Building a Micro/Nanotechnology Cleanroom Training

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Abstract: The Central Coast Partnership for Regional Industry-Focused Micro/Nanotechnology Education (CC-PRIME) is a regional collaboration between Santa Barbara City College (SBCC), the University of California Santa Barbara (UCSB), and local industry partners, with the goal of addressing a demonstrated local workforce need in the field. Existing training available through the Support Center for Microsystems Education (SCME) was adapted with input from local industry to develop an initial cleanroom training in Micro/Nanotechnology for community college students and faculty. Two summer training sessions have been implemented, with student focus groups and industry feedback guiding modifications and additional training development. Ongoing input from local industry partners and an opportunity to leverage the existing SCME curriculum that project staff and faculty were trained on have proven critical in the development of the training. Access to local cleanroom facilities and staff and initial training for community college faculty were essential to successfully implementing the project. Additional modules and trainings are being developed to build out further and broaden this initial cleanroom training.

Keywords: micro/nano technology, regional collaboration, cleanroom training, curriculum, local workforce

Introduction

The California Central Coast hosts a surprisingly large number of high-tech semiconductor and micro- and nanotechnology companies. The cities of Santa Barbara, Goleta, and Carpinteria in Santa Barbara County host more than 45 companies that utilize semiconductor cleanroom facilities in their manufacturing [1]. The facilities span the Micro/Nanotechnology and semiconductor application space, including integrated photonics, microelectronics, microfluidics, medical imaging, biotechnology, infrared, defense, and space-based applications [1].

Many local high-tech companies regularly utilize the Nanofabrication (NanoFab) Facility at the University of California Santa Barbara (UCSB) [2]. This 12,000 square foot, class 100 and 1,000 state–of–the–art cleanroom facility is available to researchers, faculty, and industry [3]. Additional cleanroom facilities at UCSB that are primarily utilized by faculty and researchers include the Quantum Structures Facility (QSF) at UCSB's California NanoSystems Institute. The QSF houses a mix of traditional semiconductor processing equipment, specialty deposition tools, a photoluminescent/Raman spectroscopy suite, and a Crystal Growth Facility [4]. It is one of the locations for the new National Science Foundation (NSF) funded Quantum Foundry [5].

Santa Barbara City College (SBCC), a public community college and Hispanic Serving Institution, has a long history of collaborating with UCSB, often through its Center for Science and Engineering Partnerships (CSEP), particularly in Physical and Life Sciences and Engineering. Through these existing

collaborations, UCSB NanoFab staff, researchers, and SBCC faculty and administrators initially connected with local Micro/Nanotechnology industry partners.

Table 1. Project Partners, Roles, and Facilities

Project Partner	Acronym	Role/Facility
Santa Barbara City College [6]	SBCC	Community College; Project Lead
University of California, Santa Barbara [7]	UCSB	R1 Research Institution; Project Subawardee; Cleanroom Facilities
NanoFabrication Facility [2]	NanoFab	UCSB Research and Industry Cleanroom Facility; Technical Project Staff
California NanoSystems Institute [8]	CNSI	Project Lecture/UCSB Lab Facilities; Project Support Staff
Quantum Structures Facility [4]	QSF	CNSI Cleanroom Facility/ Project Cleanroom; Technical Project Staff
Center for Science and Engineering Partnerships [9]	CSEP	External Evaluator
Math, Engineering, Science Achievement Program[10]	MESA	SBCC Student Recruitment and Support

This collaboration between SBCC, local high-tech industry partners, and UCSB's NanoFab and QSF cleanroom facilities grew into the Central Coast Partnership for Regional Industry-Focused Micro/Nanotechnology Education (CC-PRIME), currently funded through the National Science Foundation (NSF), in an effort to solve this critical regional workforce development challenge.

CC-PRIME is a collaborative project between SBCC and UCSB to utilize local industry input and leverage the advanced cleanroom facilities at UCSB to fill a demonstrated local industry need for job-ready cleanroom technicians. The project goals are (1) to build industry visibility and relations within the community, (2) to provide SBCC students and faculty with training and experiences in manufacturing at the university cleanroom facility, and (3) to create a student educational pathway to acquire semiconductor manufacturing jobs, incorporating industry input.

