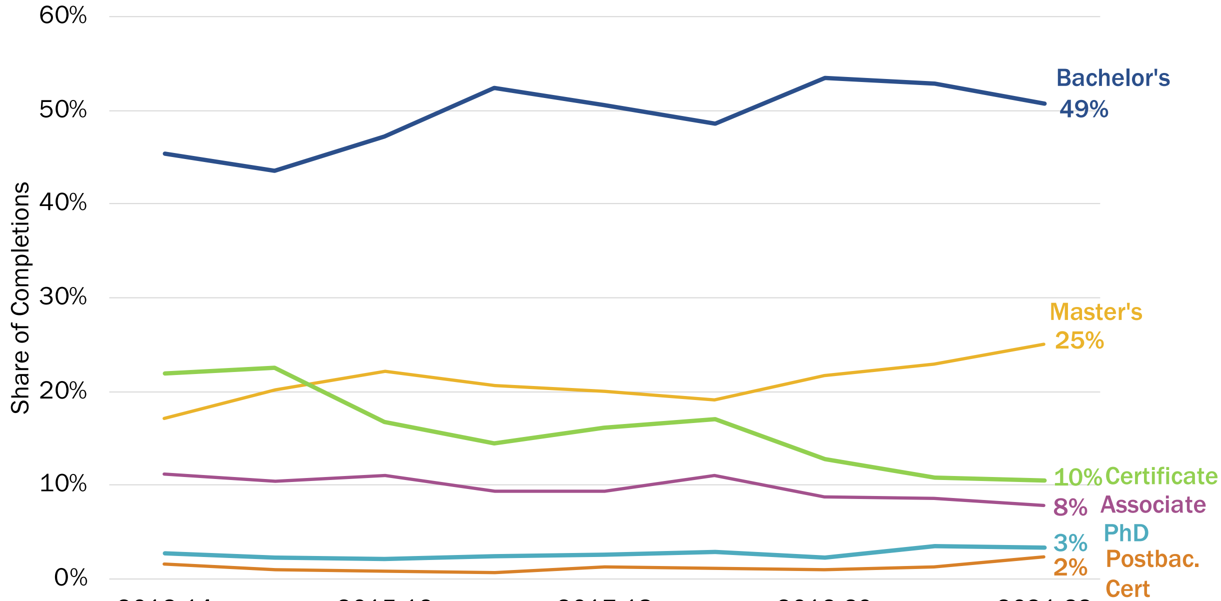
Undergraduate and graduate credentials comprise the largest shares of completions in the core semiconductor-related programs after the 2019-20 academic year (see Exhibit 27 and Exhibit 28). Completions have recently declined across all categories but the decline in community college completions has been more pronounced. Over a longer period, graduate completions have increased—by an average of 4 percent annually since 2013-14. The recent declines in credentials awarded–likely due in part to COVID-19 disruptions–present a challenge for the state's efforts to support a rapidly expanding semiconductor industry. The length and ultimate depth of the decline remains to be seen.

Exhibit 27. Core Semiconductor-Related Completions



Data source: Oregon Higher Education Coordinating Commission

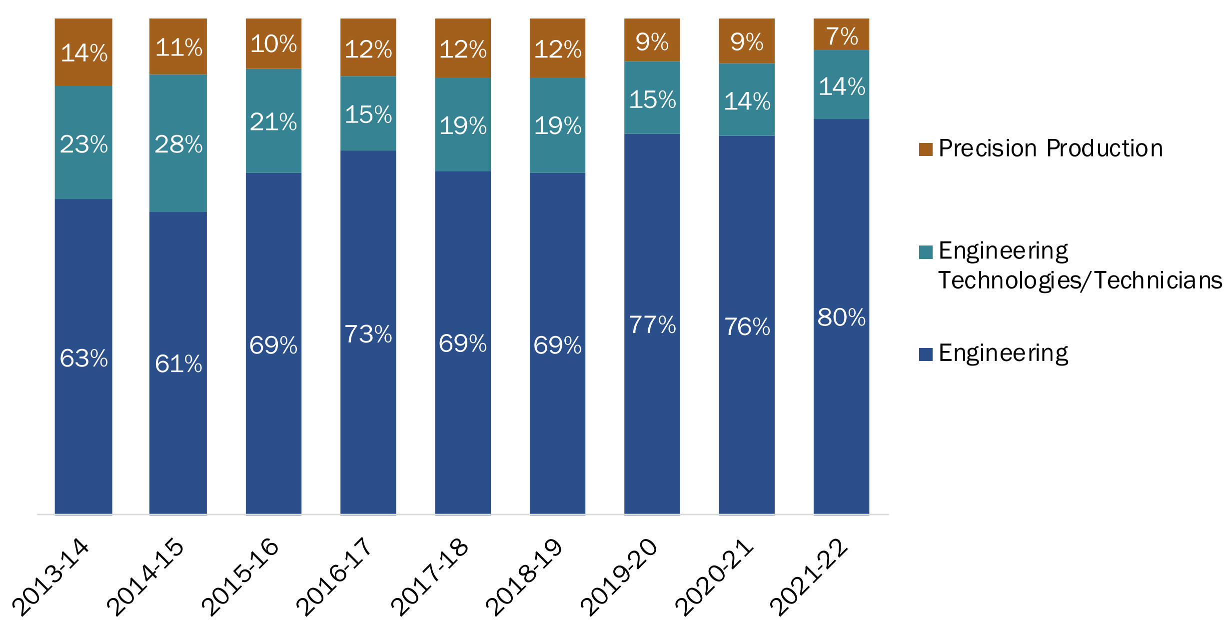
Exhibit 28. Core Semiconductor-Related Completions by Credential Type



Data source: Oregon Higher Education Coordinating Commission

Completions in engineering have increased while those in engineering technologies and precision production programs have decreased over the specified period (see Exhibit 29). Specifically, in 2019-20, the share of engineering completions increased by 8 percentage points above the 2018-19 share, while the shares in engineering technologies and precision production decreased by 4 and 3 percentage points, respectively.

Exhibit 29. Core Semiconductor-Related Completions by Program Category



Data source: Oregon Higher Education Coordinating Commission

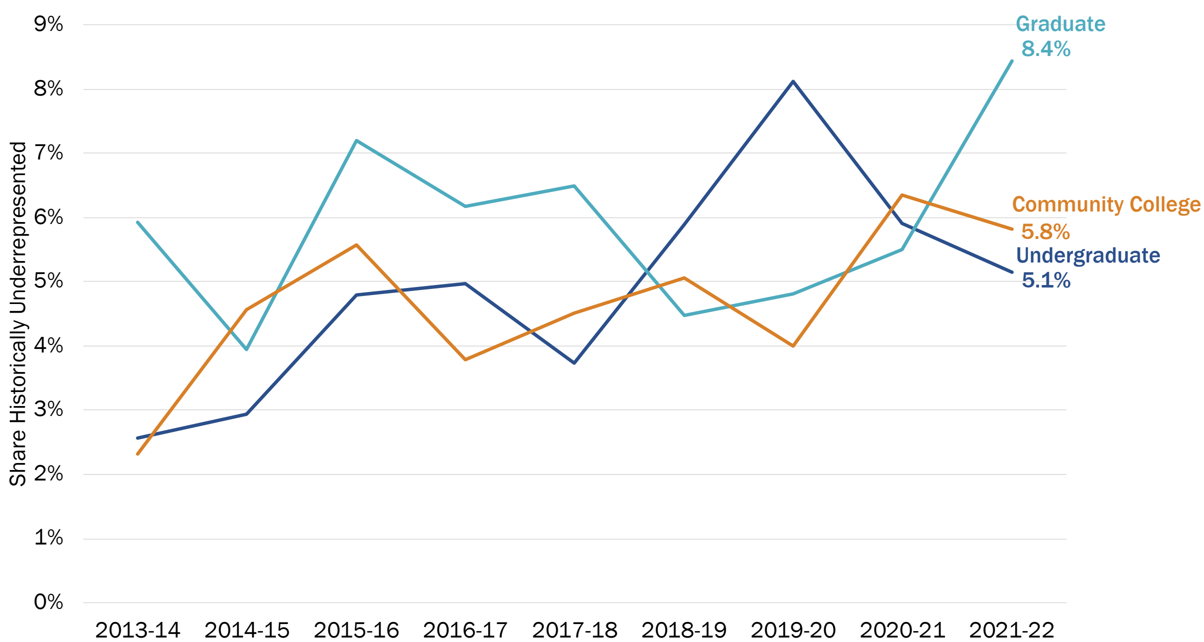
Characteristics of Core Semiconductor-Related Program Completers

Completer Demographics

As discussed in Chapter 2, historically underrepresented populations in STEM include those who identify as Black or African American, Hispanic or Latino, Native Hawaiian or Pacific Islander, or American Indian or Alaska Native. The historically underrepresented share of completers in core semiconductor-related graduate programs has increased the most since the 2013-14 academic year, followed by completers at community colleges (see Exhibit 30).

In 2021-22, historically underrepresented completers comprised 8.4 percent of graduate core completions, 5.1 percent of undergraduate completions, and 5.8 percent of community college completions. Although the share of historically underrepresented groups in core programs has increased over time, the share of these groups in university and community college completions still lies far below their prevalence in the statewide population. In 2021, Black or African American, Hispanic or Latino, Native Hawaiian or Pacific Islander, and American Indian or Alaska Native individuals in Oregon together comprised 21 percent of the population.[41]

Exhibit 30. Historically Underrepresented Completers in Core Semiconductor-Related Programs



Note: Historically underrepresented races/ethnicities in STEM include Black or African American, Hispanic or Latino, Native Hawaiian or Pacific Islander, and American Indian or Alaska Native.
Data source: Oregon Higher Education Coordinating Commission

Combining completers during the 2013-14 through 2021-22 academic years, Exhibit 31 shows the share of historically underrepresented and nonresident completers by core semiconductor-related program for undergraduate and graduate credentials. Materials engineering, engineering chemistry, and general computer engineering have the highest shares of

[41] U.S. Census Bureau. (2021) Oregon American Community Survey 5-year Estimates.

historically underrepresented completers and relatively low shares of nonresident completers. Engineering/industrial management, electrical/electronics engineering, and industrial engineering have the highest shares of nonresident[42] completers.

Exhibit 31. Historically Underrepresented and Nonresident Completers in Core Semiconductor-Related University Programs

Program	Historically Underrepresented	Nonresident	Resident and Non-Underrepresented
Materials Engineering	14%	14%	70%
General Computer Engineering	7%	10%	80%
Engineering Chemistry	6%	2%	87%
Other Engineering	4%	10%	78%
Mechatronics, Robotics, and Automation Engineering	4%	33%	60%
Mechanical Engineering	4%	16%	78%
Industrial Engineering	4%	38%	55%
Computer Software Technology/Technician	4%	1%	92%
Engineering/Industrial Management	3%	55%	38%
Electrical/Electronics Engineering	3%	43%	51%
Engineering Physics	3%	1%	92%
Manufacturing Engineering	3%	18%	74%
Chemical Engineering	2%	28%	67%

Data source: Oregon Higher Education Coordinating Commission. Rows may not sum to 100% due to missing data. Historically underrepresented races/ethnicities in STEM include Black or African American, Hispanic or Latino, Native Hawaiian or Pacific Islander, and American Indian or Alaska Native. Non-historically underrepresented populations include White, Asian, and/or Two or More Races.

Exhibit 32 displays the share of historically underrepresented community college completers in core semiconductor-related programs for the combined 2013-14 through 2021-22 cohorts. Computer software and manufacturing engineering technology/technicians programs have the highest share of historically underrepresented completers. Machinist and mechatronics programs have relatively lower shares of historically underrepresented completers.

[42] *Nonresident* describes a person who is not a citizen or national of the United States and who is in the country on a visa or temporary basis and does not have the right to remain indefinitely.

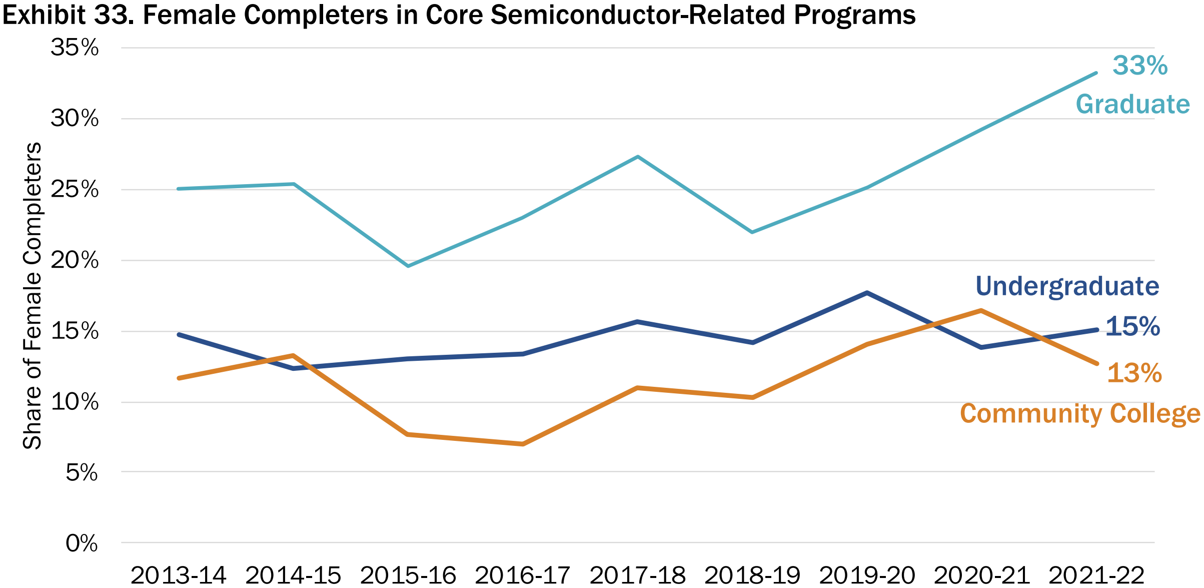
Exhibit 32. Historically Underrepresented Completers in Core Semiconductor-Related Community College Programs

Program	Historically Underrepresented	Non-Underrepresented
Computer Software Technology/Technician	11%	84%
Machine Shop Technology	8%	84%
Manufacturing Engineering Technology/Technician	7%	81%
General Engineering	6%	88%
Machine Tool Technology/Machinist	5%	88%
CNC Machinist Technology	5%	92%
Mechatronics, Robotics, and Automation Engineering	5%	95%

Data source: Oregon Higher Education Coordinating Commission. Rows may not sum to 100% due to missing data. Historically underrepresented races/ethnicities in STEM include Black or African American, Hispanic or Latino, Native Hawaiian or Pacific Islander, and American Indian or Alaska Native. Non-historically underrepresented populations include White, Asian, and/or Two or More Races.

Graduate credential completions in core semiconductor-related programs have the highest share of female completers (see Exhibit 33). Between 2013-14 and 2021-22, the female share of graduate completers increased by 10 percentage points, to 33 percent. The share of female completers in core undergraduate programs has remained close to 15 percent since 2016-17, while female completers at the community college level have represented between 11 and 16 percent of completers.

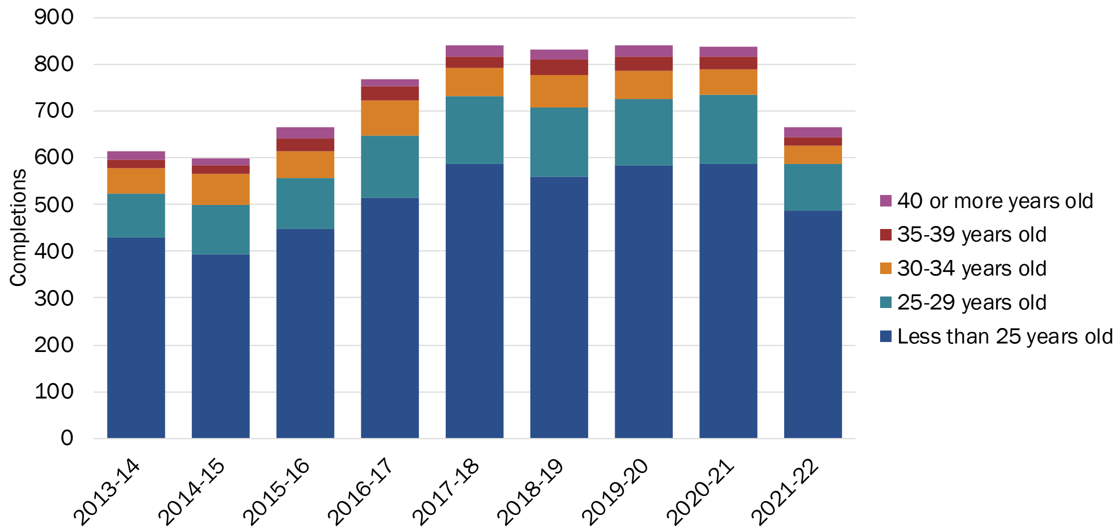
Exhibit 33. Female Completers in Core Semiconductor-Related Programs



Data source: Oregon Higher Education Coordinating Commission

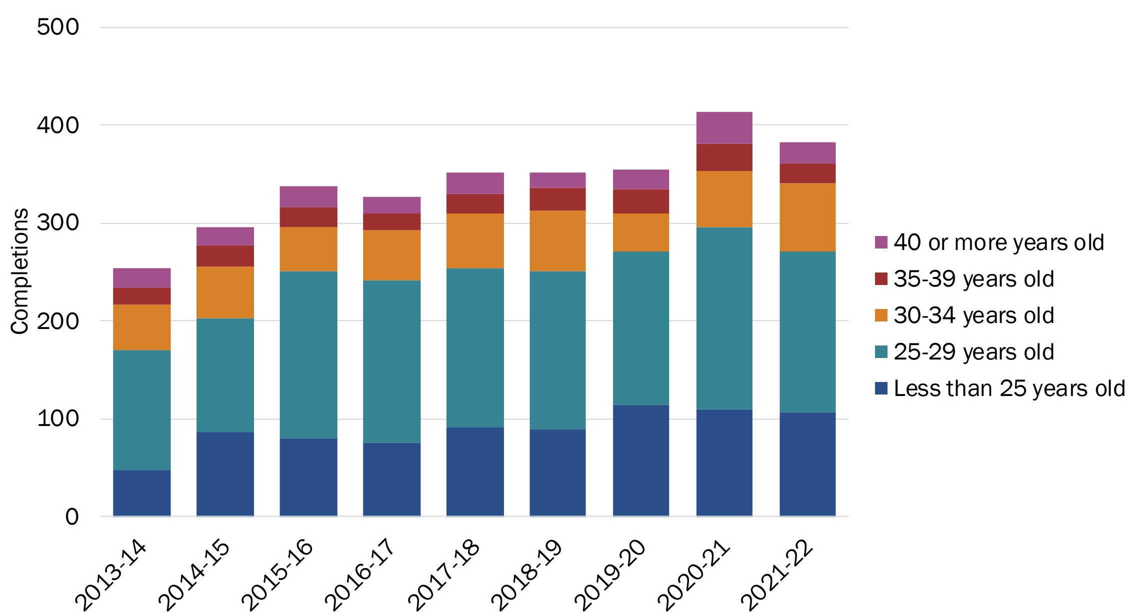
In 2021-22, close to three fourths of undergraduate completers in core semiconductor-related programs were under the age of 25 years old (see Exhibit 34). Graduate completers were slightly older, with approximately 71 percent under the age of 29 years old in 2021-22 (see Exhibit 35). The age of community college completers in core programs was less concentrated in younger ages, though the share of completers age 40 or older dropped considerably beginning in 2019-20 (see Exhibit 36). In 2021-22, 40 percent of community college completers were younger than 25 years old, 19 percent were between 25 and 29 years old, and 17 percent were over 40 years old.

Exhibit 34. Core Semiconductor-Related Undergraduate Completers by Age Group



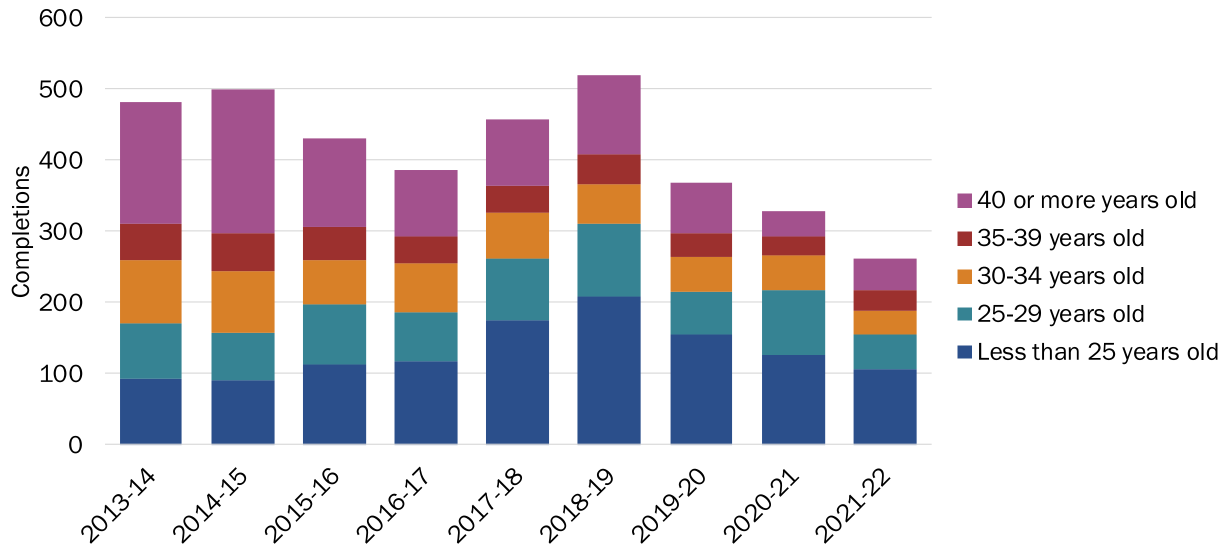
Data source: Oregon Higher Education Coordinating Commission

Exhibit 35. Core Semiconductor-Related Graduate Completers by Age Group



Data source: Oregon Higher Education Coordinating Commission

Exhibit 36. Core Semiconductor-Related Community College Completers by Age Group



Data source: Oregon Higher Education Coordinating Commission

Employment Prior to Graduating from Core Semiconductor-Related Programs

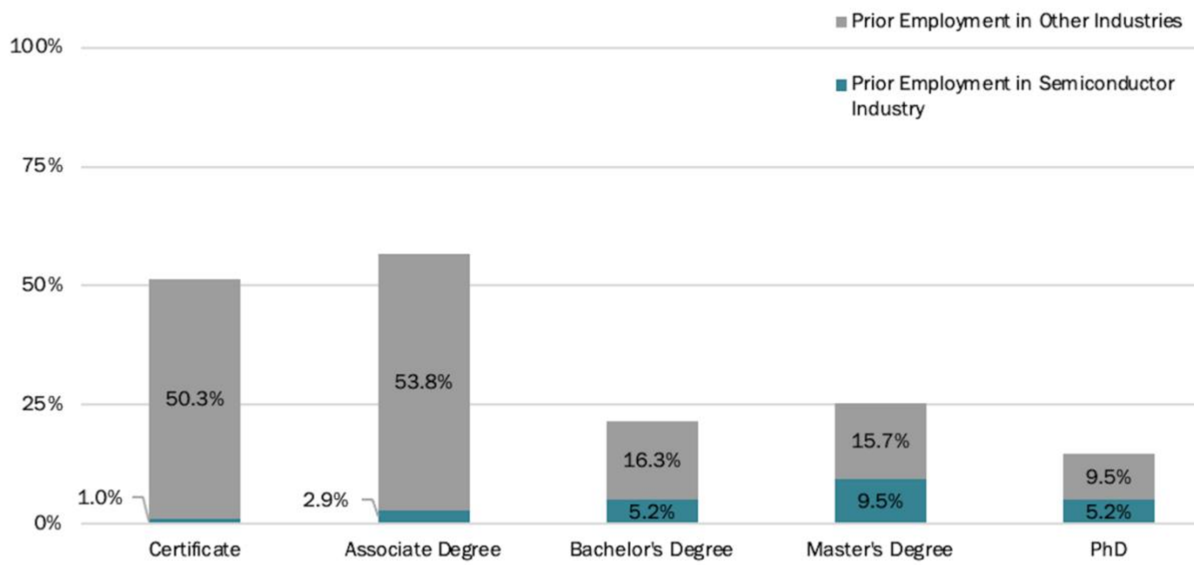
The semiconductor industry employs workers at all educational attainment levels, including high school students, as described in Chapter 3. The pathways analysis aims to identify individuals who worked in the semiconductor industry prior to graduating from a community college or university, including those who worked after high school graduation but prior to earning a postsecondary credential and those who returned to a university or community college after obtaining a postsecondary credential.

Prior employment is defined as any employment within a year prior to completion.[43] If an identified completer is matched with wage information in the employment data before the quarter of their credential completion, they are considered employed prior to graduation. Many students are not employed prior to graduating from a postsecondary program or are employed in industries that have no relation to their planned postsecondary studies. However, examining prior employment for those students who will complete a core semiconductor-related program provides a high-level assessment of the connections between education and industry.

Many more community college completers, compared to university students, had been employed in the year prior to completing an associate degree or certificate in a core semiconductor-related program. Only a small share of certificate completers—1 percent—had been employed in the semiconductor industry in the year prior to completion, compared with 3 percent of associate degree completers, 5 percent of bachelor's degree completers, 10 percent of master's degree completers, and 5 percent of PhD completers (see Exhibit 37).

[43] The year prior to graduation is determined based on academic quarter, rather than graduation year. For example, if a student graduated in the summer quarter of 2019, their employment outcomes would be examined in the third and fourth quarters of 2018 as well as the first and second quarters of 2019.

Exhibit 37. Employment Prior to Completion, Core Semiconductor-Related Credential Completers



Data source: Oregon Higher Education Coordinating Commission

Exhibit 38 details the share of university and community college completers who have prior employment in the semiconductor industry by race and ethnicity. Overall, approximately 8 percent of university completers worked in the semiconductor industry in the year prior to completion, with considerable variation across race and ethnicity of completers. Community college completers were less likely to have had prior semiconductor employment (3 percent) with similar, but less dramatic, variation by race and ethnicity.

Exhibit 38. Shares of Core Semiconductor-Related Credential Completers Who Had Prior Employment in the Semiconductor Industry, by Race/Ethnicity

Race/Ethnicity	University Completers	Community College Completers
Historically Underrepresented	14%	3%
Asian	13%	4%
Unknown Race and Ethnicity	11%	NA
White	9%	3%
Two or more races	9%	6%
Nonresident	5%	NA
Total	**8%**	**3%**

Note: Historically underrepresented races/ethnicities in STEM include Black or African American, Hispanic or Latino, Native Hawaiian or Pacific Islander, and American Indian or Alaska Native.
Data source: Oregon Higher Education Coordinating Commission

Post-Graduation Employment Outcomes for Core Semiconductor-Related Program Completers

Employment outcomes for completers are described for two points in time—one year after graduation and up to five years after graduation—to capture both shorter and longer term outcomes.[44] The employment outcomes described in Exhibit 41 are for the approximately 1,400 community college (certificate and associate degree) completers and 2,970 university-level (post-baccalaureate certificate,[45] bachelor's degree, master's degree, and PhD) completers (see Exhibit 39).

Exhibit 39. Core Semiconductor-Related Completers by Credential

Credential Type	Employment Cohort	Share of Total
Community College Level		
Certificate	828	59%
Associate Degree	573	41%
Total	**1,401**	**100%**
University Level		
Bachelor's Degree	1,962	66%
Postbaccalaureate Certificate	27	1%
Master's Degree	871	29%
PhD	109	4%
Total	**2,969**	**100%**

Data source: Oregon Higher Education Coordinating Commission

Exhibit 40 describes the demographic characteristics of the employment cohort. The university portion of the cohort has a relatively high share of nonresident completers and a lower share of historically underrepresented completers. In comparison, the community college portion of the cohort has a higher share of historically underrepresented completers and a notable share of Asian completers. The universities have a slightly higher share of women completers compared to community colleges.

[44] Employment outcomes are presented for those with more than half-time employment (1,040 hours per year). See Data Descriptions and Definitions above for more information about the employment cohort.
[45] Post-baccalaureate certificate completers are excluded from employment outcome results by credential type due to small sample size, however these completers are included in summaries by student demographic characteristics.

Exhibit 40. Core Semiconductor-Related Completers by Demographic Characteristic

Characteristic	University		Community College	
	Count	Share of Total	Count	Share of Total
Race and Ethnicity				
White	1,593	54%	889	63%
Nonresident	842	28%	NA	NA
Asian	179	6%	207	15%
Two or More Races	142	5%	49	3%
Unknown Race and Ethnicity	129	4%	131	9%
Historically Underrepresented	84	3%	125	9%
Total	**2,969**		**1,401**	
Gender				
Male	2,199	74%	1,246	89%
Female	435	15%	151	11%
Unknown Gender	335	11%	4	0.3%
Total	**2,969**		**1,401**	

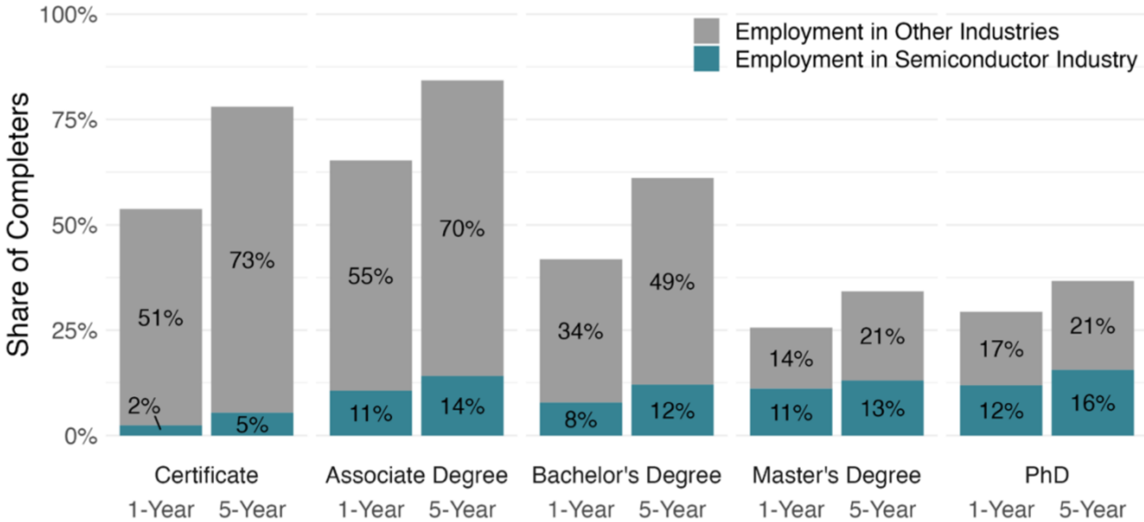
Note: Historically underrepresented races/ethnicities in STEM include Black or African American, Hispanic or Latino, Native Hawaiian or Pacific Islander, and American Indian or Alaska Native.
Data source: Oregon Higher Education Coordinating Commission

Between 8 and 12 percent of university completers in the employment cohort gained employment in the semiconductor industry *within one year of graduation* (see Exhibit 41). Of bachelor's degree completers, 8 percent gained employment in the semiconductor industry and 34 percent gained employment in another industry within Oregon. The remaining 58 percent do not have employment records in Oregon, meaning those individuals could be unemployed or employed less than half-time, or could have moved out of the state or country after graduation. *Within five years of graduation*, 12 percent of bachelor's degree completers gained employment in the semiconductor industry.

Far fewer master's-degree and PhD completers have associated Oregon employment records—most graduates either moved out of the state or country or were unemployed or employed less than half-time one and five years after graduation. Slightly higher shares of graduate degree completers gained employment in the semiconductor industry within one and five years after graduation compared to bachelor's degree completers.

At the community college level, 2 percent of certificate completers and 11 percent of associate degree completers gained employment in the semiconductor industry *within one year of graduation*, compared with 5 percent of certificate completers and 14 percent of associate degree completers *within five years of graduation*.

Exhibit 41. Post-Graduation Employment Outcomes (1-Year and 5-Year) for Core Semiconductor-Related Program Completers, Oregon, 2014-2017 Completers



Data source: Oregon Higher Education Coordinating Commission

Demographics of Employed Completers

Exhibit 42 details the demographic characteristics of those employed in the semiconductor industry one-year and five-years post-graduation, in addition to the demographic characteristics of the employment cohort as presented in Exhibit 40.

At the university level, historically underrepresented completers represent a larger share of those that gained employment in the semiconductor industry than are present in the employment cohort. Similarly, historically underrepresented community college completers comprise the same or a larger share of those employed in the industry than are present in the employment cohort. Still, this subpopulation remains underrepresented in the semiconductor industry compared to its presence in Oregon's workforce (16 percent) and population overall (12 percent).

Women completers at both the university and community college levels, while still dramatically underrepresented in semiconductor employment, comprise higher shares of those that gained employment in the industry at one-year and five-years post-graduation than are present in the employment cohort overall.

At the university level, completers over 30 years old comprise a higher share of those that gained employment in the semiconductor industry than are present in the employment cohort. Community college completers between 25 and 34 years old comprise a higher share of those that gained employment in the industry than are present in the employment cohort, while those 40 years or older comprise a lower share.

Exhibit 42. Demographic Characteristics of Completers Employed in the Semiconductor Industry

Characteristic	University			Community College		
	Share	1-Year	5-Year	Share	1-Year	5-Year
Race/Ethnicity						
White	54%	56%	57%	63%	56%	48%
Nonresident	28%	17%	14%	NA	NA	NA
Asian	6%	10%	13%	15%	22%	29%
Two or More Races	5%	8%	8%	3%	6%	6%
Unknown Race and Ethnicity	4%	5%	4%	9%	7%	6%
Historically Underrepresented	3%	5%	5%	9%	9%	11%
Gender						
Male	74%	69%	71%	89%	81%	81%
Female	15%	17%	17%	11%	17%	18%
Unknown Gender	11%	13%	12%	0%	1%	1%
Age Group						
Less than 25 years old	48%	42%	45%	22%	20%	25%
25-29 years old	24%	20%	21%	16%	21%	21%
30-34 years old	10%	12%	12%	17%	23%	19%
35-39 years old	4%	9%	7%	11%	11%	13%
40 or more years old	3%	5%	4%	34%	25%	23%
Unknown Age Group	11%	12%	12%	0%	0%	0%

Note: Historically underrepresented races/ethnicities in STEM include Black or African American, Hispanic or Latino, Native Hawaiian or Pacific Islander, and American Indian or Alaska Native.
Data source: Oregon Higher Education Coordinating Commission

Demographics of Completers Employed One Year Post-Graduation

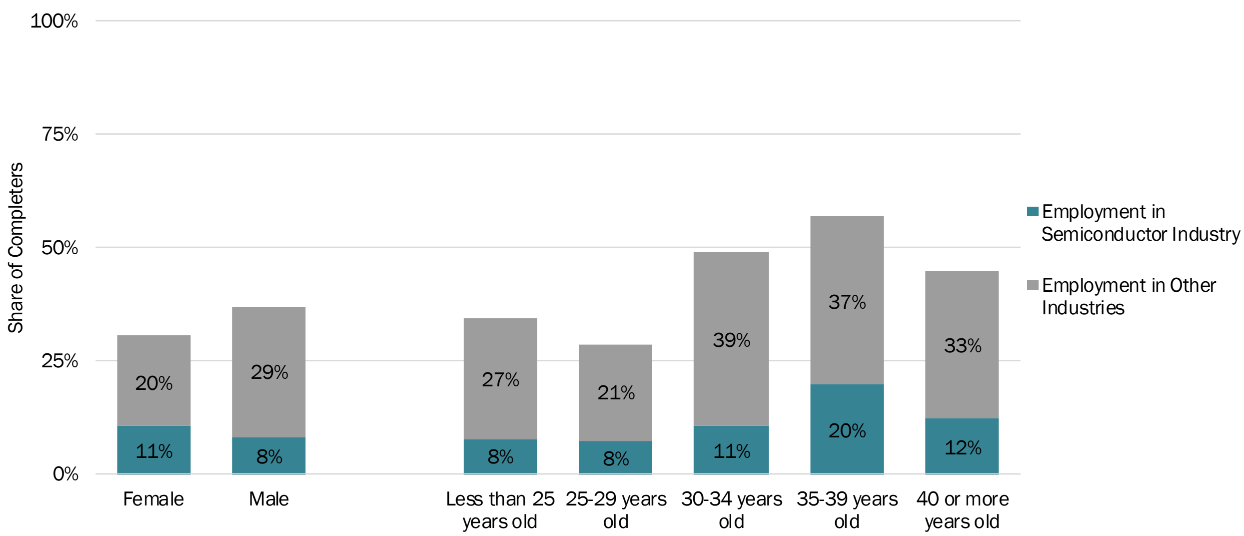
Exhibit 43 displays one-year employment outcomes for university-level completers by race/ethnicity. Completers of historically underrepresented races/ethnicities have the highest employment rates compared to other races and ethnicities: 17 percent gained employment in the semiconductor industry within one year and 35 percent gained employment in other industries. Of nonresident completers, 91 percent do not have Oregon employment records within one year of graduation; those with employment records gained employment in the semiconductor industry at approximately the same rate as other industries.

Community college completers who identify as Asian or two or more races gained employment in the semiconductor industry within one year of graduation at a higher rate than other races and ethnicities (see Exhibit 44). Community college completers entered other industries in Oregon at higher rates compared to university completers in the same groups.

Of female completers at the university level, 11 percent gained employment in the semiconductor industry within one year, compared to 8 percent of male completers (see Exhibit 43). University completers between the ages of 35 and 39 years old gained employment in the industry at the highest rate compared to other age groups, likely reflecting the higher share of graduate-level completers, who tend to be within this age group, gaining employment in the industry.

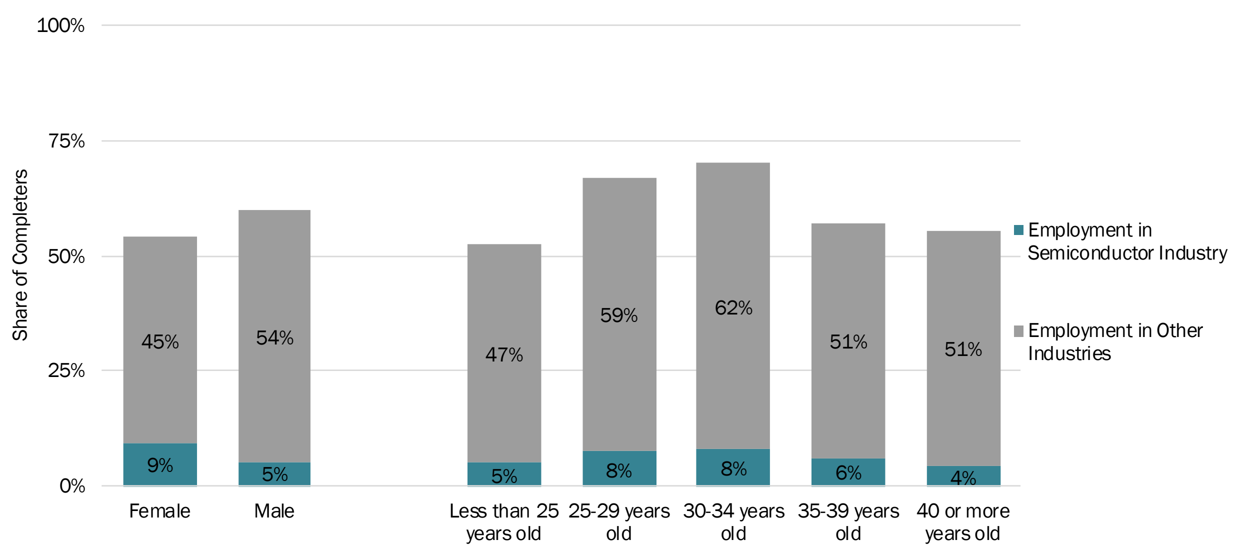
Female community college completers gained employment in the semiconductor industry at a rate of 9 percent compared to 5 percent for male students (see Exhibit 44). Younger community college completers gained employment in the semiconductor industry at rates similar to younger university completers, while relatively fewer older community college completers gained employment in the industry.

Exhibit 43. One-Year Employment Outcomes for University Completers by Gender and Age



Data source: Oregon Higher Education Coordinating Commission

Exhibit 44. One-Year Employment Outcomes for Community College Completers by Gender and Age



Data source: Oregon Higher Education Coordinating Commission

Demographics of Completers Employed Five Years Post-Graduation

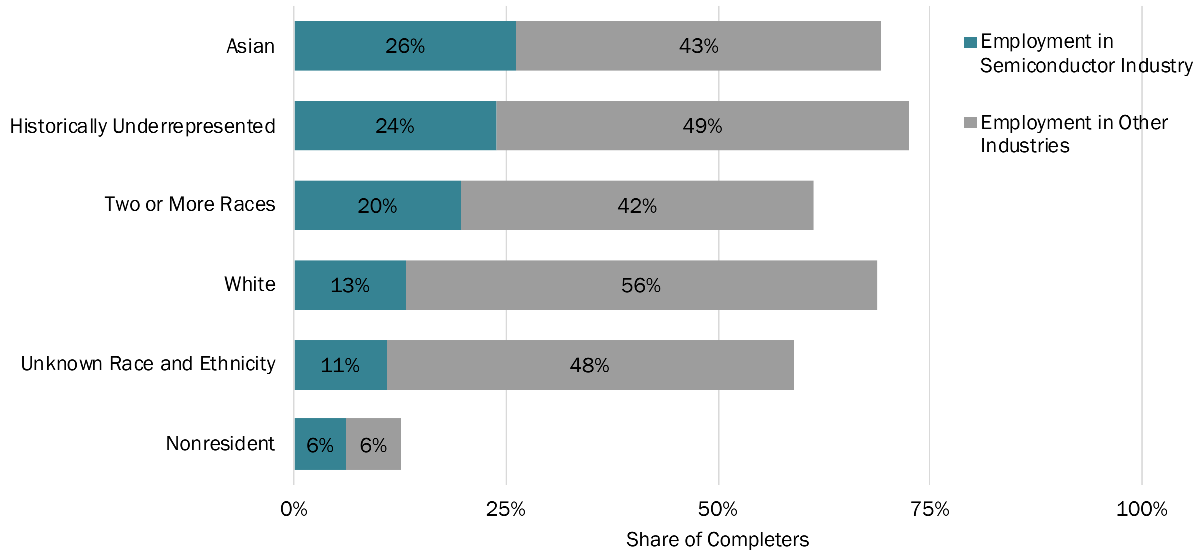
Within five years of graduation, completers gained employment, regardless of industry, at higher rates than within one year of graduation, across all demographics. As with the one-year employment outcomes, a relatively higher share of university-level completers who are historically underrepresented races/ethnicities, Asian, or two or more races, gained employment in the semiconductor industry five years after graduation, compared to other races and ethnicities (see Exhibit 45). Approximately 24 percent of historically underrepresented university completers gained employment in the semiconductor industry five years post-graduation, compared to 17 percent one year post-graduation (see Exhibit 44). Nonresidents gained employment in the semiconductor industry at a relatively similar rate across one-year and five-year employment outcomes (5 versus 6 percent).

Community college five-year employment outcomes differ from one-year employment outcomes by race and ethnicity. Specifically, historically underrepresented races/ethnicities and Asian completers gained employment in the semiconductor industry at higher rates five years post-graduation compared to one year post-graduation (see Exhibit 46 and Exhibit 43).

Relatively more women completers of core semiconductor-related university programs had gained semiconductor employment within five years compared to one year (15 percent versus 9 percent) (see Exhibit 47 and Exhibit 43). University completers between the ages of 35 and 39 years old gained employment in the semiconductor industry at the highest rate (21 percent) and those less than 29 years old at the lowest rate, similar to the one-year outcomes.

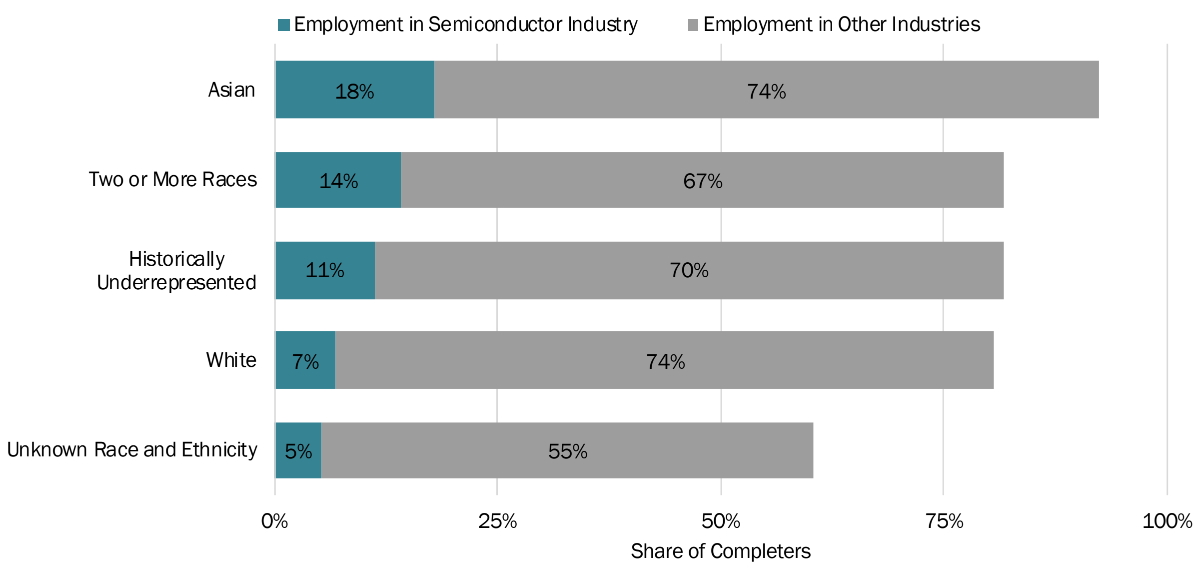
At the community college level, more women than men completers gained employment in the semiconductor industry within five years (15 percent versus 8 percent) (see Exhibit 48). As at the university level, more community college completers of both genders—but especially women—gained semiconductor employment within five years compared to one year. And except for the oldest group, community college completers across age groups gained employment in the industry at approximately the same rates.