Informal inquiries revealed that California Central Coast high-tech companies experience great difficulty and financial risk in hiring technicians and operators in Micro/Nanotechnology and semiconductors [11]. While positions at the bachelor's and graduate degree levels often can be filled with local talent graduating from UCSB or graduates from other institutions moving to the region, filling positions at the technician/operator and associate's degree levels has proven extremely difficult for many companies in the area [11], [12], [13]. No Micro/Nanotechnology-specific training existed at SBCC or other regional community colleges. Many companies have resorted to hiring non-local applicants from other institutions with cleanroom experience and training/degrees/certificates. Still, without local roots, they tend to leave due to the region's extraordinarily high cost of housing. This particular challenge is most acutely felt by small companies where person power is at a premium [11], [12], [14].

Methods

Initial Training Development

Identifying and connecting to existing resources in the Micro/Nanotechnology education sector proved critical for generating the initial framework of the CC-PRIME project. This included the three NSF-funded Advanced Technological Education (ATE) Centers: the Micro Nano Technology Education Center (MNT-EC) at Pasadena City College [15], the Support Center for Microsystems Education (SCME) at the University of New Mexico [16], and the Nanotechnology Applications and Career Knowledge Network (NACK) at Pennsylvania State University [17]. The established 40-hour-long microchip fabrication "bootcamp" developed by Dr. Matthias Pleil at the University of New Mexico proved particularly suitable as a model for adaptation to our local industry needs [16].

In addition to Dr. Pleil providing documentation, curriculum resources, and advising regarding his overall cleanroom training and micro-pressure sensor fabrication lab, several CC-PRIME project leads, including two UCSB cleanroom staff and one SBCC faculty member, were able to participate in SCME's week-long training at its cleanroom facility at the University of New Mexico. Attending Dr. Pleil's training as participants provided valuable insights for project leads at both institutions beyond the covered curriculum. This was particularly true for the set-up and streamlining of the overall training methodology, including splitting each session into classroom and cleanroom sections, effective utilization of graduate student TA assistance, and establishing the requirement to offer online safety training before starting the class. Having an instructor with specific semiconductor industry experience was also noted as a particularly important and helpful training component.

While some of these training components could have been pulled from training outlines and shared course curricula, it is doubtful that their relative importance and associated values would have become apparent. These integral components of SCME's cleanroom training have been developed, implemented, evaluated, and reformulated over many years. These nuances and the relative importance of different training components would not have been as apparent to our project staff and faculty without completing the existing training ourselves. Having this knowledge readily available facilitated and informed the formation of our training, particularly with respect to which program components are critical to keep for this project and which might be less critical and could reasonably be adapted to our local needs.

CC-PRIME's initial industry needs assessment among the project's Industry Advisory Board (IAB) members identified exposure to working in a cleanroom environment as a critical component of an initial technician/operator training and overall showed significant alignment with SCME's microchip fabrication bootcamp curriculum [18]. Some IAB members expressed a desire for additional company-specific training, e.g., on specific instrumentation/processes heavily utilized at their facility. Accommodating very company-specific training needs proved not to be feasible for a variety of reasons. This approach would have focused the student training on a small subset of companies rather than being broadly applicable to the entire industry. Student recruitment is highly dependent on the broad applicability of the training in that it should make the student a viable candidate for as many jobs/companies as possible. We found that the students' needs for broadly applicable training conflicted with the industry request for training specific to one company's needs. It was critical to explain this disparity to our industry partners, who often did not intuit the student perspective but very much appreciated the insight. Therefore, the overall focus of adapting the existing curriculum was on training components that would broadly apply to many industry partners, e.g., those focused on production tracking methods and communication protocols that we have observed at many local semiconductor companies [18], [19].