Exhibit 45. Five-Year Employment Outcomes for University Completers by Race and Ethnicity



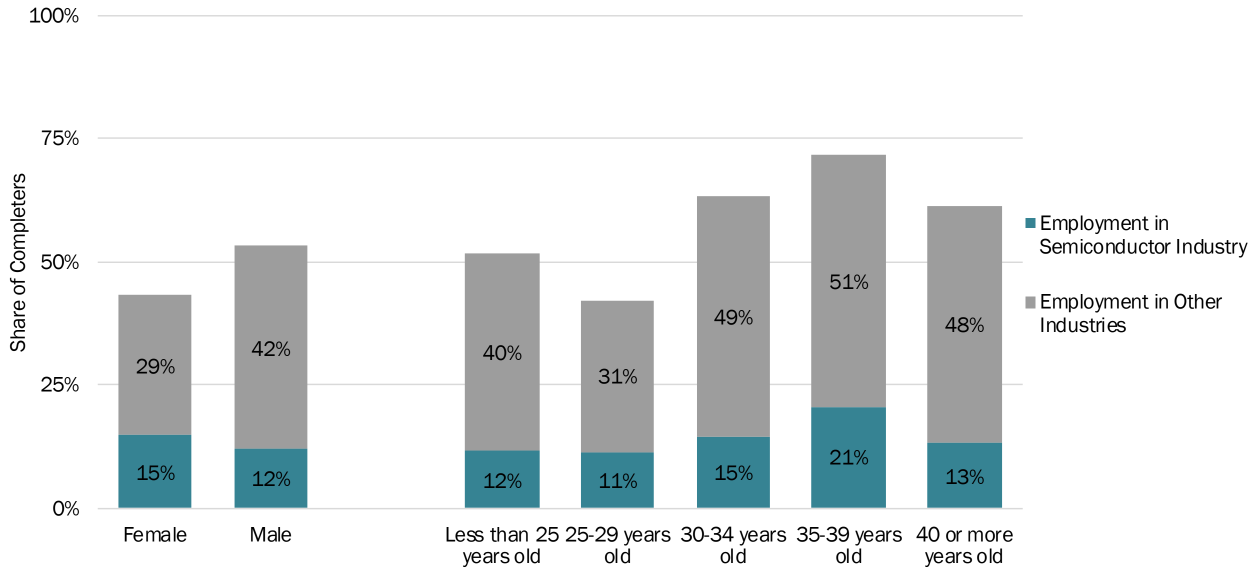
Data source: Oregon Higher Education Coordinating Commission

Exhibit 46. Five-Year Employment Outcomes for Community College Completers by Race and Ethnicity



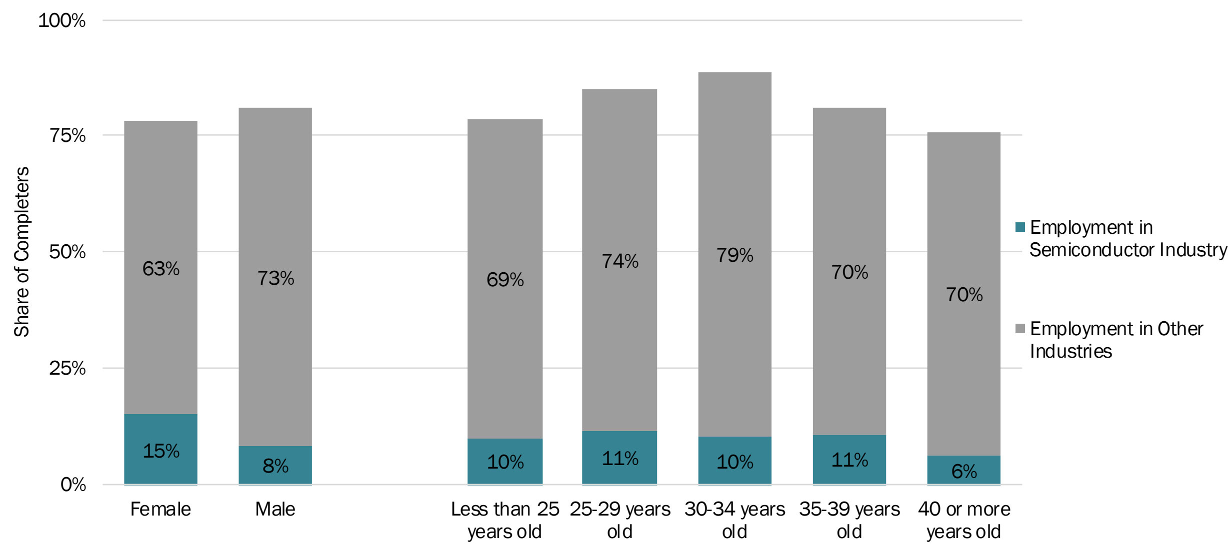
Data source: Oregon Higher Education Coordinating Commission

Exhibit 47. Five-Year Employment Outcomes for University Completers by Gender and Age



Data source: Oregon Higher Education Coordinating Commission

Exhibit 48. Five-Year Employment Outcomes for Community College Completers by Gender and Age

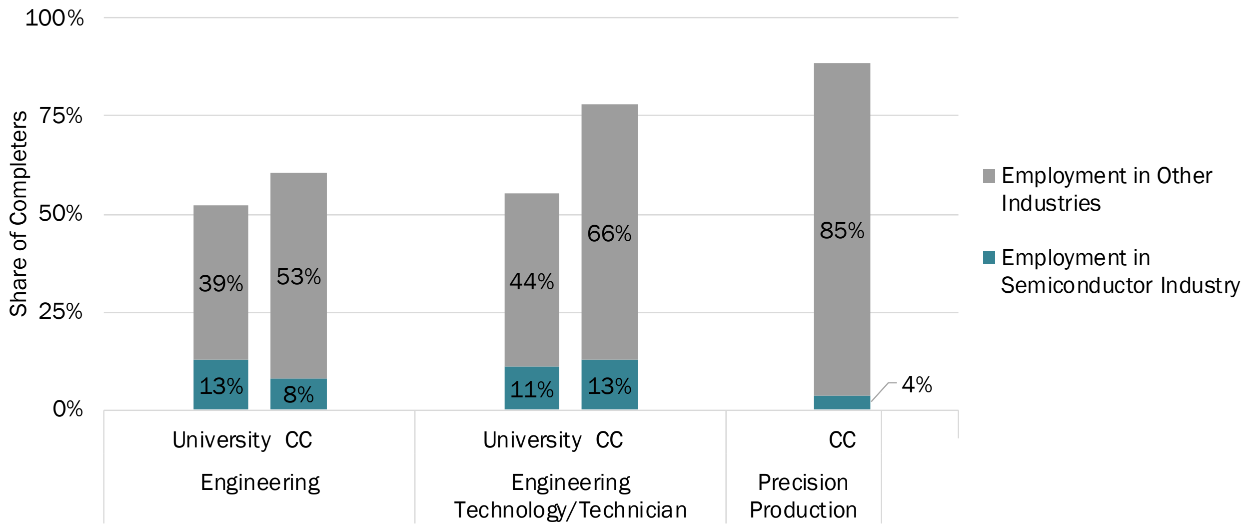


Data source: Oregon Higher Education Coordinating Commission

Employment Outcomes Five Years Post-Graduation by Program Category

Within core semiconductor-related engineering programs, 13 percent of university completers and 8 percent of community college completers gained employment in the semiconductor industry within five years (see Exhibit 49). Of university completers in engineering technology programs, 11 percent gained employment in the semiconductor industry. Community college completers within engineering technology and precision production programs gained employment in the industry at rates of 13 percent and 4 percent, respectively.

Exhibit 49. Five-Year Employment Outcomes for University and Community College Completers by Core Program Category



Data source: Oregon Higher Education Coordinating Commission

Computer engineering and electrical/electronics engineering completers gained employment in the semiconductor industry at the highest rates, 42 and 18 percent, respectively (see Exhibit 50). Notably, manufacturing, computer engineering, and computer software technology completers have the highest rates of employment in Oregon. For both computer engineering and electrical/electronics engineering completers, the share employed in other industries is relatively close to the share employed by the semiconductor industry, indicating the semiconductor industry's heavy reliance on employees with training in the relevant programs.

In contrast, semiconductor industry reliance on community college completers in machinist and machine shop technology programs is low compared to other industries–consistent with the small share of the industry employed in related occupations and the small share of the occupation employed by the semiconductor industry.

Exhibit 50. Five-Year Employment Outcomes for University and Community College Completers by Program

Program Name	Employment in Semiconductor Industry	Employment in Other Industries
University		
Computer Engineering, General	42%	40%
Electrical and Electronics Engineering	18%	27%
Manufacturing Engineering	17%	61%
Industrial Engineering	15%	33%
Chemical Engineering	13%	35%
Computer Software Technology/Technician	13%	60%
Engineering/Industrial Management	9%	30%
Mechanical Engineering	6%	50%
Engineering, Other	2%	67%
Community College		
Manufacturing Engineering Technology/Technician	18%	67%
Machine Tool Technology/Machinist	4%	85%
Machine Shop Technology/Assistant	4%	84%

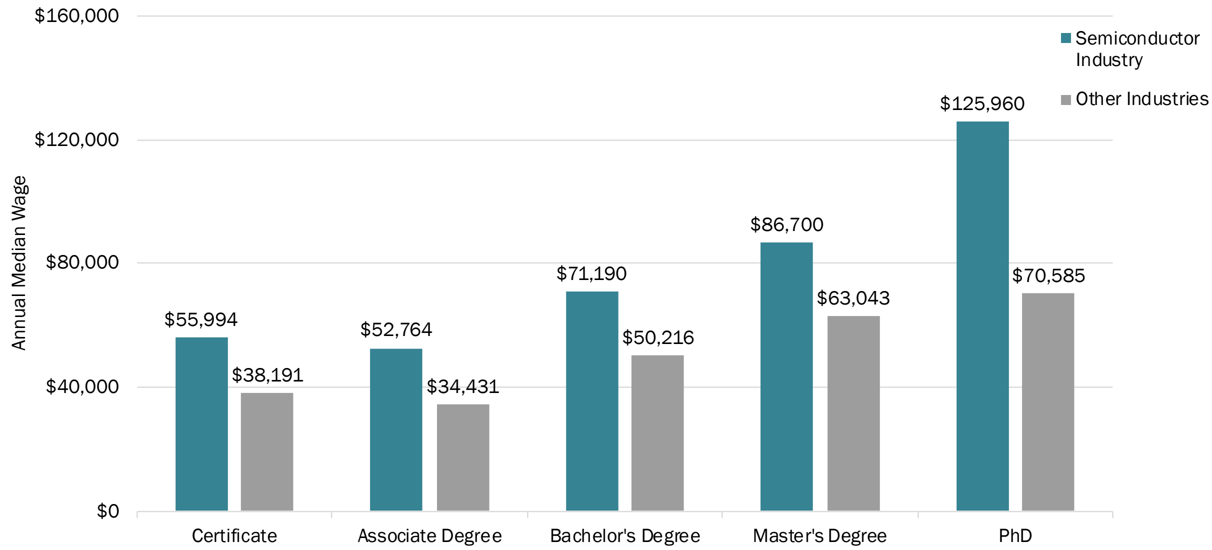
Data source: Oregon Higher Education Coordinating Commission

Post-Graduation Employment Metrics

This section concludes with a description of annual wages and annual hours of the employment cohort. Exhibit 51 and Exhibit 52 present median annual wages earned at one year and five years post-graduation for core semiconductor-related program completers employed in the semiconductor industry and other industries. Across credential types, annual wages in the semiconductor industry compared to other industries were, on average, 52 percent higher within one year of graduation and 30 percent higher within five years of graduation. Completers who gained semiconductor employment experienced higher wages over time, but with larger gains, compared to other industries, immediately following graduation.

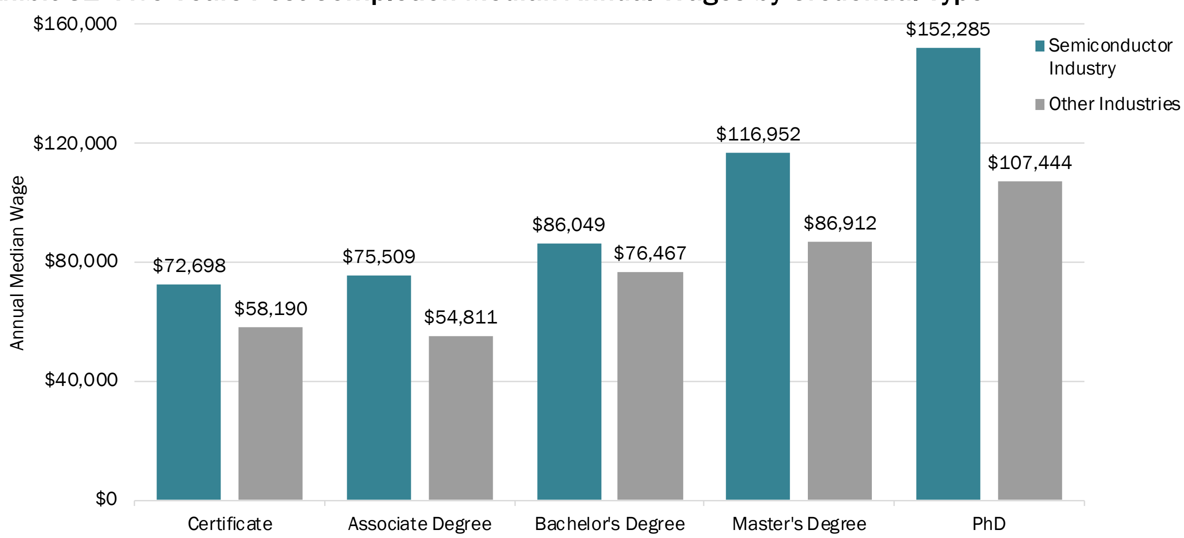
At one year post-graduation, the wage gap between other industries and the semiconductor industry was largest for PhD and associate degree completers, who earned 78 percent ($55,375) and 53 percent ($18,300), respectively, more in the semiconductor industry than those in other industries. Other credential types saw gaps of 38 to 47 percent. At five years post-graduation, semiconductor industry wages remained proportionally higher than those in other industries, but to a lesser degree (e.g., 42 percent and 38 percent gaps for PhD and associate degree completers, respectively). Notably, for bachelor's degree completers, semiconductor industry wage gains diminish somewhat over time, with a 42 percent ($21,000) gap at one year post-graduation and a 13 percent ($9,600) gap at five years post-graduation.

Exhibit 51. One Year Post-Completion Median Annual Wages by Credential Type



Data source: Oregon Higher Education Coordinating Commission

Exhibit 52. Five Years Post-Completion Median Annual Wages by Credential Type

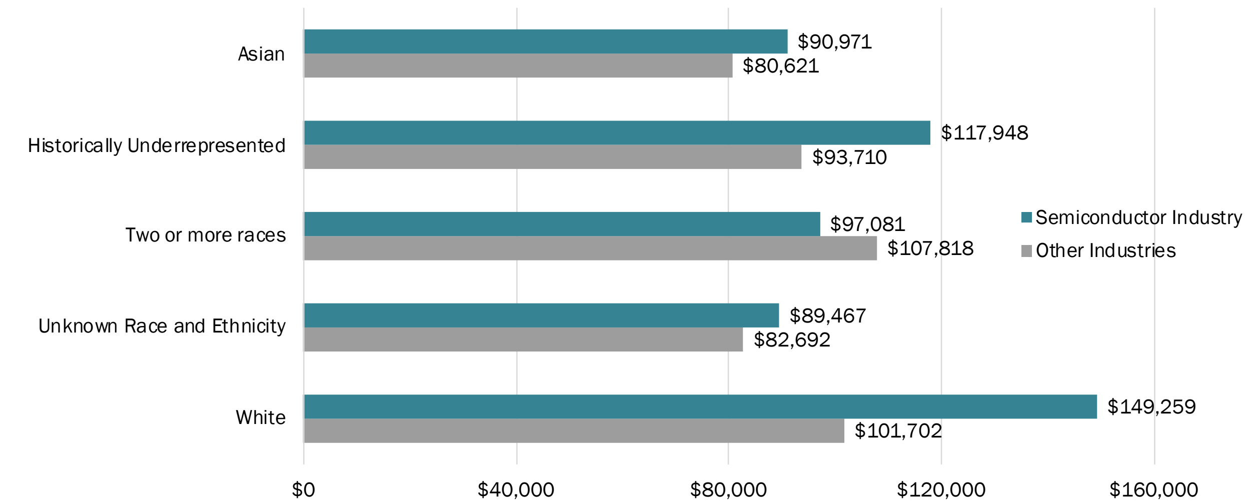


Data source: Oregon Higher Education Coordinating Commission

Exhibit 53 and Exhibit 54 depict wage outcomes by race and ethnicity. Gaps exist at the race/ethnicity-group level (white earners compared to earners of color) and at the industry level (semiconductor industry compared to all other industries). At five years post-graduation, white core-university-program completers had the highest average annual semiconductor wages (with a 47 percent gap relative to other industries) followed by historically underrepresented completers (with a gap of 26 percent relative to other industries) (see Exhibit 53).

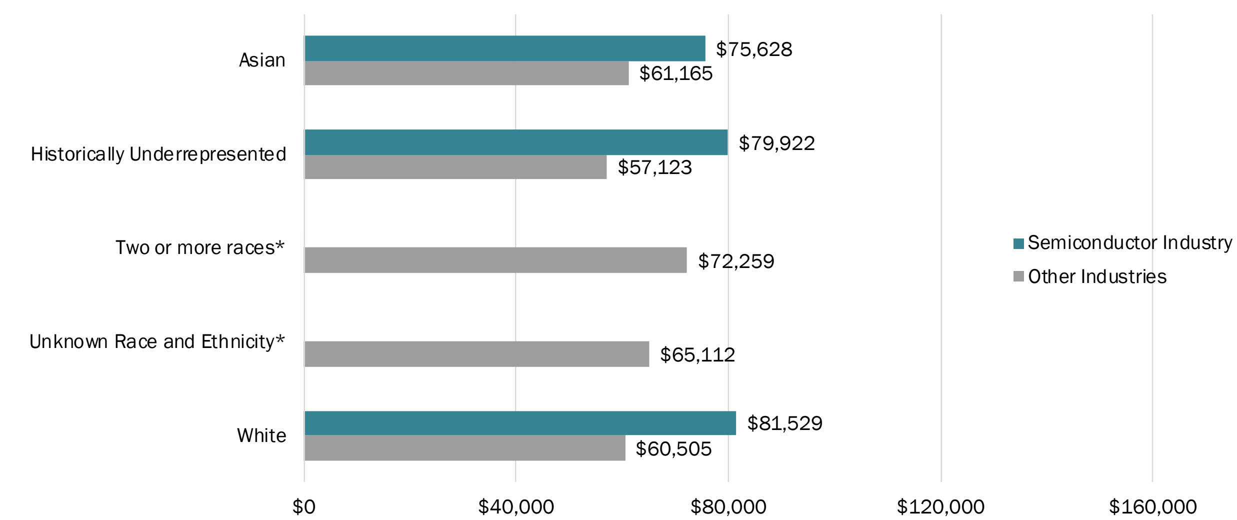
Although wages are generally lower for community college completers in the semiconductor industry and other industries, the semiconductor wage premium at the community college level is similar to the university wage premium across races and ethnicities (see Exhibit 54). Among community college completers, the semiconductor-industry wage premium was largest for the historically underrepresented race/ethnicity group, with an average annual wage of almost $80,000 in the semiconductor industry compared to $57,100 in other industries—a gap of 40 percent.

Exhibit 53. Five Years Post-Completion Median Annual Wages for University Completers by Race and Ethnicity



Data source: Oregon Higher Education Coordinating Commission

Exhibit 54. Five Years Post-Completion Median Annual Wages for Community College Completers by Race and Ethnicity



*Redacted to protect confidentiality
Data source: Oregon Higher Education Coordinating Commission

Female completers of university core semiconductor-related programs earned approximately the same wages in the semiconductor industry compared to other industries (a gap of 1 percent). In comparison, male completers employed in the semiconductor industry earned approximately $58,000 more than completers in other industries, or a premium of 66 percent (see Exhibit 55). Male community college completers earned approximately 34 percent (or

$21,000) more in the semiconductor industry compared to other industries, while female completers earned approximately 23 percent (or $13,000) more.

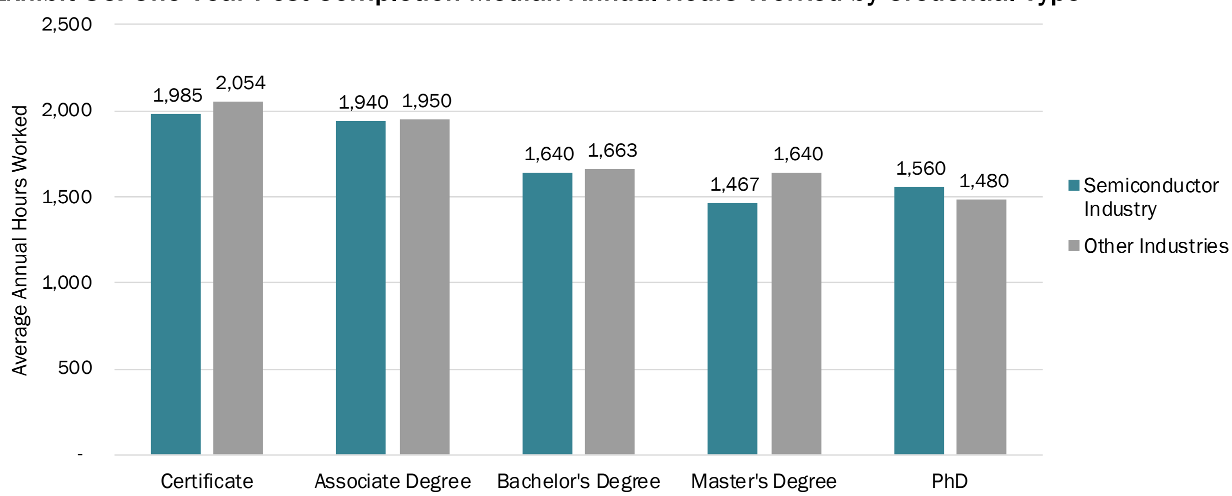
Exhibit 55. Five Years Post-Completion Median Annual Wage Outcomes for Completers by Gender

Gender	Semiconductor Industry	Other Industries
Community College		
Female	$67,370	$54,642
Male	$83,067	$61,859
University		
Female	$108,892	$108,300
Male	$145,661	$87,855

Data source: Oregon Higher Education Coordinating Commission

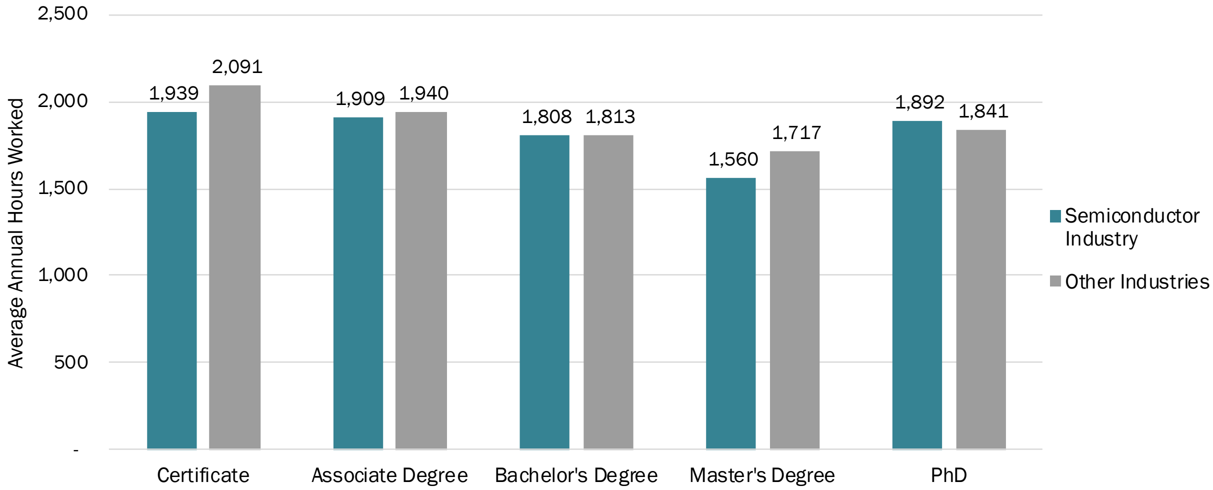
Exhibit 56 and Exhibit 57 display annual hours worked at one year and five years post-graduation for core semiconductor-related program completers employed in the semiconductor industry and other industries. At one year and five years post-graduation, average annual hours worked decreased progressively across credential types, with certificate completers working the most hours and PhD completers working the least. The exception to this trend is PhD completers in the semiconductor industry who work more hours than master's degree completers. Average annual hours worked are higher for employment outcomes five years post-graduation than for one year post-graduation outcomes in the semiconductor industry and other industries.

Exhibit 56. One Year Post-Completion Median Annual Hours Worked by Credential Type



Data source: Oregon Higher Education Coordinating Commission

Exhibit 57. Five Years Post-Completion Annual Hours Worked by Credential Type



Data source: Oregon Higher Education Coordinating Commission

Dual-Credit Enrollees

For many students, enrollment in a dual-credit course during high school serves as an introduction to an industry or occupation and, as such, these courses can play an important role in education pathways that support the semiconductor industry. The extent to which they do so is an empirical question partially addressed by our analysis for this report. We quantify the connections between enrollment in at least one of the dual-credit courses described in Appendix C, courses that might indicate an interest in or aptitude for work in the semiconductor industry, and completion of a semiconductor-related postsecondary credential (i.e., a core credential).

Definitions

The findings described below quantify postsecondary completion outcomes for a subset of Oregon dual-credit students. Specifically, we identify a set of students who enrolled in at least one of the dual credit courses described in Appendix C and subsequently graduated from high school during academic years 2012-13 through 2018-19. Throughout, we refer to these students simply as “dual-credit students”. Most of the analysis focuses on students who enrolled in an identified dual credit course and graduated during 2012-13 through 2016-17 to allow at least five years to enroll in and complete a credential at a public Oregon postsecondary institution.

For students who do not have a high school graduation year associated in the data we assigned the academic year in which the student turned 18 as the graduation year. For students who graduated at a younger age, this assignment would allow a longer follow-up period; the reverse is true for students who graduated at an older age. We excluded a small number (less than 1 percent) of observations because we lacked enough age or graduation year data to assign them to a graduating cohort.

We classify students according to the most advanced credential earned during the follow-up period of five academic years after high school graduation. Students who earn a core credential are identified as completing the most advanced core credential earned, regardless of any other credential earned.

Findings

Exhibit 58 displays the count of identified dual-credit students and selected demographics by year of high school graduation. The table shows increasing participation in the relevant courses over time, increasing by 75 percent between 2012-13 and 2018-19. Similar to the trend observed across the semiconductor workforce, the share of these students identified as female has increased, albeit relatively slowly. The share identified as a historically underrepresented race or ethnicity increased by 35 percent (8 percentage points) over the same period, but from a low base. Averaged across cohorts, Hispanic students account for 88 percent of the underrepresented student category, Black or African American students for 6 percent, American Indian/Alaska Native students for 4 percent, and Native Hawaiian/Pacific Islanders for 2 percent. Except for Hispanic students, nondisclosure requirements significantly limit our ability to disaggregate outcomes for subpopulations of the underrepresented group. The distribution of race and ethnicity among these dual-credit students generally aligns reasonably well with that of graduates of Oregon's public high schools, with a small relative overrepresentation of Asian students and a small underrepresentation of white students and of underrepresented races and ethnicity as a group.[46]

Exhibit 58. Dual-Credit Student Demographics Over Time

HS Graduation Year	Total Dual-Credit Students	Percent Female	Percent Historically Underrepresented	Percent Asian	Percent Two or More Races
2012-13	480	19%	14%	9%	4%
2013-14	519	19%	13%	6%	6%
2014-15	517	20%	20%	6%	6%
2015-16	640	20%	18%	5%	9%
2016-17	736	21%	18%	6%	8%
2017-18	749	22%	19%	4%	7%
2018-19	838	22%	22%	7%	8%

Data source: Oregon Higher Education Coordinating Commission

Exhibit 59 displays the share of dual-credit students completing a credential at an Oregon public postsecondary institution. Across the identified cohorts, 40 percent of students earned at least one credential and 14 percent earned at least one core credential, with both completion

[46] See https://www.oregon.gov/ode/reports-and-data/students/Pages/Cohort-Graduation-Rate.aspx

rates generally falling for later cohorts. At about 80 core credentials per high school graduation cohort, these core completions represent about 5 percent of annual core completions at Oregon's public postsecondary institutions.

As shown in Chapter 2, Exhibit 23, core credentials comprise about 3.5 percent of postsecondary credentials awarded in Oregon. In our sample of dual-credit students who earned a credential within five years of high school graduation, 35 percent earned a core credential (40 percent of the group completed a credential and 14 percent of the group completed a core credential)—ten times the statewide average. This is not necessarily surprising given the dual-credit courses used to identify the sample but does confirm that dual-credit courses provide a viable pathway to, and pool of students for, postsecondary credentials relevant to the semiconductor industry. The remaining exhibits combine outcomes across the cohorts shown in Exhibit 59.

Exhibit 59. Credential Completion at Oregon Public Postsecondary Institutions of Dual-Credit Students, by High School Graduation Year

HS Graduation Year	Total Dual-Credit Students	Share Earning a Credential Within Five Years	
		Any	Core
2012-13	480	48%	18%
2013-14	519	50%	18%
2014-15	517	38%	14%
2015-16	640	38%	13%
2016-17	736	32%	10%
Combined	**2,892**	**40%**	**14%**

Data source: Oregon Higher Education Coordinating Commission

Exhibit 60 shows the distribution of most advanced credentials earned among completers as well as core completers as a share of all completers at each level. Among dual-credit students that earned a credential, nearly all had earned at least an associate degree (97 percent overall; 98 percent among core completers). Nearly two thirds earned an associate degree; almost one third earned a bachelor's degree. Not surprisingly given the short (five year) follow-up period, relatively few students had completed a graduate degree.

With a longer follow-up period we would expect somewhat higher shares earning bachelor's and more-advanced degrees as highest attainment. However, among core completers, nearly four fifths (79 percent) had already earned at least a bachelor's degree. Notably, core completers accounted for more than four fifths of students who had at least completed a bachelor's degree.

Exhibit 60. Distribution of Most Advanced Credential Type for Dual-Credit Student Completers, High School Graduation Cohorts 2012-13 through 2016-17

Credential Type	Share of All Completers	Share of Core Completers	Core Completers as a Share of All Completers
Certificate	3%	2%	20%
Associate Degree	63%	19%	10%
Bachelor's Degree*	32%	75%	82%
Graduate Degree	2%	4%	85%

Data source: Oregon Higher Education Coordinating Commission
*Includes a small number of certificates and associate degrees awarded by universities (less than 1 percent of all undergraduate credentials awarded by universities).

The remaining exhibits in this section display various completion-rate statistics overall and for demographic subpopulations. They identify the share of a student population that completes a specific type of credential at a public Oregon postsecondary institution within five years of high school graduation but are not graduation rates. We do not have information about credentials awarded by private or out-of-state institutions and have not calculated the time between postsecondary matriculation and completion (e.g., a student who finishes an associate degree within one year of high school graduation is treated the same as one who starts one year after graduation and earns an associate degree four years later). Completion rates are based on the most advanced credential earned, with core credentials treated as more advanced than non-core credentials, regardless of award type (e.g., a student who earns an associate degree in a core program and a bachelor's degree in language arts is counted as earning an associate degree).

Exhibit 61 shows the share of each identified student population that completed any credential within five years of high school graduation, any core credential, and similar shares for credentials awarded by community colleges, and by universities. The table does not distinguish further by award type because individuals with certificates or graduate degrees as their most advanced credential account for very small shares of the total.

Overall, university credentials account for a much larger share of individuals with a core credential than non-core credentials, as indicated in the top row: 14 percent of the dual-credit students ultimately earned a core credential and 11 percent earned a university core credential (79 percent of the total) whereas more than two thirds of all credential earners had a certificate or associate degree (27 percent with community college completion out of 40 percent with any completion). Female students were more likely to complete a credential but only two-thirds as likely to complete a core credential and less likely to complete a university degree.

Asian students had the highest completion rates overall and of core credentials. White and students of an underrepresented race or ethnicity had similar overall completion rates, but the core completion rate for the latter was two-thirds that of white students. Exhibit 64 displays selected completion-rate statistics by race and ethnicity, illustrating where individuals are potentially stepping off the pathway into the industry as dual-credit students from underrepresented races and ethnicities have lower completion rates than white and Asian students.

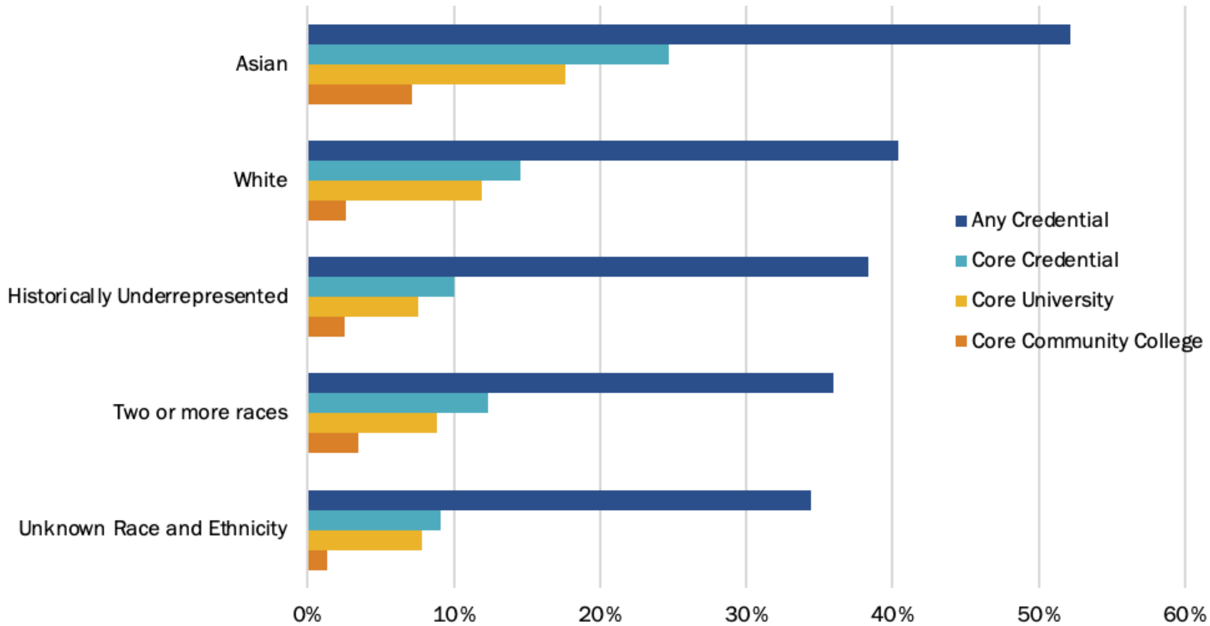
Exhibit 63 and Exhibit 64 illustrate the effect of these differential completion rates on diversity of completers. Students of underrepresented races and ethnicities are relatively underrepresented among all core completers, although to a lesser extent among those earning a community college core credential, credentials that typically lead to lower wages than do university core degrees.

Exhibit 61. Credential-Completion Outcomes by Dual-Credit Student Population, High School Graduation Cohorts 2012-13 through 2016-17

Demographic Characteristic	Completers	Any	Core	Any		Core	
				Community College	University	Community College	University
Total	2,892	40%	14%	27%	14%	3%	11%
Female	578	47%	10%	38%	8%	3%	7%
Male	2,302	39%	15%	24%	15%	3%	12%
White	1,876	40%	15%	26%	14%	3%	12%
Historically Underrepresented	477	38%	10%	29%	10%	3%	8%
Two or more races	203	36%	12%	25%	11%	3%	9%
Asian	182	52%	25%	30%	23%	7%	18%
Unknown	154	34%	9%	25%	9%	1%	8%

Data source: Oregon Higher Education Coordinating Commission

Exhibit 62. Credential-Completion Outcomes by Dual-Credit Student Population, High School Graduation Cohorts 2012-13 through 2016-17



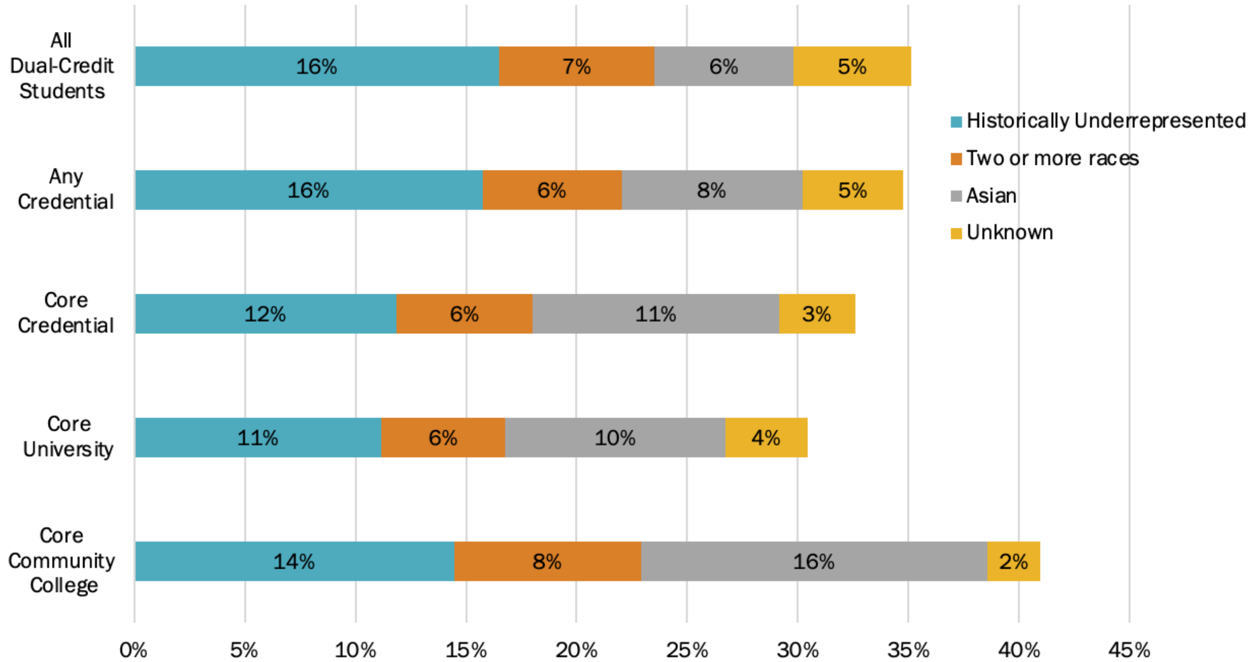
Data source: Oregon Higher Education Coordinating Commission

Exhibit 63. Demographics of Dual-Credit Students by Completion Outcome, High School Graduation Cohorts 2012-13 through 2016-17

Demographic Characteristic	Total	Any	Core	Any		Core	
				Community College	University	Community College	University
Female	20%	23%	15%	29%	12%	24%	12%
Male	80%	77%	85%	71%	88%	76%	88%
White	65%	65%	67%	64%	69%	59%	70%
Historically Underrepresented	16%	16%	12%	18%	12%	14%	11%
Two or more races	7%	6%	6%	7%	6%	8%	6%
Asian	6%	8%	11%	7%	10%	16%	10%
Unknown	5%	5%	3%	5%	4%	2%	4%

Data source: Oregon Higher Education Coordinating Commission

Exhibit 64. Race and Ethnicity of Dual-Credit Students by Completion Status, High School Graduation Cohorts 2012-13 through 2016-17



Data source: Oregon Higher Education Coordinating Commission

Limitations

The analysis comes with important limitations. We do not have data about postsecondary outcomes for students who only took other dual-credit courses or who never had a dual-credit course. The scope and timeline for the project did not allow a comprehensive assessment of whether specific courses or groups of courses appear more closely linked to core postsecondary programs than others or the extent to which dual-credit enrollment is associated with other outcomes of interest, such as time to complete a postsecondary credential or to post-completion employment outcomes. Finally, similar to the limitations identified for the main pathways analysis, we can only observe postsecondary enrollment in Oregon's public institutions and do not have information about enrollment in private or out-of-state institutions.

An expanded analysis, possibly including additional data, could address to a large extent these limitations. The additional work could help the HECC and other industry partners identify dual-credit pathways that exceed or fall below expectations in terms of the extent to which they feed into postsecondary programs and ultimately employment in Oregon's semiconductor industry.

Implications of CHIPS Act Investments for Oregon's Postsecondary System

As noted in Chapter 1, the state anticipates investments related to CHIPS Act grants and loans to total about $40 billion and bring 6,300 additional semiconductor jobs in the coming years, an increase of 21 percent over 2022 employment levels in semiconductor manufacturing in Oregon.[47] Also as described in this report, semiconductor employers and industry groups at the national and state levels anticipate significant shortages of trained semiconductor workers even absent the infusion of federal investments. The brief scenario analysis presented in this section provides context, grounded in data, for the response needed from Oregon's public postsecondary institutions to meet the additional industry growth within a state and national environment already expected to fall short of meeting anticipated employer needs.

Modeling Scenarios

At the time of publication, we did not have an estimate for the distribution of the 6,300 jobs across the industry sectors described in Chapter 1. For the purposes of this analysis we assume the jobs will be created in semiconductor manufacturing (NAICS 334413), although we would expect some to be created in other subsectors, such as semiconductor machinery manufacturing (NAICS 333242), about which we have less detailed information. The timing of increased employment is similarly uncertain. For this analysis we characterize the implications of workforce expansions fostered by private and CHIPS Act investments as if hiring for newly created positions occurs in equal increments for each of five years (i.e., an additional 1,250 jobs created per year).

Although the industry requires numerous occupations for which postsecondary training specific to industry needs is critical, we focus our analysis on the most common occupations in the industry (see Exhibit 4) that are also associated with specific core educational programs (CIP codes) (see Exhibit A-3). Together, these 17 occupations comprise 36 percent of the national industry.[48] Although Oregon's semiconductor industry may differ from the national industry in terms of the need for specific occupations, assuming that 36 percent of the additional jobs created by private and CHIPS Act investments will require a credential from a core postsecondary pathway provides a reasonable starting point for this analysis. This amounts to demand for an additional 450 individuals with a core credential per year for five years.