Table 2. Initial Industry Advisory Board (IAB) Members

Company	Location	Employees
BEGA North America	Carpinteria, CA	500 +
Freedom Photonics LLC (a Luminar company)	Goleta, CA	< 500
Kyocera SLD Laser	Goleta, CA	500 +
Nexus Photonics	Goleta, CA	< 500
Praevium Research Inc.	Goleta, CA	< 500
Thorlabs Crystalline Mirrors	Santa Barbara, CA	500 +
Transphorm Inc.	Goleta, CA	< 500

Implementation

To facilitate the initial training, SCME-trained CC-PRIME project staff identified and trained two UCSB graduate students to primarily support sessions in the cleanroom. A retired semiconductor professional from one of the local industry partners was recruited as additional instructional support and to provide the participants with relevant industry input.

In the summer of 2022, the initial training was carried out at the QSF facility at UCSB, overseen by an industry professional supported by two graduate students and the project staff originally trained at the University of New Mexico's SCME. One of the objectives of the CC-PRIME project was to train faculty in the first training before bringing in students. The initial training was performed during ten roughly half-day sessions over two weeks to enable better use of periodic downtime for individual trainees during several cleanroom processes and to give trainees more flexibility with their schedules. The initial faculty cohort consisted of four community college faculty from SBCC and Allan Hancock College, a neighboring community college, and six up-skilling participants [20]. The project's first-year focus was on faculty professional development, testing, and streamlining the developed training and corresponding processes. Focusing on faculty professional development prior to opening the training to students allowed for increasing awareness about the local Micro/Nanotechnology industry and its employee needs among faculty. It also provided faculty with an opportunity to bring back training experiences and modules into their existing courses at the community college and equipped them with the background knowledge to serve as ambassadors for the program going forward [21].

In the summer of 2023, the subsequent training was again carried out at the QSF facility, with six community college student participants and four industry/non-academic participants. Based on previous staff and participant feedback, the training was adjusted to be held in five full-day sessions over one week. Community college student recruitment relied heavily on existing student support structures and associated programs at SBCC, such as the Math, Engineering, and Science Achievement (MESA) Program[10] and the STEM Transfer Program (STP) [22]. Faculty who participated in the previous training served as ambassadors for student outreach and recruitment. Interested students were asked to complete a brief application, including a transcript and a personal statement discussing their educational goals and reasons for participating. Student participants were selected based on merit criteria, previously completed courses, and training alignment with their academic goals. All student participants were SBCC Engineering and Computer Science majors on initial transfer pathways. Industry participants were selected with help from IAB members based on the alignment of the training with IAB member-specific employee upskilling needs [23].

Results and Discussion

The initial cleanroom training during the summer of 2022 focused on faculty professional development and was completed by four community college faculty. Several industry partners, including IAB member Kyocera SLD Laser, sent six new or existing employees to the same training as an upskilling opportunity, providing additional industry exposure to faculty and networking opportunities between faculty and industry. As a result of the training, and in addition to collaborating with industry to develop additional course curricula and training modules, the role of faculty to serve as ambassadors to students for the program and the local industry was strengthened. Through this direct industry exposure, participating faculty have gained a much deeper understanding of the existing local Micro/Nanotechnology industry sector, its workforce needs, and the corresponding job opportunities that exist in the local area for community college students [1], [12], [13], [21], [24].

The subsequent cleanroom training during summer 2023 was slightly modified based on previous participant feedback, primarily with respect to logistical and operational day-to-day aspects of the training. It was completed by six community college students and four industry/non-academic participants. Similarly to the networking aspect between faculty and industry participants, providing students with an opportunity to learn side-by-side with industry members resulted in additional exposure to the local industry and networking opportunities for students [23].

After completion of the training, the project's external evaluator held focus groups with training participants to gather their feedback and level of satisfaction with it. Participants were asked for their reasons for participating, what they hoped to get out of the training, and whether it accomplished what they had hoped for. Participants were also interviewed about the curriculum, whether the training covered the concepts and techniques they had envisioned being covered, and whether they felt adequately prepared for it with respect to their previously completed courses. Additional questions centered around logistical aspects of the training, support during the training, and participants' future educational and career goals [21], [23].