Implications

The IPEDS data presented in Chapter 2 indicate that students at Oregon postsecondary institutions earned about 2,000 credentials per year in the identified core programs, with a peak of about 2,200 in the 2019 academic year. In academic year 2022, production of core credentials

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[47] Oregon CHIPS Act September 2023 Update, https://olis.oregonlegislature.gov/liz/2023I1/Downloads/CommitteeMeetingDocument/277234

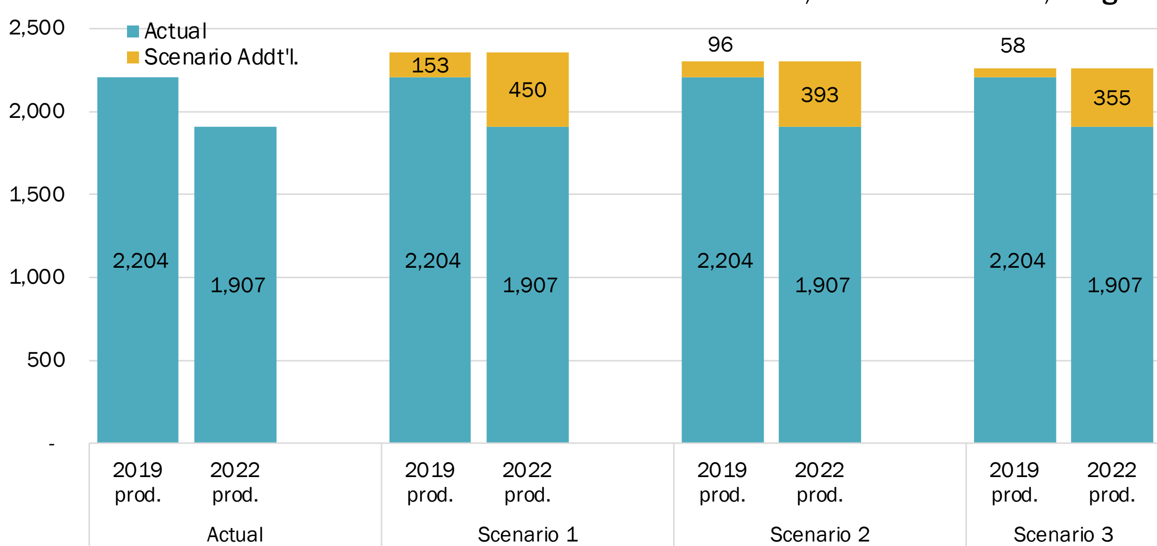
[48] Associated occupations include Industrial Production Managers; Architectural and Engineering Managers; Computer Programmers; Chemical Engineers; Computer Hardware Engineers; Electrical Engineers; Electronics Engineers, Except Computer; Industrial Engineers; Mechanical Engineers; Engineers, All Other; Electrical and Electronic Engineering Technologists and Technicians; Industrial Engineering Technologists and Technicians; Cutting, Punching, and Press Machine Setters, Operators, and Tenders; Metal and Plastic Machinists; Inspectors, Testers, Sorters, Samplers, and Weighers; Semiconductor Processing Technicians; and Computer Numerically Controlled Tool Operators. This list excludes 4 of the most common occupations employed in NAICS 3344: Electrical, Electronic, and Electromechanical Assemblers (no associated CIP code), Software developers (not specific to the industry), Miscellaneous Assemblers and Fabricators (no associated CIP code; not specific to the industry), and First-line Supervisors of Production and Operating Workers (no associated CIP code; not specific to the industry).

fell further, to 1,907. Historically, Oregon's public institutions account for 85 to 90 percent of this total. The following calculations assume baseline production of 1,907. We also calculate the number of additional credentials needed relative to the peak level of 2019, a potential indicator of capacity, conditional on adequate student interest.

Producing a baseline 1,907 credentials plus an additional 450 credentials per year would amount to an increase of 24 percent over 2022 production, or 7 percent over the capacity suggested by 2019 production (Scenario 1 in Exhibit 65 describes the modeled credential output). Core credential production would have to increase by about 27 percent if Oregon's public institutions generated all of the increase (a 9 percent increase relative to the peak in 2019).

Rather than attempting to meet all new demand with newly credentialed individuals, Oregon could seek to keep core credential production at a similar level relative to the size of the industry in Oregon (see Exhibit 23). Core credential production has fallen in recent years, primarily due to fewer credentials awarded by community colleges but more recently also to falling undergraduate production (see Exhibit 13 and Exhibit 27) as the industry has grown. Using 2022 as a benchmark, maintaining production at a consistent level relative to semiconductor manufacturing employment would require an expansion of 21 percent over 2022 credential production and 9 percent over that of 2019 (see Scenario 2 in Exhibit 65). The required growth is slightly less aggressive—19 percent and 3 percent over 2022 and 2019 levels, respectively—if the broader semiconductor and related device manufacturing industry is used as a benchmark (see Scenario 3 in Exhibit 65).

Exhibit 65. Actual and Modeled Annual Core Credential Production, Various Scenarios, Oregon



Source: IPEDS; ECOnorthwest modeling. See accompanying text for description of scenarios.

While increasing capacity by 10 to 25 percent in a single year would constitute a major expansion in a short period of time, such increases are not out of line with recent trends. Between 2009 and 2019 core credential production in Oregon increased by an average of 9.5 percent per year. However, this increase was driven not just by demand from semiconductor manufacturers, but at least in part by all industries that employ similarly trained individuals—not all core-credential recipients find or even seek employment in Oregon's semiconductor industry.

Our pathways analysis suggests that less than 20 percent of core completers are employed by a semiconductor manufacturer in Oregon within five years of completing their credential. If this proportion remained constant as the system expanded, core program capacity would have to increase by at least five times as much as the number of newly credentialed individuals needed, up to 2,250 additional credentials per year.[49] Under the least aggressive growth scenario described above (Scenario 3, requiring 3 percent growth over 2019 levels and 19 percent growth over 2022), the resulting need would represent growth of at least 15 percent relative to 2019 production and at least 95 percent relative to 2022. Because the industry is the source of new demand, however, we would expect the share of core completers employed in Oregon's semiconductor industry to increase, possibly substantially, but there will always be some "leakage" to other industries.

Regardless of benchmark, accommodating the anticipated increase in Oregon's semiconductor industry in the coming years may pose challenges to the state's higher education institutions, particularly in light of very recent declines in production of industry-relevant credentials. As noted below, the size of the industry in Oregon suggests the state should not aspire to meet all anticipated demand but should focus on systems and structures that strengthen existing pathways that address the most critical industry needs.

Additional Implications

Additional exploration of the data used in the pathways analysis could yield more precise answers to some of the questions suggested by the high-level scenario analysis just described, helping further focus strategies pursued by the HECC. For example, which pathways lead to long-term industry employment and which to switching industries one or more times over a short period of time? Which pathways are more and less likely to produce graduates that earn multiple industry-related credentials or stable semiconductor employment?

In addition, beyond semiconductor jobs, private and CHIPS Act investments are expected to produce up to 1,000 construction jobs, potentially placing additional strain on employers facing already tight labor markets and on the capacity of postsecondary pathways feeding the building trades. Similarly, the need for well-trained workers in occupations critical for but much less specific to the industry, such as software developers, will also likely place additional demands on Oregon's workforce development and postsecondary systems.

Further, the scenario analysis focuses on credential completion. However, industry growth will also require expansion of the state's capacity to provide lifelong learning and other types of training across the educational and workforce "ladder" described in the next chapter. The extent to which Oregon can successfully formalize intermediary entities and/or programs could

[49] 450 * 5 = 2,250

play a role as important as expanding traditional educational programs in determining Oregon's future success as a world-class semiconductor hub.

Oregon has a larger semiconductor industry—both absolutely and, even more so, relative to population—than nearly any other state, as well as a correspondingly small postsecondary system, relative to the size of the local semiconductor industry. The same is true from a regional perspective. Oregon, Idaho, and Washington all have postsecondary systems that emphasize the core programs associated with the semiconductor industry to a greater extent than the national average and than other states with a large industry presence. But even when combined, the number of core credentials produced is relatively small compared to the size of the regional semiconductor industry. In an environment with anticipated national and international shortages of semiconductor workers, rather than seek to meet all industry needs with local programs, the HECC should focus on strategies that build on Oregon's advantages, whether due to proximity to industry partners, specific highly regarded programs, or other factors.

5. Recommendations

Improvements in education, spanning from preschool to postdoctoral studies, play an important role in shaping Oregon's attractiveness to high-technology companies. The state's appeal is not solely determined by the skilled workforce it can offer but extends to the quality of education accessible to employees and their families. A comprehensive education system, encompassing arts, sciences, and civics across all levels, contributes significantly to the overall desirability of Oregon as a hub for innovation-driven industries. This assessment of local education programming that serves the state's semiconductor industry's talent needs recognizes the broader impact of education on economic development.

Education programming in the state generally focuses on teaching skills that will serve students well, no matter which career they choose after graduation. While there are exceptions, a majority of programs in fields such as engineering, computer science, physics, and chemistry are not intended to directly fulfill the specific needs of the semiconductor industry. This creates a strategic opportunity to bridge the gap between existing postsecondary education initiatives and the industry.

Oregon's semiconductor-related programs and curricula are well established and on par with programs and curricula in other states.[50] However, accredited programs in particular are not designed to adapt swiftly to the rapidly changing demands of the semiconductor industry. Bridging the gap in ways that further both industry-specific job skills and broader essential skills (e.g., problem-solving) will benefit both recent program graduates and seasoned professionals in the semiconductor field.

As discussed in this report, certain groups of workers have long been underrepresented in the state's semiconductor workforce. Improved access to education, training, and employment opportunities and pathways are essential to increasing gender, racial, ethnic, and other types of diversity in the industry. The state has an opportunity to increase semiconductor workforce diversity through investments and long-term tracking of workforce and talent metrics.

This chapter first presents a framework for thinking about the relationship(s) between education/training and the semiconductor industry (the educational ladder), then provides recommendations in four categories: Workforce Entry, Lifelong Learning, Strengthening Education Programs through Research, and Additional Recommendations Based on the Quantitative Analysis. The concluding section proposes that next steps be discussed and developed by a working group or consortium structure organized in teams. Many of the

[50] The brief in Appendix D, *Oregon's Semiconductor Workforce: Harnessing Workforce Education and Training Investments to Prepare Oregonians for Equitable Prosperity*, highlights some specific statewide efforts among public institutions and partners.

recommendations align with those in the Oregon Semiconductor Competitiveness Task Force's 2022 report.[51]

Educational Ladder Framework

During this study, interviewees identified numerous successful programs that effectively operate in the gap between postsecondary programs and Oregon's semiconductor industry. These initiatives, often driven by innovative educators or supported by industry funding, address specific needs and adapt to evolving requirements. While many of these programs operate for limited lengths of time based on the needs of individual projects, there is a latent potential for them to become enduring resources with coordinated support. Through strategic coordination and support, these initiatives can evolve into valuable assets for the local industry, helping to attract and launch new companies and programs. This, in turn, would position Oregon as a magnet for new industry partnerships while retaining existing ones. Exhibit 66, a visual representation of an educational ladder, provides a simple conceptual framework for programs that bridge the gap between education and industry.

Green items in the exhibit depict pathways from postsecondary education to the semiconductor industry, encompassing well-established credentials alongside emerging apprenticeships and internships.[52] Fortifying these pathways requires implementing programs that teach essential and job-specific skills. Blue items (workforce enhancement) signify routes from the semiconductor industry back into postsecondary education that are primarily informal and reliant on individual decisions regarding timing and financing.

A well-functioning system would enable students to enter the industry early and gain essential work skills while securing income. Then, clear incentives (financial rewards, increased responsibility) would encourage individuals to take pathways from industry into postsecondary education to acquire new skills and qualifications. A current lack of such incentives poses a substantial deterrent to talent development. Strengthening "return pathways" with explicit incentives would foster better opportunities and promote lifelong learning. Notably, the top rung, signifying the opportunity for highly qualified employees to contribute to postsecondary education institutions, is depicted once but is applicable across all levels, from high school talks to post-doctoral teaching and research.

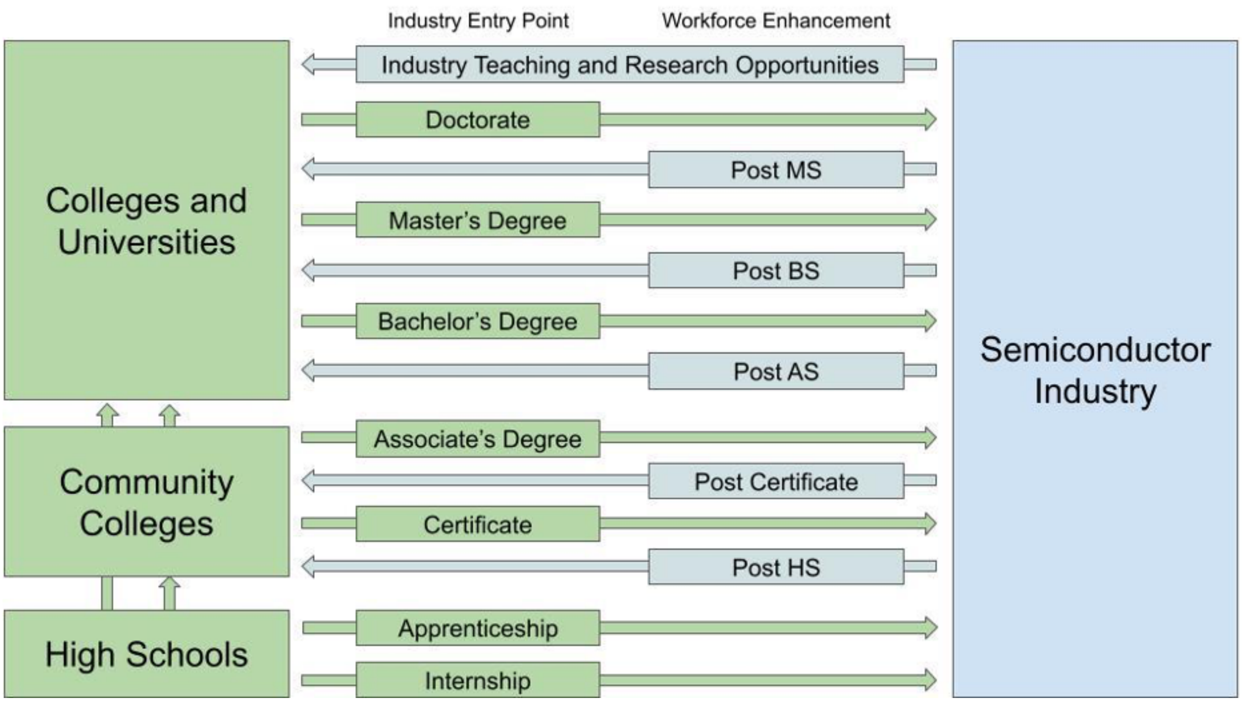
Many of the opportunities raised in the interviews exist in the space between postsecondary education and the semiconductor industry. As described in more detail below, we recommend the creation of (1) a working group or consortium to plan, develop, and guide next steps, and (2) a permanent intermediary organization or entity to support and enhance lifelong learning and strengthen the Oregon semiconductor talent pool. Such an entity would require the support

[51] Oregon Semiconductor Competitiveness Task Force (2022). *Seizing Opportunity*. http://oregonbusinessplan.org/wp-content/uploads/2022/08/Semiconductor-Task-Force-Report-for-Release.pdf
[52] Apprenticeship and internship programs are represented at the high school level in the graphic but are also found at other levels of education.

of the four primary stakeholder groups in workforce development: Government, Industry, Education, and Community and Workforce (including worker representatives and/or workforce development leaders). The intermediary organization could potentially begin as a loose structure around existing programs while plans to expand and formalize are put into place. Governance and accountability will be important questions to address. Orchestrating collaboration among the stakeholder groups will also require ongoing effort and support; a framework such as the Quadruple Helix could be applied to guide the needed coordination.[53]

In sum, the educational ladder concept holds promise but, to thrive, requires robust support through well-defined and incentivized pathways and the engagement of major stakeholder groups. Pathways that go both directions between education and industry need to facilitate skill development, increased responsibilities, and lifelong learning, thereby removing barriers, expanding the talent pool, promoting equity, and fostering diversity.

Exhibit 66. Educational Ladder Framework



Pathways: Workforce Entry

The semiconductor workforce pathway begins in the K12 system, with introductions to STEM and career and technical education (and potentially semiconductors) in elementary school and throughout, along with career-connected learning experiences such as internships and apprenticeships. Pathways continue into community colleges, four-year universities, and workforce training programs. This section includes recommendations applicable across

53 See, for example, https://link.springer.com/book/10.1007/978-3-319-29677-7

pathways (up and down the ladder framework), including in the key area between formal education programs and the semiconductor industry.

Promote the Oregon Semiconductor Industry and Reduce the Size of Awareness Gaps: Interviewees identified a lack of knowledge across all levels of education regarding the abundant opportunities available for impactful careers within the semiconductor industry. Bridging this awareness gap is fundamental to channeling talented individuals toward this innovative industry. Specifically, aptitude-exceeding-interest gaps in middle and high school, especially in Computers & Technology and Advanced Manufacturing (see Exhibit 26), highlight an opportunity to boost pathways intake and build the local talent pool for the semiconductor industry.

Strengthen Project-Based Learning and Essential Skills: Industry interviewees pointed to a need for all employees to have strong leadership, problem-solving, communication, and teamwork skills. To help build these essential skills, programs across the education spectrum should emphasize project-based learning opportunities. In earlier grades/levels, project-based learning can take place in STEM and CTE environments. Nurturing these competencies ensures that trainees and graduates not only possess technical proficiency but also the practical skills required for success in dynamic work environments.

Address the Debt Barrier and Expand Wraparound Services: Student debt acts as a formidable barrier to postsecondary education, disproportionately affecting individuals from economically disadvantaged backgrounds, people of color, and other historically underrepresented populations. Well-structured grants, scholarships, and tax incentives can help. The state's housing shortage also poses a major challenge, affecting students at all income levels but disproportionately those from underrepresented and economically disadvantaged communities. Addressing student debt and housing challenges as well as transportation and child care barriers will require culturally responsive wraparound services similar to those currently offered by some community college and workforce programs in partnership with community-based organizations.

Strategically Use Remote Learning and AI Technologies to Help Reduce the Need for On-Premises Learning. Online, AI-supported learning environments are increasingly common and can provide more-accessible opportunities to advance in training and credential programs. Increased accessibility must be balanced with awareness of essential skills development that can suffer without in-person interaction and team building; periodic in-person convenings can be paired with virtual courses/programs. Repurposing classroom facilities that are made available by remote learning to support project-based learning experiences can offer high value.

Develop and Support Programs that Bridge Education and Industry: Many relevant, formal, postsecondary education programs, such as in Chemistry, Physics, Math, and most engineering and computer science programs, are not intended to directly fulfill the specific needs of the semiconductor industry. Traditional accreditation bodies, such as the Accreditation Board for

Engineering and Technology, focus on ensuring that students acquire professional qualifications. While these qualifications form a robust foundation for semiconductor careers, they do not necessarily prepare students for immediate entry into the industry. This creates a gap between education programs and industry —a figurative space awaiting programs that reinforce the workforce entry pathways. An intermediary entity could serve as a resource for teaching and updating industry-specific job skills, benefiting both recent graduates and seasoned professionals in the semiconductor field.

Pathways: Lifelong Learning

Ensuring lifelong learning opportunities and seamless pathways between education and industry is critical for sustaining a dynamic, diverse, and skilled workforce in the semiconductor sector. The recommendations that emerged from our interviews underscore the imperative to establish accessible and transparent pathways for career advancement through continuous education and skill development. Pathways work takes place at more-specific locations within the ladder framework—at the occupation and program level.

Unveil Hidden Pathways: Existing pathways for career advancement are frequently obscured, expensive, or hindered by other barriers. A collaborative effort between educational institutions, government, and industries is essential. Educational institutions contribute by imparting knowledge, while employers provide practical experience. The challenge lies in making career advancement pathways visible, affordable, and devoid of unnecessary obstacles.

Encourage Industry-Educator Collaborative Learning: To enhance the learning experience, industry employees can contribute critical skills and real-world experience to the classroom. Leading project-based learning initiatives, they bring direct practical insights into industry methods. This collaborative approach not only enriches the educational experience but also strengthens the alignment between academic learning and industry needs.

Grow the Use of Online Learning: The COVID-19 pandemic accelerated the integration of online learning into postsecondary settings, creating a transformative shift that can increase opportunities for lifelong learning. Oregon institutions have robust online education programs that support adult learners and individuals with family responsibilities. The flexibility of these programs caters to working adults, facilitates seamless transitions between education and industry, and eliminates traditional barriers such as geographical constraints and time limitations.

Incorporate New Technology: AI can enhance learning experiences through personalized and adaptive educational content. Intelligent algorithms can analyze individual learning patterns, identify strengths and weaknesses, and tailor educational materials to meet the specific needs of each learner. This adaptive approach not only ensures a more efficient learning process but also increases engagement and motivation. Furthermore, AI-powered tools can offer real-time feedback, track progress, and recommend additional resources, creating a dynamic and supportive learning environment. As postsecondary institutions integrate these technologies into their educational frameworks, they not only facilitate lifelong learning but also contribute to the evolution of education toward a more inclusive, personalized, and accessible model.

Implement Mid-Career Incentives: The number of students returning to postsecondary education after age 30 are low, limiting formal education's role in lifelong learning. To address this, the industry should play an active role in incentivizing upskilling programs. By promoting programs tailored for mid-career professionals, the industry can harness their valuable experiences while fostering continual learning.

Eliminate Disincentives to Complete Additional Training: There are disincentives to returning to an educational institution from industry. For example, highly experienced technicians can have higher compensation and a more rewarding working environment than entry engineers. This creates a disincentive to take on the financial and time burden of a four-year college program. Taking actions to remove these disincentives would help open up pathways. For example, pay-level-transition programs could be put in place and function in a way that employers agree to increase the salaries of individuals who complete additional levels of training. Such programs exist in Oregon in the construction industry.

Leverage Industry Leaders as Exemplars: The case of Pat Gelsinger, CEO of Intel, stands as a compelling example of someone who embarked on a technical track and advanced through education and employment. Such success stories can serve as powerful motivators and illustrate the potential for upward mobility within the semiconductor industry. By showcasing these examples, educational programs can inspire students and professionals alike to envision a similar trajectory, promoting long-term commitment and dedication to the industry.

Strengthening Education Programs through Research

Universities have a pivotal role in advancing fields of study and catalyzing the birth of innovative startups. However, in the semiconductor industry, the high cost of equipment poses a barrier to universities playing a fully active role.[54] Even with this challenge, there is an untapped potential for collaboration. The following recommendations focus on the upper half of the ladder framework and suggest possible next steps for discussion.

Overcome Equipment Costs: The high cost of semiconductor equipment has historically hindered universities from fully leveraging their potential in this field. Nevertheless, there is an opportunity to foster collaborative research environments that bridge the gap between academic exploration and the practical demands of the industry. Strategic collaboration between industry employers and educational institutions could provide universities with access

[54] Equipment costs pose a major challenge to community colleges as well.

to cutting-edge equipment and industry insights, fostering a more dynamic and mutually beneficial research landscape.

Remove Barriers to Industry Participation and Clarify Pathways from Industry to Educational Opportunities: While industry employees possess highly valuable skills and experience, notable barriers such as intellectual property prevent their full participation in teaching and research within academic settings. The industry needs clearly defined pathways to enable industry professionals to engage actively in leadership roles in academic research programs. Sabbaticals or academic breaks could serve as opportune periods for industry experts to contribute to educational endeavors, bringing a practical and real-world perspective to research initiatives.

Incentivize Industry Participation: To encourage highly qualified industry employees to actively participate in educational programs, companies can offer incentives both during their active employment and post-retirement. Establishing well-organized programs that facilitate the placement of these industry experts and retirees in positions where they can strengthen links between education and industry is essential. This proactive approach enhances collaboration and ensures a seamless flow of knowledge and expertise.

Additional Recommendations Based on the Quantitative Analysis

The quantitative analysis for this project provides baseline information about the existing semiconductor industry workforce and Oregon education pathways that support or could support this workforce. Findings from the analysis suggest numerous possibilities for benchmarking progress toward strengthening these pathways and for additional analysis to inform decision making by the HECC and other industry partners.