The external evaluator reported that all participants felt that the training experience met their expectations. Faculty who participated gained greater familiarity with and exposure to the local Micro/Nanotechnology industry, specifically its cleanroom utilization. They also have begun to explore ways of potentially using the training at their respective institutions and assisting with student outreach and recruitment [21], [23]. For industry, one main goal has been for the training to help mitigate the existing local talent shortage in Micro/Nanotechnology [11], [13]. In addition, trainees not currently working in cleanroom environments noted the benefit of improving their understanding of the overall cleanroom processes and familiarizing themselves with the various requisites to pursue a cleanroom job [21], [23]. Students noted that, besides the technical training and skills learned in the cleanroom and during corresponding lectures, they expanded their understanding of possible local career paths in Micro/Nanotechnology that they did not know existed prior to taking the training. They also formed valuable connections with local industry partners and staff and faculty at the four-year institution [21], [23].

All participants from all three groups, community college students, faculty, and industry, reported that the training met and exceeded their expectations and needs. Several expressed an interest in additional and more in-depth training. At the same time, some thought that additional prior preparatory knowledge could be helpful, such as around chemical concepts or commonly used acronyms. Some students noted that having more explicit connections to potential internships or job opportunities with local companies could be beneficial [21], [23]. This is now integrated into the program more directly through additional follow-up with industry partners about job openings or internship opportunities and also by directly connecting students who completed the training to industry collaborators.

Industry partners noted a desire for additional training, not all of which would need to be in a cleanroom, and some of which vary from company to company in terms of what learning objectives should be covered. This includes areas related to semiconductor manufacturing, equipment maintenance, facilities maintenance, and assembly and testing [21], [23]. Dialogues with IAB members and other industry partners are currently ongoing to identify the next steps in building additional training opportunities and modules [18], [19], [25].

Faculty have expressed interest in ongoing collaborations and networking opportunities with industry partners for them and their students [21], [23]. Current efforts include guest lectures, industry tours, community outreach events, and other professional networking opportunities to grow awareness about this field and associated local employment needs and opportunities.

Conclusion

In developing this Micro/Nanotechnology cleanroom training, several key points have emerged as having been critical throughout the development and initial implementation phases:

Addressing local need

The project was initially developed in an attempt to address a local and somewhat specific workforce development need [11], [13]. Keeping efforts centered around that idea when developing and implementing the program and growing and expanding it has proven to be critical. It has ensured local industry buy-in, assisted with local community college student recruitment and outreach, and generated buy-in from additional local and regional community and workforce development partners [26]. This is particularly important as this training is not specifically designed to serve large-scale semiconductor fabrication facilities, which do not exist in our region [14].

Working collaboratively with local industry partners

The project's IAB members have been instrumental in designing the training curriculum in collaboration with faculty. Getting industry partners to collaborate and come to a consensus on specific training needs in addressing the common workforce challenge has opened up networking and outreach opportunities that were not available to students and faculty before [21], [23]. Local industry input into the specific workforce training needs continues to guide the development of additional training modules to ultimately become part of an entirely new student pathway into the semiconductor industry [18], [19].

Gaining access to cleanroom facility

Access to a cleanroom facility is critical for this particular training. We have been fortunate to be able to build on long-standing collaborations between the two partnering institutions, SBCC and UCSB, to gain access to one of UCSB's cleanroom facilities for this training. It is likely that some of the additional training currently in development will also require cleanroom access; however, we are also exploring options of designing additional training modules in regular laboratory settings with the appropriate equipment. Maximizing cleanroom utilization for those training components that truly need to be carried out in a cleanroom environment will reduce constraints around cleanroom access times.

Utilizing existing and established training curriculum

Adapting the existing SCME microchip fabrication bootcamp curriculum to our specific local needs has been critical to our successful launch [16]. Dr. Matthias Pleil's willingness to share SCME's established curriculum with us and allow us to adapt it with input from our local industry partners enabled us to develop and initially implement this training in a much shorter time than we would have otherwise been able to. Particularly important in this regard was the fact that several of our project staff members and

faculty were able to complete SCME's training themselves first. This proved to be critical, as it provided direct insight into the training itself. The relative importance of certain aspects of the training, its previous iterations, improvements, reasoning behind them, and first-hand experience regarding some of the specific logistical or pedagogical considerations became apparent. This would not have been effectively relayed through simple sharing of curriculum resources without going through the training first.