- **Use Data to Inform Workforce Diversity Strategies.** The semiconductor workforce is diversifying but workforce diversity remains below population diversity in many respects, particularly with regard to gender diversity. The quantitative analysis suggests how pathways generally become less diverse as students move from high school, to postsecondary majors important to the industry, and into the workforce. These and similar data should be considered in developing strategies to further support diversity.
- **Focus on High School Students and Dual-Credit Courses.** The analysis of outcomes for students who enrolled in a semiconductor-related dual-credit course in high school highlights the value to the industry of this potential pool of talent. Although relatively small at present compared to the broader core postsecondary pathways–we estimate that our sample of dual-credit students accounts for about 5 percent of core completers–a focus on this pool can help meet anticipated state, national, and international shortfalls in talent. Efforts to better advertise the benefits of semiconductor work to students could draw more students into relevant dual-credit coursework and increase the share of such students who pursue employment in the industry.

- **Focus on Critical Shortages and Existing Advantages.** The analysis found that, while Oregon's postsecondary system emphasizes semiconductor-related pathways as much as or more than other states with a large industry presence do, the system produces core credentials at a lower rate, relative to industry employment, than the national average or other states with a large industry. This suggests Oregon's semiconductor employers will continue to rely on drawing talent from beyond the state's borders. Instead of seeking to meet all industry workforce needs, Oregon institutions should instead focus on the most critical shortages and in areas where the state has existing advantages. Regional collaboration would support this approach, building on strengths in multiple states to support both Oregon and regional semiconductor industries.
- **Be Realistic about Meeting Anticipated Workforce Demand.** Private and CHIPS Act investment could increase industry employment by 21 percent over 2022 employment levels, suggesting a need for a similarly ambitious increase in the capacity of relevant education pathways. Our calculations suggest meeting this anticipated need, in the current context of declining credential production and competition from other industries for similar workers, would require a potentially extraordinary expansion relative to recent years. Doing so over many years may be feasible but the magnitude of increased need and the fact that Oregon is a relatively small state with an outsized semiconductor industry suggests focusing on strengthening pathways, whether the explicit education pathways considered by the quantitative analysis or the less-recognized pathways embodied in the education ladder framework, might better serve student, worker, and industry needs.
- **Further the Analysis Included in this Study.** The quantitative analysis provides a foundation for pursuing many important questions more deeply, with additional data:
    - A broader analysis of data held by the HECC and the Oregon Department of Education could, by overcoming some of the analytic limitations described earlier, help to more precisely quantify the role of specific dual credit courses, or constellations of courses, in supporting industry-relevant education pathways.
    - A similarly expanded analysis at the postsecondary level could identify opportunities to draw more, and more diverse, students into relevant pathways. It could also serve to identify "hidden" academic pathways–majors or courses that lead to employment in Oregon's semiconductor industry more frequently than might otherwise be expected.
    - Additional work could also add detail to the employment outcomes described above by, for example, characterizing the range of industries in which core completers gain employment. It could deepen understanding about post-completion employment by tracking tenure of completers with the industry to understand further the strength of connections between groups of programs and the industry. As suggested above, tracking metrics similar to those presented in this report could also help the HECC quantify progress toward strengthening the state's ability to support the workforce of this critical industry.

Next Steps

Through our interviews, we learned about many successful programs already leveraging many of the opportunities described in this chapter. These programs, frequently spearheaded by creative educators or backed by industry funding, tackle particular needs and adjust to changing demands. They underscore the underlying need for programs that ready students for roles in the semiconductor industry and are adaptable and attuned to industry requirements.

A critical next step is to establish a working group or consortium to continue researching and addressing semiconductor workforce questions and needs. A group with three teams—Workforce Entry, Lifelong Learning, and Research—each with representatives from the four stakeholder groups—Government, Industry, Education, and Community/Workforce—would provide space for holistic and successful initiatives.

<table>
<tr><th></th><th>Workforce Entry</th><th>Lifelong Learning</th><th>Research</th></tr>
<tr><td>Government</td><td rowspan="4">Team 1</td><td rowspan="4">Team 2</td><td rowspan="4">Team 3</td></tr>
<tr><td>Industry</td></tr>
<tr><td>Education</td></tr>
<tr><td>Community/Workforce</td></tr>
</table>

The following are some potential ways each stakeholder group can contribute to the working group or consortium:

Government

- Provide data, analysis, and supportive policies, regulations, incentives, and funding for workforce development programs
- Offer incentives for industry to invest in education and training
- Ensure that there is equal access to opportunities for all individuals, regardless of background

Industry

- Actively participate in the design and implementation of educational and training programs
- Offer real-world experiences, internships, and apprenticeships to bridge the gap between education and industry needs
- Collaborate with educational institutions to align curriculum with industry requirements

Education

- Develop and deliver relevant and up-to-date curricula that align with the needs of the semiconductor industry
- Foster research and innovation that can contribute to advancements in semiconductor technology
- Establish partnerships with industry to facilitate technology transfer and practical learning experiences

Community/Workforce[55]

- Represent the interests of the workforce in shaping educational and workforce development initiatives
- Advocate for inclusivity and equal access to educational opportunities
- Provide valuable feedback on the societal impact of workforce development efforts

This organizational structure will allow for deep discussion of the needs in each of the three areas: the left-to-right pathway of workforce entry, the back-and-forth pathways between industry and education, and the increased collaboration between industry and universities required to support innovation and industry growth. Organization and governance of the working group could follow the pattern of industry consortia established by Future Ready Oregon. The group or consortium could use the recommendations in this chapter as a starting place for their discussions and work.

This collaborative approach will be instrumental in tracking metrics and other approaches to measure the success of ongoing initiatives. Regular assessments and data collection can ensure the continuous improvement and adaptability of programs, fostering innovation, workforce diversity, and sustained growth in the semiconductor industry.

[55] Individual workers could represent the larger workforce on initial working group teams; workforce development program representatives could assume roles within larger ongoing structures that develop.

Appendix A: Supplemental Data

Engineers, semiconductor processing technicians, and supervisors of production and operating workers realized the greatest increases in the BIPOC (Black, Indigenous, or People of Color) share of workers between 2012 and 2021 (see Exhibit A-1). For example, BIPOC workers comprised 32 percent of electrical/electronics engineers in 2012 and 44 percent in 2021. The occupations with the highest relative shares of BIPOC workers in 2021 were assemblers, technicians, computer hardware engineers, and electrical/electronics engineers. Most of the listed occupations were more racially/ethnically diverse in 2021 than was the statewide workforce (25 percent BIPOC).[56]

Exhibit A-1. Top Semiconductor Occupations and BIPOC Worker Shares, Oregon

Occupation	2012	2021
Software Developers	25%	28%
Other Production Workers/1	29%	39%
Inspectors/testers	24%	32%
Miscellaneous Assemblers	39%	40%
First-line Supervisors of Production and Operating Workers	18%	31%
Engineering Technologists & Technicians/2	21%	30%
Electrical/Electronics Engineers	32%	44%
Mechanical Engineers	16%	13%
Industrial Engineers	17%	18%
Engineering Managers	18%	18%
Heating, Air Conditioning, Refrigeration Mechanics and installers	15%	22%
Electrical/Electronics Assemblers	51%	54%
Computer Hardware Engineers	32%	42%
Chemical Engineers	16%	14%
Semiconductor Industry Average/3	31.9%	44.8%
Oregon Workforce Average	19.5%	25.4%

Notes:
/1: Includes Semiconductor Processing Technicians
/2: Occupation defined as Industrial Engineering Technologists/Technicians and Electrical and Electronics Engineering Technologists/Technicians
/3: The ACS industry estimates are for Electronic Component Manufacturing which includes Semiconductor and Other Electronic Component Manufacturing and Manufacturing and Reproducing Magnetic and Optical Media.
Data source: U.S. Census Bureau, ACS 5-year Estimates 2012 and 2021

[56] Differences between the share of workers that identify as BIPOC in the statewide workforce and those in the top occupations in the semiconductor industry are not necessarily statistically significant.

Broad semiconductor-related postsecondary programs fall into five primary NCES categories:

- Engineering
- Engineering technologies and technicians
- Computer and information science and support services
- Precision production
- Mechanic and repair technologies and technicians

Programs that train engineers and engineering technicians account for more than half of the identified postsecondary programs. Computer and information science programs train the computer programmers, software developers, and computer system analysts who support chip design and EDA. Workers in occupations that support fabrication, such as machine operators, machinists, and HVAC technicians, earn credentials in precision production and mechanic and repair technologies and technician programs.

Across this broad set of programs, engineering and computer and information sciences have the largest number of completions. Precision production programs account for relatively few postsecondary completions, as most fabrication and ATP semiconductor occupations require instead a high school diploma and on-the-job training.

Core semiconductor-related programs (see Exhibit A3) include those most directly related to the production process, rather than the wider supply chain. Core programs are drawn from the following three NCES categories:

- Engineering
- Engineering technologies and technicians
- Precision production

Exhibit A-2. Number of Postsecondary Fields of Study, by Occupation and Category

SOC Code	Occupation Title	Engineering	Engineering Technologies & Technicians	Computer & Information Sciences and Support Services	Precision Production	Mechanic & Repair Technologies & Technicians
11-9041	Architectural and Engineering Managers	25	1	0	0	0
17-2041	Chemical Engineers	5	0	0	0	0
51-9011	Chemical Equipment Operators and Tenders	0	0	0	0	0
51-8091	Chemical Plant and System Operators	0	0	0	0	0
19-4031	Chemical Technicians	0	0	0	0	0
19-2031	Chemists	0	0	0	0	0
17-2061	Computer Hardware Engineers	4	0	0	0	0
51-9161	Computer Numerically Controlled Tool Operators	0	0	0	1	0

15-1299	Computer Occupations, All Other	0	0	3	0	0
15-1251	Computer Programmers	0	1	7	0	0
15-1211	Computer Systems Analysts	0	0	3	0	0
51-4031	Cutting, Punching, and Press Machine Setters, Operators, and Tenders, Metal and Plastic	0	0	0	2	0
17-3023	Electrical and Electronic Engineering Technologists and Technicians	0	7	0	0	0
17-2071	Electrical Engineers	4	0	0	0	0
17-2072	Electronics Engineers, Except Computer	2	0	0	0	0
17-2199	Engineers, All Other	13	1	0	0	0
49-9021	Heating, Air Conditioning, and Refrigeration Mechanics and Installers	0	1	0	0	1
17-3026	Industrial Engineering Technologists and Technicians	0	4	0	0	0
17-2112	Industrial Engineers	3	0	0	0	0
11-3051	Industrial Production Managers	1	1	0	0	0
51-9061	Inspectors, Testers, Sorters, Samplers, and Weighers	0	1	0	0	0
51-4041	Machinists	0	0	0	2	0
17-2141	Mechanical Engineers	3	0	0	0	0
51-4081	Multiple Machine Tool Setters, Operators, and Tenders, Metal and Plastic	0	0	0	2	0
51-9141	Semiconductor Processing Technicians	0	1	0	0	1
15-1252	Software Developers	2	1	8	0	0
51-4121	Welders, Cutters, Solderers, and Brazers	0	1	0	1	0

Data source: National Center for Education Statistics, CIP to SOC Crosswalk, 2021

Exhibit A-3. Number of Institutions with Postsecondary Programs Related to the Semiconductor Workforce, by Institution Type, Oregon

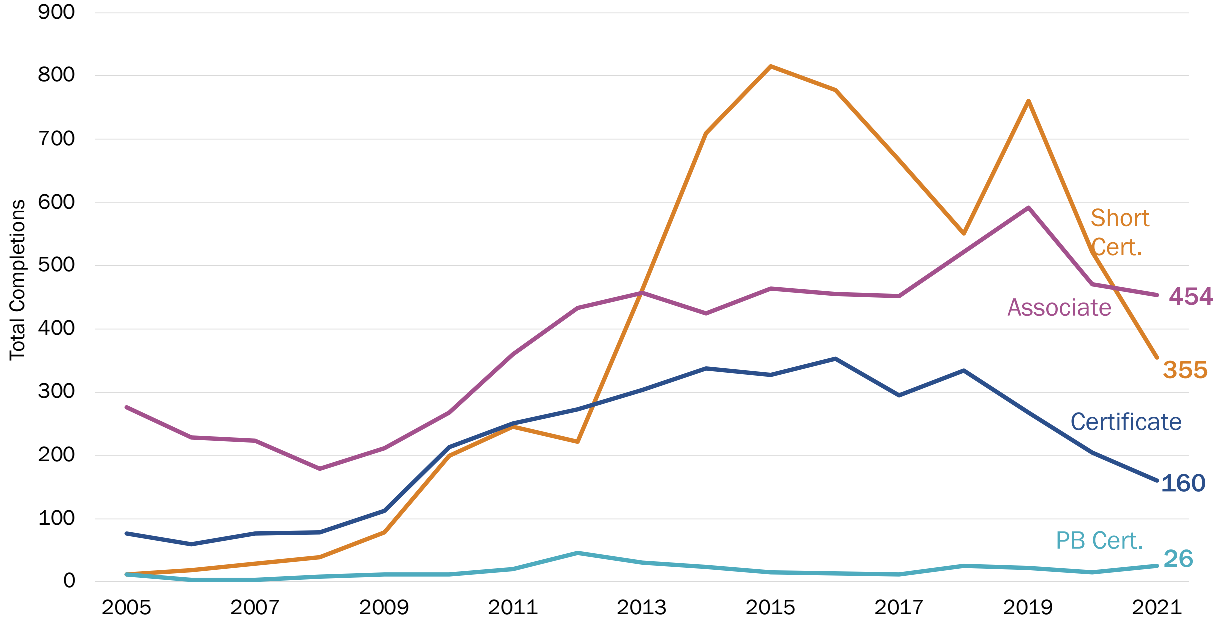
CIP Code	CIP Name / Field of Study	Included in Core Programs?	Four or more years	At least 2 but less than 4 years	Less than 2 years (below associate)	Total Oregon Institutions
11.0101	Computer and Information Sciences, General.	No	11	11	0	22
11.0103	Information Technology.	No	3	3	0	6
11.0201	Computer Programming/Programmer, General.	No	5	2	0	7
11.0202	Computer Programming, Specific Applications.	No	1	6	0	7
11.0203	Computer Programming, Vendor/Product Certification.	No	0	1	0	1
11.0205	Computer Programming, Specific Platforms.	No	0	0	0	0
11.0299	Computer Programming, Other.	No	1	2	0	3
11.0401	Information Science/Studies.	No	3	2	0	5
11.0501	Computer Systems Analysis/Analyst.	No	3	1	1	5
11.0701	Computer Science.	No	8	8	0	16
11.0804	Modeling, Virtual Environments and Simulation.	No	0	0	0	0
14.0101	Engineering, General.	Yes	4	4	0	8
14.0701	Chemical Engineering.	No	1	1	0	2
14.0901	Computer Engineering, General.	No	6	0	0	6
14.0902	Computer Hardware Engineering.	No	0	1	0	1
14.0903	Computer Software Engineering.	No	5	1	1	7
14.0999	Computer Engineering, Other.	No	1	0	0	1
14.1001	Electrical and Electronics Engineering.	Yes	6	3	0	9
14.1003	Laser and Optical Engineering.	Yes	0	0	0	0
14.1099	Electrical, Electronics, and Communications Engineering, Other.	Yes	1	0	0	1
14.1101	Engineering Mechanics.	Yes	0	1	0	1
14.1201	Engineering Physics/Applied Physics.	Yes	2	0	0	2
14.1301	Engineering Science.	Yes	1	0	0	1
14.1801	Materials Engineering.	Yes	1	0	0	1
14.1901	Mechanical Engineering.	Yes	5	0	0	5

14.2001	Metallurgical Engineering.	Yes	0	0	0	0
14.2701	Systems Engineering.	Yes	1	0	0	1
14.3201	Polymer/Plastics Engineering.	Yes	0	1	0	1
14.3501	Industrial Engineering.	Yes	1	1	0	2
14.3601	Manufacturing Engineering.	Yes	1	0	0	1
14.4101	Electromechanical Engineering.	Yes	0	0	0	0
14.4201	Mechatronics, Robotics, and Automation Engineering.	Yes	1	2	0	3
14.4701	Electrical and Computer Engineering.	Yes	1	0	0	1
14.9999	Engineering, Other.	Yes	3	2	0	5
15.0000	Engineering Technologies/Technicians, General.	Yes	2	1	0	3
15.0001	Applied Engineering Technologies/Technicians.	Yes	0	0	0	0
15.0306	Integrated Circuit Design Technology/Technician.	Yes	0	0	0	0
15.0399	Electrical/Electronic Engineering Technologies/Technicians, Other.	Yes	2	0	0	2
15.0406	Automation Engineer Technology/Technician.	Yes	0	0	0	0
15.0501	Heating, Ventilation, Air Conditioning and Refrigeration Engineering Technology/Technician.	No	0	1	0	1
15.0612	Industrial Technology/Technician.	Yes	2	8	0	10
15.0613	Manufacturing Engineering Technology/Technician.	Yes	2	9	0	11
15.0614	Welding Engineering Technology/Technician.	No	0	2	0	2
15.0616	Semiconductor Manufacturing Technology/Technician.	Yes	0	0	0	0
15.0699	Industrial Production Technologies/Technicians, Other.	Yes	0	3	0	3
15.0702	Quality Control Technology/Technician.	Yes	0	1	0	1
15.1201	Computer Engineering Technology/Technician.	Yes	1	3	0	4
15.1202	Computer/Computer Systems Technology/Technician.	Yes	0	3	0	3

15.1204	Computer Software Technology/Technician.	Yes	1	2	0	3
15.1501	Engineering/Industrial Management.	Yes	3	0	0	3
15.1601	Nanotechnology.	Yes	0	0	0	0
30.3001	Computational Science.	No	0	0	0	0
41.0301	Chemical Technology/Technician.	No	0	0	0	0
41.0303	Chemical Process Technology.	No	0	0	0	0
47.0105	Industrial Electronics Technology/Technician.	Yes	0	0	0	0
47.0201	Heating, Air Conditioning, Ventilation and Refrigeration Maintenance Technology/Technician.	No	0	2	1	3
48.0501	Machine Tool Technology/Machinist.	Yes	0	6	0	6
48.0503	Machine Shop Technology/Assistant.	Yes	0	3	0	3
48.0506	Sheet Metal Technology/Sheetworking.	Yes	0	1	0	1
48.0508	Welding Technology/Welder.	No	0	13	0	13
48.0510	Computer Numerically Controlled (CNC) Machinist Technology/CNC Machinist.	Yes	0	1	0	1

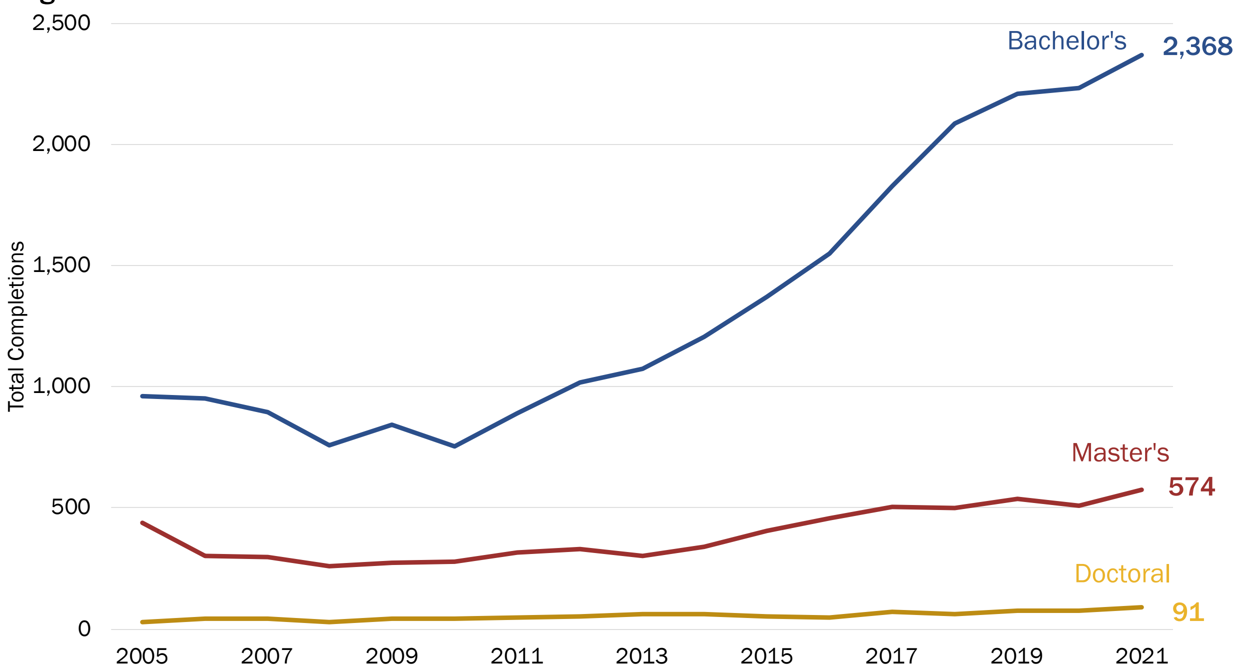
Data source: National Center for Education Statistics, 2021

Exhibit A-4. Broad Classification: Completions by Award Level, Certificates and Associate Degrees, Oregon



Data source: Integrated Postsecondary Education Data System, Completions

Exhibit A-5. Broad Classification: Completions by Award Level, Bachelor's and Graduate Degrees, Oregon



Data source: Integrated Postsecondary Education Data System, Completions

Exhibit A-6. Broad Classification: Female Completers in Semiconductor-Related and All Programs, by Award Level, Oregon

Award Level	2005		2021	
	All Programs	Broad Semiconductor Programs	All Programs	Broad Semiconductor Programs
Short-term Certificates	84%	0%	66%	21%
Certificates	81%	24%	76%	18%
Post-bachelor's Certificates	67%	36%	70%	38%
Associates	58%	16%	61%	18%
Bachelor's	57%	13%	56%	17%
Master's	58%	24%	62%	28%
Doctoral	51%	15%	58%	26%
Total	62%	16%	61%	20%

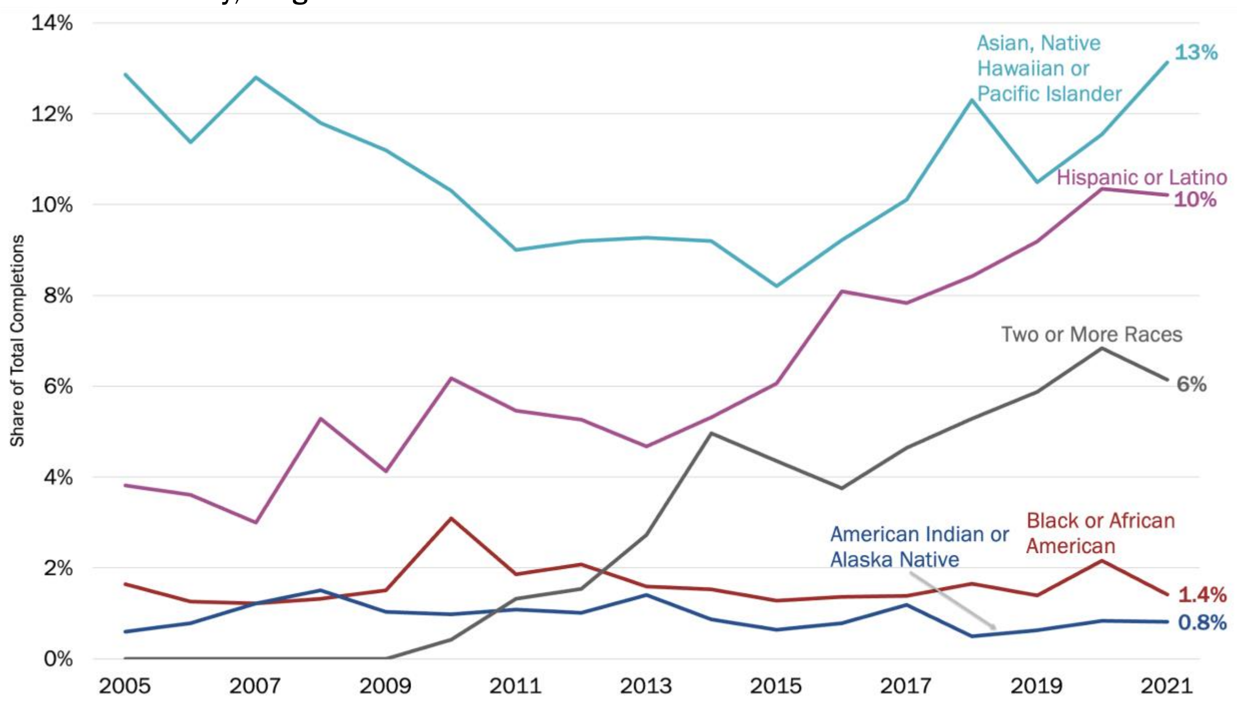
Data source: Integrated Postsecondary Education Data System, 2005 and 2021

Exhibit A-7. Broad Classification: BIPOC Completers in Semiconductor-Related and All Programs, by Award Level, Oregon

Award Level	2005		2021	
	All Programs	Broad Semiconductor Programs	All Programs	Broad Semiconductor Programs
Short-term Certificates	13%	0%	30%	35%
Certificates	12%	18%	31%	28%
Post-bachelor's Certificates	11%	25%	23%	17%
Associates	13%	18%	28%	28%
Bachelor's	12%	18%	30%	33%
Master's	10%	27%	21%	27%
Doctoral	9%	0%	24%	20%
Total	12%	17%	30%	30%

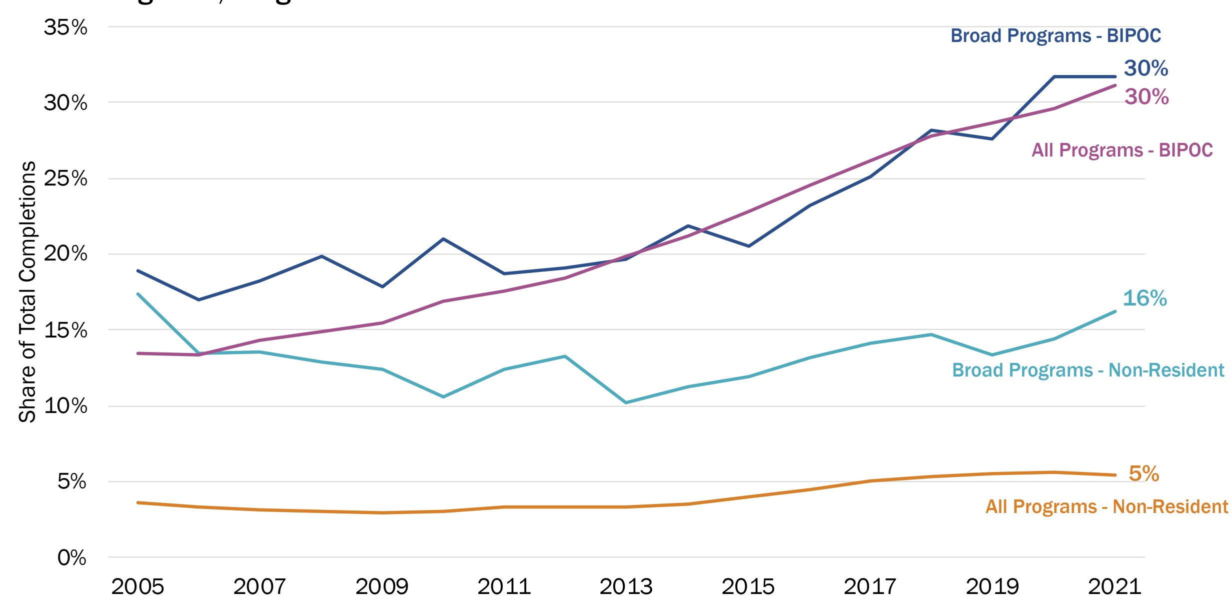
Data source: Integrated Postsecondary Education Data System, 2005 and 2021

Exhibit A-8. Broad Classification: Percent of Completions in Semiconductor-Related Programs, by Race and Ethnicity, Oregon



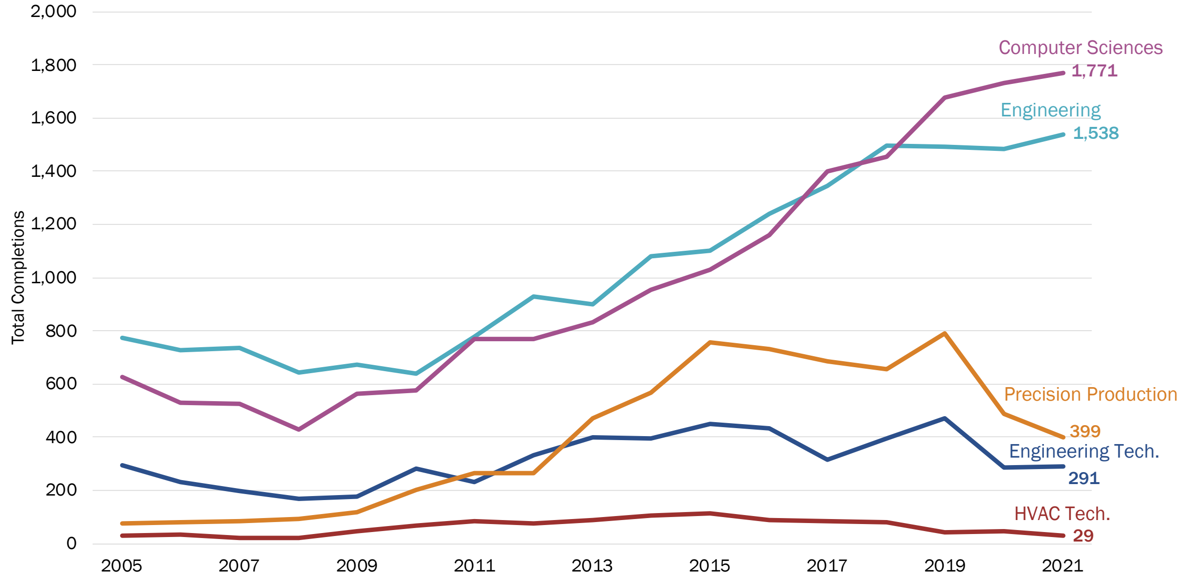
Data source: Integrated Postsecondary Education Data System, Completions

Exhibit A-9. Broad Classification: BIPOC and Non-Resident Completions in Semiconductor-Related and All Programs, Oregon



Data source: Integrated Postsecondary Education Data System, Completions

Exhibit A-10. Broad Classification: Completions by Program Category, Oregon



Data source: Integrated Postsecondary Education Data System, Completions

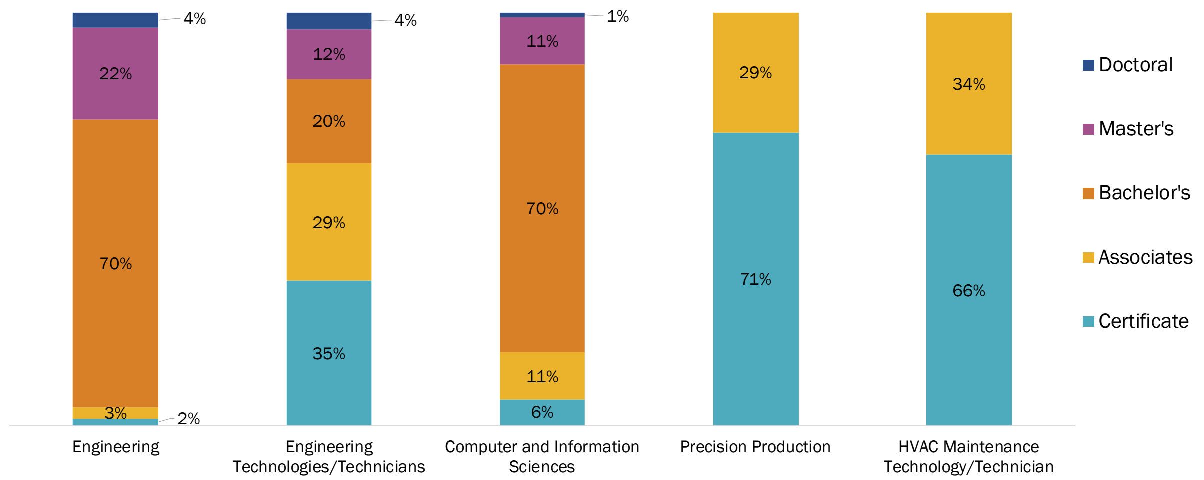
Exhibit A-11. Broad Classification: Completions by Corresponding Occupation, Oregon, 2005-2021

Occupation	2005	2010	2015	2021
Engineering Managers	818	699	1,149	1,571
Computer Occupations, All Other	489	431	753	1,567
Computer Programmers	157	245	730	1,534
Mechanical Engineers	212	221	354	643
Computer Hardware Engineers	395	239	410	512
Electrical Engineers	304	223	389	470
Electronics Engineers, Except Computer	304	223	389	356
Computer Systems Analysts	514	292	331	303
Engineers, All Other	59	56	143	260
Welders, Cutters, Solderers, and Brazers	45	146	575	242
Industrial Engineering Technologists and Technicians	50	171	303	141
Chemical Engineers	44	60	111	139
Industrial Production Managers	89	112	132	131
Machinists	31	55	182	125
Multiple Machine Tool Setters, Operators, and Tenders, Metal and Plastic	31	55	182	125
Industrial Engineers	69	69	105	110
Cutting, Punching, and Press Machine Setters, Operators, and Tenders, Metal and Plastic	32	28	78	90

Computer Numerically Controlled Tool Operators	-	-	-	36
Heating, Air Conditioning, and Refrigeration Mechanics and Installers	32	66	114	34
Electrical/electronic engineering technologists and technicians	138	21	27	17
Inspectors/testers	-	-	8	-

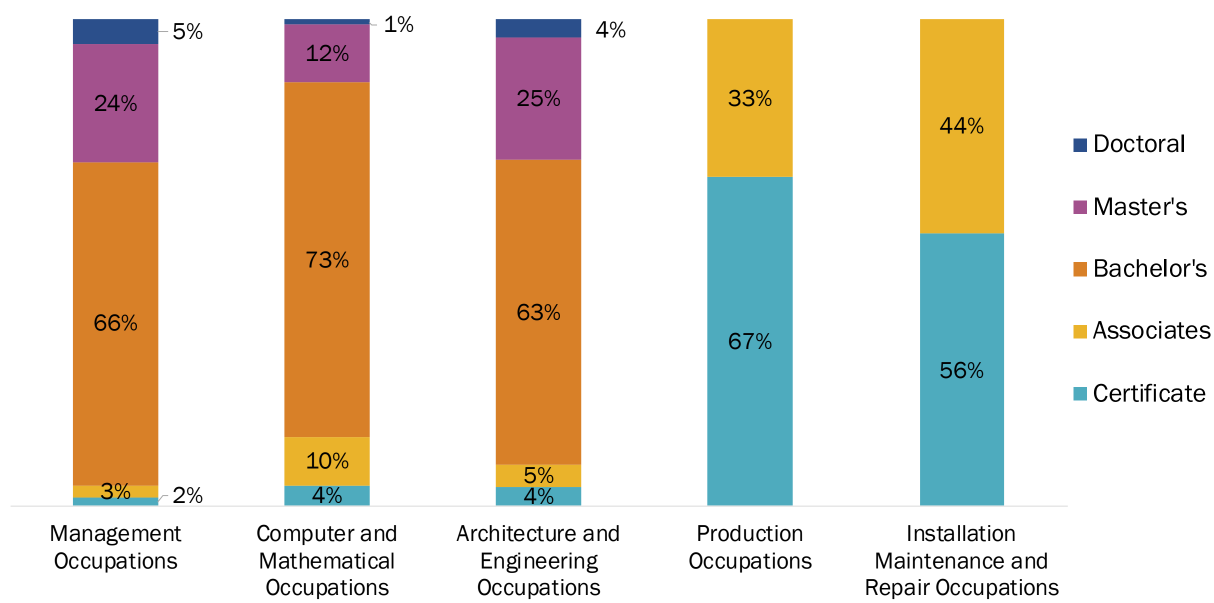
Data source: Integrated Postsecondary Education Data System, Completions

Exhibit A-12. Broad Classification: Completions by Program Category and Award Level, Oregon, 2021



Data source: Integrated Postsecondary Education Data System, Completions

Exhibit A-13. Broad Classification: Completions by Occupation Group and Award Level, Oregon, 2021



Data source: Integrated Postsecondary Education Data System, Completions

Appendix B: Engagement Questions

Interview Questions for Educators

Curriculum

- What are the key skills and knowledge areas that are essential for students aspiring to work in the semiconductor industry?
- How well aligned are your current curriculum and programs with the needs of semiconductor manufacturers in Oregon? Are there any areas that could be strengthened or expanded?
- How do you incorporate emerging technologies and industry trends into your curriculum to ensure students are up to date with the latest advancements in the semiconductor field?
- Are there specific foundational/introductory courses that are useful indicators of future interest in or value to the industry?
- Have there been significant changes over the past decade in relevant postsecondary programs we should be aware of?

Alignment with Industry

- What types of hands-on experiences or practical training opportunities do students in semiconductor-related programs currently have access to?
- Are there specific labs or facilities equipped with semiconductor manufacturing equipment where students can gain hands-on experience? If so, what types of equipment are available?
- How frequently do students have the opportunity to work directly with semiconductor manufacturing equipment? Is it integrated into their coursework or offered through specialized programs?
- How do you ensure that students receive sufficient training and supervision when working with semiconductor manufacturing equipment to ensure safety and skill development?
- Are there any plans or initiatives in place to expand students' access to semiconductor manufacturing equipment or enhance their practical experience? If yes, what are these plans and how will they be implemented?

Collaborations Industry-wide

- What partnerships or collaborations do you have with semiconductor companies in Oregon to enhance students' learning experiences, industry exposure, and practical training opportunities?
- How are these partnerships structured and what benefits do they offer to students?

Recruitment & Retention Barriers

- Are there any challenges or barriers you face in preparing students for careers in the semiconductor industry? How can these challenges be addressed?
- How diverse are your semiconductor-related programs? What challenges/opportunities does your institution face in diversifying the potential talent pool for the semiconductor industry?
- What strategies or initiatives do you have in place to attract and retain students in semiconductor-related programs?

Recommendations

- What aspects of the semiconductor training pipeline should HECC focus on? What changes are or should be on the horizon?

Interview Questions for Employers

Industry Skills & Talent Pool Attraction

- What specific skill sets or attributes are you looking for when hiring talent for your semiconductor manufacturing operations in Oregon?
- Are you satisfied with the current talent pool available in Oregon? If not, what are the gaps or areas of improvement you observe?
- What level of importance do you place on candidates having practical experience with semiconductor manufacturing equipment during their education?
- Do you believe that students who have hands-on experience with semiconductor manufacturing equipment are better prepared for industry roles? If yes, what specific advantages do they bring?
- How diverse is the semiconductor industry? What challenges/opportunities does your company face in diversifying the talent pool for the semiconductor industry?

Collaboration with Higher Education

- What suggestions do you have for higher education institutions in Oregon to better align their programs with the industry's needs and ensure graduates are well prepared for semiconductor manufacturing roles?
- How can collaboration between semiconductor companies and educational institutions be enhanced to foster a stronger talent pipeline?
- Are there any programs or initiatives in place to support educational institutions in providing access to semiconductor manufacturing equipment for students? If yes, how do you collaborate with these institutions?
- How can industry and educational institutions work together to enhance students' practical experience with semiconductor manufacturing equipment? Are there any

challenges or limitations you observe in terms of students' practical experience with semiconductor manufacturing equipment? How can these challenges be addressed?

Industry Role

- In your opinion, what role can industry professionals play in supporting and mentoring students pursuing careers in the semiconductor industry?
- Are there any specific training or internship opportunities you offer to students or recent graduates to bridge the gap between academia and industry? How effective have these programs been?

Recommendations

- What advice or recommendations do you have for educational institutions in terms of improving students' access to and utilization of semiconductor manufacturing equipment for practical training?

Appendix C: Major and Course Lists

The following fields of study (majors) were considered semiconductor-related programs of study in the analysis described in Chapter 4.

Core CIP Code	CIP Name / Field of Study for Core Semiconductor-Related CIP Codes
14.0101	Engineering, General.
14.1001	Electrical and Electronics Engineering.
14.1003	Laser and Optical Engineering.
14.1099	Electrical, Electronics, and Communications Engineering, Other.
14.1101	Engineering Mechanics.
14.1201	Engineering Physics/Applied Physics.
14.1301	Engineering Science.
14.1801	Materials Engineering.
14.1901	Mechanical Engineering.
14.2001	Metallurgical Engineering.
14.2701	Systems Engineering.
14.3201	Polymer/Plastics Engineering.
14.3501	Industrial Engineering.
14.3601	Manufacturing Engineering.
14.4101	Electromechanical Engineering.
14.4201	Mechatronics, Robotics, and Automation Engineering.
14.4701	Electrical and Computer Engineering.
14.9999	Engineering, Other.
15.0000	Engineering Technologies/Technicians, General.
15.0001	Applied Engineering Technologies/Technicians.
15.0306	Integrated Circuit Design Technology/Technician.
15.0399	Electrical/Electronic Engineering Technologies/Technicians, Other.
15.0406	Automation Engineer Technology/Technician.
15.0612	Industrial Technology/Technician.

15.0613	Manufacturing Engineering Technology/Technician .
15.0616	Semiconductor Manufacturing Technology/Technician.
15.0699	Industrial Production Technologies/Technicians, Other.
15.0702	Quality Control Technology/Technician.
15.1201	Computer Engineering Technology/Technician.
15.1202	Computer/Computer Systems Technology/Technician.
15.1204	Computer Software Technology/Technician.
15.1501	Engineering/Industrial Management.
15.1601	Nanotechnology.
30.3001	Computational Science.
41.0301	Chemical Technology/Technician.
41.0303	Chemical Process Technology.
47.0105	Industrial Electronics Technology/Technician.
48.0501	Machine Tool Technology/Machinist.
48.0503	Machine Shop Technology/Assistant.
48.0506	Sheet Metal Technology/Sheetworking.
48.0510	Computer Numerically Controlled (CNC) Machinist Technology/CNC Machinist.

CIP Code	CIP Title
11.0101	Computer and Information Sciences, General.
11.0102	Artificial Intelligence.
11.0103	Information Technology.
11.0104	Informatics.
11.0201	Computer Programming/Programmer, General.
11.0202	Computer Programming, Specific Applications.
11.0203	Computer Programming, Vendor/Product Certification.
11.0205	Computer Programming, Specific Platforms.
11.0299	Computer Programming, Other.
11.0401	Information Science/Studies.
11.0501	Computer Systems Analysis/Analyst.
11.0701	Computer Science.
11.0804	Modeling, Virtual Environments and Simulation.
14.0101	Engineering, General.
14.0103	Applied Engineering.
14.0601	Ceramic Sciences and Engineering.
14.0701	Chemical Engineering.
14.0799	Chemical Engineering, Other.
14.0901	Computer Engineering, General.
14.0902	Computer Hardware Engineering.
14.0903	Computer Software Engineering.
14.0999	Computer Engineering, Other.
14.1001	Electrical and Electronics Engineering.
14.1003	Laser and Optical Engineering.
14.1099	Electrical, Electronics, and Communications Engineering, Other.
14.1101	Engineering Mechanics.
14.1201	Engineering Physics/Applied Physics.
14.1301	Engineering Science.
14.1801	Materials Engineering.
14.1901	Mechanical Engineering.
14.2001	Metallurgical Engineering.
14.2701	Systems Engineering.
14.3201	Polymer/Plastics Engineering.
14.3501	Industrial Engineering.
14.3601	Manufacturing Engineering.
14.4101	Electromechanical Engineering.
14.4201	Mechatronics, Robotics, and Automation Engineering.
14.4401	Engineering Chemistry.
14.4701	Electrical and Computer Engineering.
14.9999	Engineering, Other.

CIP Code	CIP Title
15.0000	Engineering Technologies/Technicians, General.
15.0001	Applied Engineering Technologies/Technicians.
15.0306	Integrated Circuit Design Technology/Technician.
15.0399	Electrical/Electronic Engineering Technologies/Technicians, Other.
15.0406	Automation Engineer Technology/Technician.
15.0501	Heating, Ventilation, Air Conditioning and Refrigeration Engineering Technology/Technician.
15.0612	Industrial Technology/Technician.
15.0613	Manufacturing Engineering Technology/Technician.
15.0614	Welding Engineering Technology/Technician.
15.0616	Semiconductor Manufacturing Technology/Technician.
15.0699	Industrial Production Technologies/Technicians, Other.
15.0702	Quality Control Technology/Technician.
15.1201	Computer Engineering Technology/Technician.
15.1202	Computer/Computer Systems Technology/Technician.
15.1204	Computer Software Technology/Technician.
15.1501	Engineering/Industrial Management.
15.1601	Nanotechnology.
30.3001	Computational Science.
30.7001	Data Science, General.
30.7103	Data Visualization.
40.0501	Chemistry, General.
40.0502	Analytical Chemistry.
40.0503	Inorganic Chemistry.
40.0504	Organic Chemistry.
40.0506	Physical Chemistry.
40.0507	Polymer Chemistry.
40.0508	Chemical Physics.
40.0511	Theoretical Chemistry.
40.0599	Chemistry, Other.
40.1001	Materials Science.
40.1002	Materials Chemistry.
41.0301	Chemical Technology/Technician.
41.0303	Chemical Process Technology.
47.0105	Industrial Electronics Technology/Technician.
47.0201	Heating, Air Conditioning, Ventilation and Refrigeration Maintenance Technology/Technician.
48.0501	Machine Tool Technology/Machinist.
48.0503	Machine Shop Technology/Assistant.
48.0506	Sheet Metal Technology/Sheetworking.
48.0508	Welding Technology/Welder.
48.0510	Computer Numerically Controlled (CNC) Machinist Technology/CNC Machinist.

Course #	Dual-Credit Course Title	Course Count	Course #	Dual-Credit Course Title	Course Count
PH211	Physics/Engineers & Scientists	13	ELT111	Electronics Orientation	1
PH212	Physics/Engineer & Scientists	10	ELT126	Int Program Cntrl (PC Based)	1
ENGR101	Engineering Orientation I: Careers, Skills	7	ENGR-115	Engineering Graphics	1
GE101	Engineering Orientation	7	ENGR-221	Electrical Circuit Analysis I	1
ENGR111	ENGINEERING ORIENTATION I	6	ENGR-222	Elect Circuit Analysis II	1
PH213	Physics/Engineers & Scientists	5	ENGR-223	Electric Circuit Analysis III	1
ENGR-111	Introduction to Engineering	4	ENGR-223L	Electric Circuit Analysis III	1
ENGR-112	Engineering Programming	4	ENGR-271	Digital Systems	1
MT105	Introduction to Robotics	4	ENGR*111	Intro to Engineering	1
ENGR114	Engineering Programming	3	ENGR*112	Engineering Computation	1
ENGR211	Statics	3	ENGR102	Engineering Graphics	1
ENGR212	DYNAMICS	3	ENGR105	ENG. Graph. 3-D	1
ENGR221	Electrical Circuits I	3	ENGR112	ENGINEERING ORIENTATION II	1
ENGR248	Engineering Graphics: Solidworks	3	ENGR201	ELECTRICAL FUND: DC CIRCUITS	1
EET104	Fundamentals of Manufacturing Electronics	2	ENGR203	ELECTRIC FUND:SIGNALS/CONTROLS	1
EET112	Introduction to Mechatronics	2	ENGR223	Electrical Circuits III	1
ELT125	Basic Prog Controllers-PC Base	2	ENGR245	Eng Graphics and Design	1
ENGR100	Exploring Engineering	2	ENGR271	DIGITAL LOGIC DESIGN	1
ENGR202	ELECTRICAL FUND: AC CIRCUITS	2	ET120	Engineering Problem Solving	1
ENGR213	Strength of Materials	2	GE115	Engineering Graphics	1
ENGR222	Electrical Circuits II	2	ENG1XX	ENG Elective	1
MT101	Intro to Semiconductor Manuf	2	IMTL143	CNC Cutting	1
MT121	Digital Systems I	2	MFG140	CNC Controls	1
EET-112	Elec Eqpmnt and Assem I	1	MEC131	AC/DC Electrical Systems	1
EET-113	Elec Eqpmnt and Assembly II	1	MT102	Intro to Semiconductor Dev	1
EET-137	Electrical Fundamentals I	1	MT103	Intro to Micro and Nano Proc	1
EET-141	Electrical Fundamentals II	1	MT3.812	MECHANICAL SYSTEMS	1
EET-142	Electrical Fundamentals III	1	MT3.836	INDUSTRIAL HYDRAULICS SYSTEMS	1
EET-157	Digital Logic I	1	MTH265	STAT FOR SCIENTIST & ENGINEERS	1
EET-215	Technical Mechanics	1	PH131	MICROCONTROLLERS IN RES/DESIGN	1
EET-254	Intro to Microcontrollers	1			
EET101	Introduction to Electronics	1			
EET121	Digital Systems 1	1			
EET129	Introduction to Embedded Systems	1			

Appendix D: *Oregon's Semiconductor Workforce*

HIGHER EDUCATION COORDINATING COMMISSION
3225 25th Street SE, Salem, OR 97302
www.oregon.gov/HigherEd

Oregon's Semiconductor Workforce:

Harnessing Workforce Education and Training Investments to Prepare Oregonians for Equitable Prosperity

June 29, 2023

Supporting the Workforce Needs of Oregon's Growing Semiconductor Industry

Oregon's semiconductor workforce, one of the largest in the nation, is poised for significant growth over the next decade. According to the August 2022 *Seizing Opportunity* report of Oregon's Semiconductor Competitiveness Task Force, the state is "home to 15 percent of the national semiconductor workforce." Findings from the Oregon Employment Department (OED) indicate that semiconductor and electronic components manufacturing currently employs more than 34,000 Oregonians—accounting for nearly one out of every six manufacturing jobs (17.6 percent of Oregon's total manufacturing employment).

> "Semiconductor industry expansion presents Oregon with an extraordinary opportunity to intentionally create the kind of jobs and investment the state needs for us to emerge from the pandemic with a stronger, more deliberately equitable economy."
> \- *Seizing Opportunity: Initial Report and Subcommittee Findings.* Oregon Semiconductor Competitiveness Task Force (August 2022)

In July 2022, Congress passed the $52 billion CHIPS Act to promote semiconductor manufacturing and design in the United States. The *Seizing Opportunity* report indicates that, with the injection of CHIPS funding, the state's semiconductor workforce could increase by more than 10,000 jobs. Significantly, Oregon workers in semiconductor and other electronic component manufacturing positions earn wages averaging $161,584 annually—nearly two and a half times as much as the average statewide wage of $65,389, according to 2022 data from the OED. Furthermore, many of these new, good-paying jobs will be accessible through short-term education and training pathways.

This brief introduces Oregon's semiconductor talent landscape and highlights recent statewide efforts among public institutions and partners. **These are highlights and not intended as a comprehensive catalog of activity; contact the institutions directly for more information on their programs.** In spring 2023, the Higher Education Coordinating Commission (HECC) convened industry and education partners to inform **a comprehensive Semiconductor Talent Assessment that will guide strategic investment and collaboration.** This more thorough assessment is expected to be complete in September 2023 and will review Oregon's current semiconductor talent profile, identify critical short- and long-term industry needs, and analyze the current capacity of Oregon's postsecondary institutions and workforce education and training providers to address gaps and seize opportunities.

Oregon's Leaders Are Investing in Collaborative and Innovative Approaches to Workforce Education and Training

As the agency working to improve equitable access to and success in higher education and workforce training statewide, Oregon's Higher Education Coordinating Commission (HECC) is well positioned to support Oregonians on their journey to meaningful careers within the semiconductor industry. The HECC envisions a future in which all Oregonians—especially those whom our systems have underserved and marginalized—benefit from the transformational power of high-quality postsecondary education and training. This work is anchored in an Equity Lens that guides efforts to improve outcomes for historically underserved populations. The HECC supports and administers several initiatives that equip community-based organizations, educational programs, and employers to prepare individuals for employment in the high-tech and manufacturing sectors that encompass semiconductor manufacturing and design.

The HECC Office of Workforce Investments (OWI) deploys funds for a variety of resources, programs, initiatives, and activities that are focused on skill attainment, work-related training, wraparound supports, and employment opportunities. OWI administers these funds through sub-grants to local workforce development boards and other partners, who prioritize these resources for regionally identified in-demand occupations and industry sectors. Manufacturing is a priority sector in every workforce region in Oregon, while technology is a priority in five of the nine workforce regions (see Targeted Industry Sectors map).

Local Workforce Development Boards

The Workforce and Talent Development Board (WTDB), which advises the Governor on workforce matters, comprises leaders representing business, labor, local workforce development boards, community-based organizations, the Oregon Legislature, local government, and state agencies. As the Governor's core advisor for the interconnection and alignment of education, training, and workforce development in order to realize equitable prosperity for all, the WTDB's primary functions are gathering, analyzing, and reporting on current issues and future trends to guide and shape workforce strategy and policy development for Oregon. This body of work includes a series of talent assessments, including the forthcoming Semiconductor Talent Assessment.

Future Ready Oregon is Well Positioned to Support Investments in the Semiconductor Workforce

In early 2022, the Oregon Legislature committed to supporting the educational and training needs of Oregonians through passage of Oregon Senate Bill 1545, also known as Future Ready Oregon. This comprehensive $200 million investment package advances equity in education and training, connecting Oregonians from historically underserved priority populations* to good-paying jobs in the technology, manufacturing, and healthcare sectors. Future Ready Oregon emphasizes a multifaceted approach to equitable prosperity through inclusive, culturally specific, and linguistically appropriate career-connected learning, employment services, and related initiatives.

- ***Workforce Ready Grants***, which represent a $95 million investment, are available to community-based and culturally specific organizations, along with workforce service providers. They fund the creation and expansion of education and training programs in the key sectors of technology, manufacturing, and healthcare; expand the capacity of organizations to provide workforce development services; and provide direct benefits and wraparound supports to individual jobseekers.
- Implementation of Future Ready Oregon will be informed by the convening of three statewide ***Industry Consortia*** representing the technology, manufacturing, and healthcare industry sectors. Industry Consortia will provide a forum for convening industry, education, and community partners to better understand the state's sector-specific workforce needs, identify education and training programs and career pathways, and recommend strategies to address gaps and opportunities.
- ***Workforce Benefits Navigators*** will be available in communities across the state to help individuals efficiently access the resources that match their unique needs and explore programs and benefits available for workforce education and training.

**Priority populations include communities of color, women, low-income communities, rural and frontier communities, veterans, persons with disabilities, incarcerated and formerly incarcerated individuals, members of Oregon's nine federally recognized Tribes, older adults, and individuals who identify as members of the LGBTQ+ community.*

Training for Oregon's semiconductor workforce begins in K-12, with support from recent statewide STEM- and career-oriented education initiatives. In 2013, the Oregon Legislature established Oregon's STEM Investment Council and charged it with "doubling the percentage of students in the 4th and 8th grades who are proficient or advanced in math and science by 2025." Oregon's Regional STEM Hub Network, established two years later, includes 13 Regional STEM Hubs covering all counties in Oregon, aims to improve student participation and outcomes in STEM education and Career and Technical Education (CTE), and increase the number who enter high-wage, high-demand STEM professions. The Oregon CTE State Plan integrates state and federal priorities into a plan for the Strengthening Career and Technical Education for the 21st Century Act by leveraging ongoing partnerships and identifying actionable strategies. The CTE State Plan focuses on supporting schools and colleges in serving underserved and marginalized students and families with equitable access to CTE programs.

PROGRAM HIGHLIGHTS: *City of Hillsboro Advanced Manufacturing Workforce Partnership & Youth Apprenticeship*

The Hillsboro Advanced Manufacturing Workforce Partnership (HAMWP) brings together the Hillsboro School District, Portland Community College, workforce service providers, and community-based organizations to expand access to training opportunities that provide pathways to direct employment, create culturally and linguistically relevant career mapping, and launch a campaign promoting careers in advanced manufacturing. The City is building capacity through investments that support a strong workforce ecosystem, including an aligned talent pathway informed by industry, community engagement to support priority populations, and advocacy and awareness of the manufacturing sector.
- Hillsboro Advanced Manufacturing Workforce Partnership 2022 Annual Report

Oregon's Semiconductor Education and Training Programs Are Advancing Opportunities for a Diverse Workforce

Oregon is home to 17 community colleges and seven public universities. Many of these institutions offer coursework, work-based learning, and research in semiconductor-related fields such as microelectronic and mechatronic engineering and technology, industrial mechanics, chemistry, and computer science. Oregon's education and training programs expand equitable opportunities for a diverse workforce and advance Oregon's economic competitiveness, providing short-term pathways to meaningful employment, higher earning potential, and opportunities for economic mobility. **The highlights here are not intended to be a comprehensive list of programs; please contact the institutions directly on their offerings.** Oregon postsecondary institutions support student success in many ways which often include:

- Career and technical education certificate and degree programs, along with transfer options, that open pathways to both further education and a variety of jobs, from entry-level positions to advanced careers;
- Partnerships with employers, community-based organizations, workforce service providers, and public agencies, which help ensure direct access to industry-informed training, internships, and job opportunities;
- Hands-on training, often using state-of-the-art technology;
- Culturally appropriate wraparound services that support a more diverse student body, and in turn, advance a more diverse workforce;
- Pathways for students to successfully transfer between programs at different institutions that maximize credits toward their degrees and certificates; and
- Many institutions offer a range of Credit for Prior Learning (CPL) opportunities as a way to obtain credit for evidence-based assessment of learning that occurs outside of traditional college-level coursework.

Oregon's approach to equitable prosperity aims to provide diverse jobseekers with culturally and linguistically relevant career-connected learning and employment services, connecting businesses to the skilled labor they need for growth.

Several of **Oregon's community colleges** prepare students for positions in the semiconductor industry through a range of certificates and degree programs, as well as through a variety of partnerships. Highlights include:

- Columbia Gorge Community College (CGCC) prepares students for careers in renewable energy and engineering fields through its Electro-Mechanical Technology (EM) associate degree. CGCC's Technology and Trades programs, like advanced manufacturing and fabrication, support employers reliant on and supporting the semiconductor industry. The EM and Technology and Trades programs teach portable skills to advance within and beyond this industry. CGCC belongs to the Gorge Technology Alliance, an innovative partnership supporting technology, industry, and workforce across the bi-state Columbia Gorge region.
- Klamath Community College offers an associate degree and certificates in Computer Engineering Technology.
- Linn-Benton Community College offers an Industrial Building Mechanic certificate; Green Technician and Mechatronics: Industrial Refrigeration certificate; and associate degrees in Mechatronics and Industrial Automation Technology.
- Mt. Hood Community College (MHCC) offers certificates in Mechatronics specializing in Maintenance or Industrial Automation and associate degrees in Mechatronics, Engineering Technology, and Engineering (Transfer). MHCC is collaborating with Microchip and onsemi for several workforce training programs that include paid internship and mobile trainings.
- Portland Community College (PCC) offers a certificate in Mechatronics and associate degrees in Microelectronics Technology and Mechatronics, Automation, and Robotics Engineering Technology; PCC's OMIC Training Center and Willow Creek Center provide customized incumbent worker training programs. PCC's non-credit workforce training, including Discovery Courses, teaches career/college readiness in the context of industry sectors. One such course is Advanced Manufacturing, with entry-level training in the semiconductor industry.
- Rogue Community College offers certificates and/or associate degrees in Electronics Technology, Electronics Technician, Electrician Apprenticeship Technologies, Manufacturing/Engineering Technology, High Technology, Computer Hardware/Embedded Systems, and Computer Science Software Engineer Technology. These programs support building foundational electrical, electronics, and manufacturing skills that are needed to design, build, and test semiconductors. This includes knowledge of systems, storage, programming, design, materials, and specialized tools in the manufacturing process.

PROGRAM HIGHLIGHTS: COLLABORATIVE AND INNOVATIVE APPROACHES TO EDUCATION AND TRAINING

MHCC: Mobile Training Project

MHCC provides workforce training opportunities for incumbent workers and jobseekers in introductory mechatronics classes and provides wraparound support for participants through student resource specialists, strengthening job attainment, retention, and promotion. With support from a Future Ready Oregon grant, MHCC is creating a mobile teaching lab that will provide onsite training for incumbent workers at local manufacturing businesses. Industry experts collaborate with college faculty to deliver trainings.

PCC: Intel Quick Start Semiconductor Technician Paid Training Program

PCC is partnering with Intel, Worksystems, Inc., and the City of Hillsboro to help deliver the Intel Quick Start semiconductor training program in Washington County. This short-term, entry-level training program intentionally recruits from culturally based organizations, and advances entry-level career opportunities for women and people of color. Participants receive a $1,000 training stipend and the program expects to train 150 participants through June 30, 2023. All completers of each QuickStart cohort are guaranteed an interview with Intel. Students can then transition with wraparound support into certificates and associate degrees.

Oregon's public universities offer a number of semiconductor-relevant programs at the undergraduate and graduate level and partnerships. **The public universities have each provided the following highlights of semiconductor-related programs and activity.**

- Eastern Oregon University (EOU) offers a Chemistry degree that includes coursework introducing students to the chemistry of semiconductors. Interested students have the opportunity to gain research experience and explore the structure/property relationships in semiconductors based on the synthetic conditions. Students gain experience with sol-gel synthesis, spin coating, four-point resistivity and Seebeck measurements, x-ray diffraction, and scanning electron microscopy.
- The Oregon Institute of Technology (Oregon Tech) offers a variety of Engineering programs that include coursework in semiconductor devices, semiconductor device physics, semiconductor process engineering, and embedded systems engineering technology. The university also participates in the Multiple Engineering Cooperative Program—a robust, hybrid educational and industry experience for university engineering students. The program enables participants to take seminars and engage in two six-month internships with partners from businesses, cities, and community-based organizations across Oregon. Oregon Tech also partners with high schools and community colleges to prepare students to transfer to the university's bachelor programs at its Klamath Falls and Wilsonville campuses.
- Oregon State University's (OSU's) College of Engineering is the 7th largest engineering college in the nation for undergraduate enrollment. In fall term 2022, the college enrolled 9,132 undergraduates, 685 master's degree students and 528 doctoral students. In 2022, OSU awarded 2,247 computer science degrees, the most of any college or university in the nation. OSU is a national leader in training data analysts, artificial intelligence scientists, circuit designers, and materials, device, and software developers vital to the semiconductor industry. OSU has research and innovation partnerships with multiple firms in the semiconductor industry, including Intel, HP, NVIDIA, and Lam Research. Related special projects underway include the development of the $213 million Jen-Hsun and Lori Huang Collaborative Innovation Complex (which will include an NVIDIA supercomputer and state-of-the-art clean room, and will also be the hub for OSU's efforts to diversify the STEM pipeline); spearheading of a $1M National Science Foundation Regional Innovation Engine development award in partnership with over 20 public sector, industry, and academic partners; joining over 200 institutions and over 1,500 SEMI member companies that are advancing the American Semiconductor Academy Initiative & SEMI project, which is focused on the U.S. semiconductor talent pipeline; and serving as a founding member in Micron's Northwest Semiconductor Network, which establishes a core group of universities to address the full

technical needs and demands of the industry and expand STEM access to underrepresented students, including women, people of color, and Indigenous and rural communities. OSU's work is guided by a Semiconductor Strategy Advisory Committee that is focused on identifying and advancing initiatives that capitalize on federal and industry calls related to CHIPS, in collaboration with industry and government partners. OSU is currently leading or participating in over 20 proposals that range from internal efforts to expand semiconductor-related curricula via various modalities and levels (onsite, online, undergraduate, graduate) to proposals seeking to advance research in areas critical to the industry such as lithography, electronic materials science, and chip cooling. OSU's depth of experience is supported by the state's two-decade investment in Oregon's public engineering and computer science programs. These funds have transformed engineering programs, supported innovation, and significantly increased the diversity of graduates in STEM fields.

- Portland State University (PSU) provides an engaged, diverse workforce for Oregon's semiconductor industry. PSU graduates work across the semiconductor enterprise: in fabrication, in the research laboratory, in the administrative offices, and in the boardroom. The university offers undergraduate and graduate degrees as well as certificates across a range of programs. These include Physics (Applied Physics, Nano & Materials Track, etc.), Computer Science (AI/ML, security, software), Electrical Engineering (Embedded Systems, Analog, RF & Microwave Circuits), Material Science, Engineering Management, and business degrees in a range of key services. Over 45 percent of undergraduates are students of color and nearly 60 percent are women. Eighty percent of PSU students are from Oregon. In 2023, PSU graduated over 5,500 students, with nearly 600 engineering graduates. PSU is also home to numerous state-of-the-art facilities and multi-university collaborations that support faculty research efforts related to semiconductors. Learn more at pdx.edu/semiconductors
- The Chemistry Department at Southern Oregon University (SOU) prepares undergraduates to enter the semiconductor job market with a B.S. in Chemistry. SOU's American Chemical Society-accredited curriculum includes core concepts and scientific principles related to semiconductors. Over the past seven years, 13 SOU undergraduate research students have been mentored in the specialized field of cationic aluminum-oxyhydroxide clusters. These aluminum nanoscale clusters have been proven to be environmentally friendly and effective precursors to create dense, defect-free aluminum oxide thin-films, which are extremely relevant to the semiconductor industry. SOU is also actively conducting research with five students on liquid crystal organic photovoltaics via the monetary support of a Providing Research Infrastructure in Space and Materials Sciences grant.
- University of Oregon (UO) supports research expertise, facilities, and programming needed to recruit diverse students and connect them with semiconductor and advanced manufacturing industries. The Oregon Center for Optical, Molecular, and Quantum Science seeks to promote and facilitate research and education that directly advance fundamental science and technology applications related to semiconductor technologies. The Materials Science Institute (MSI) facilitates leading-edge research in polymers, synthetic chemistry, and advanced materials. On average, 10-15 Ph.D. students trained in MSI are placed in the semiconductor field. Faculty in the Knight Campus for Accelerating Scientific Impact advance research at the intersection of hard and soft materials, with implications for biotechnology, semiconductors, and human health. UO's Knight Campus houses the state's first public Class 1000 cleanroom to support the fabrication of next-generation micro-and nano-scale devices on traditional semiconductor substrates as well as soft materials. Established in 2010 through state investment, CAMCOR is a full service, comprehensive materials characterization center that serves as a national resource for researchers, a training ground for students, and industry partnership for unique instrumentation. UO confers roughly 1,000 STEM undergraduate degrees annually and is number 1 in the nation in applied Physics master's degrees and number 5 in Applied Chemistry master's degrees. The Knight Campus Graduate Internship Program is an accelerated master's program with a nine-month paid internship. Tracks include Photovoltaics and Semiconductors, Polymer Science, Optical Materials & Devices, and more. On average, 25 program graduates are placed annually in the semiconductor field.
- Western Oregon University's (WOU's) Computer Science, Information Science, Data Analytics and Math-Computer Science programs can support semiconductor development and the semiconductor industry in several ways. Research and innovation at WOU can contribute to advancements in areas such as materials science, circuit design, and computational modeling. WOU can also provide education and training programs that equip students with the knowledge and skills necessary for careers in the semiconductor industry. WOU's computer science program can offer specialized courses in areas such as integrated circuit design, semiconductor physics, and device modeling. In addition, WOU's programs can provide a pipeline of talented graduates who are well-versed in programming, algorithms, data analysis, and other relevant skills.
- Oregon Tech, OSU, and PSU are members of the Oregon Manufacturing and Innovation Center (OMIC R&D). Oregon Tech also serves as the operational host of the facility. OMIC R&D is a collaboration of industry, higher education, and government entities working together to address challenges in manufacturing that may be unsolvable when approached in isolation. Center activities engage in applied research such as concept design, prototyping, third-party unbiased product testing, and development of innovative manufacturing methods to apply on the manufacturing line.
- OSU, PSU, and UO number among the 13 founding partners that comprise Micron's newly convened Northwest University Semiconductor Network. The network will "support research and experiential learning opportunities in the computer chip industry with equitable access for underrepresented students, including those in rural and tribal communities" (OSU).

For More Information

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