Training faculty first

Our initial program design called for training community college faculty prior to rolling out the training to students, with the idea of testing certain aspects with faculty before bringing in students. In addition to that effect, this also provided for increased networking opportunities between industry and faculty, and it continues to aid in faculty being able to bring the experience to their classrooms. This has helped with creating overall awareness of this local industry in the community and with recruitment and outreach efforts.

Being able to leverage an existing training curriculum that project staff and faculty have experienced themselves and collaboratively adapting it to local industry needs has been critically important in enabling the successful launch of this Micro/Nanotechnology cleanroom training. Additional curriculum and associated training are currently in development, along with efforts to broaden the community and partner outreach and local awareness. Additional semiconductor-focused workforce development grant proposals were developed as a result of this initiative and in collaboration with multiple local workforce development organizations to broaden access to local Micro/Nanotechnology training opportunities [11], [26].

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References

[1] D. Pricco, “Santa Barbara Startups and Tech Companies: Hardware.” Accessed: Jan. 25, 2024. [Online]. Available: https://www.sbtechlist.com/?wpbdp_category=hardware
[2] “UCSB Nanofabrication Facility.” University of California Santa Barbara. Accessed: Jan. 26, 2024. [Online]. Available: https://nanofab.ucsb.edu/
[3] B. Thibeault, “NanoFab User Access Data,” University of California Santa Barbara, Sep. 2023.
[4] “Quantum Structures Facility.” University of California Santa Barbara. Accessed: Jan. 26, 2024. [Online]. Available: https://www.cnsi.ucsb.edu/facilities/quantum-structures
[5] “UCSB NSF Quantum Foundry.” University of California Santa Barbara. Accessed: Jan. 29, 2024. [Online]. Available: https://quantumfoundry.ucsb.edu/
[6] “SBCC College Facts.” Santa Barbara City College. Accessed: Dec. 15, 2023. [Online]. Available: https://www.sbcc.edu/about/collegefacts.php
[7] “UCSB Facts and Figures.” University of California Santa Barbara. Accessed: Dec. 13, 2023. [Online]. Available: https://www.ucsb.edu/about/facts-and-figures
[8] “California NanoSystems Institute.” University of California Santa Barbara. Accessed: Jan. 26, 2024. [Online]. Available: https://www.cnsi.ucsb.edu/
[9] “Center for Science and Engineering Partnerships - Evaluation Services.” University of California Santa Barbara. Accessed: Jan. 26, 2024. [Online]. Available: https://csep.ucsb.edu/evaluation
[10] “Math, Engineering, Science Achievement Program.” Santa Barbara City College. Accessed: Jan. 29, 2024. [Online]. Available: https://www.sbcc.edu/mesa/

[11] K. Miller, “Industry Survey: Impediments to Growth,” presented at the Santa Barbara South Coast Chamber of Commerce, Manufacturing & Technology Committee Roundtable, Santa Barbara, CA, Jan. 31, 2020.
[12] E. Johnston, “2023 Central Coast Workforce Analysis.” TIP Strategies, Apr. 12, 2023. Accessed: Jan. 25, 2024. [Online]. Available: https://public.tableau.com/app/profile/tipstrategies/viz/2023REACHWorkforceAnalysis/Title
[13] B. Werner, “Industry Jobs Listings September 2023 - Public.” Sep. 30, 2023. Accessed: Jan. 12, 2024. [Online]. Available: https://docs.google.com/spreadsheets/d/14WC_eB5x9qi7SYPm1pZgFbfB4bIBTmCFe10RKQtFQPc/edit#gid=0
[14] E. Johnston, “2022 Central Coast Economic Explorer.” TIP Strategies, Jul. 05, 2023. Accessed: Jan. 12, 2024. [Online]. Available: https://public.tableau.com/app/profile/tipstrategies/viz/2022REACHEconomicExplorer/Title
[15] “Micro Nano Technology Education Center.” Accessed: Jan. 22, 2024. [Online]. Available: https://micronanoeducation.org
[16] “Support Center for Microsystems Education.” Accessed: Jan. 25, 2024. [Online]. Available: https://scme-support.org
[17] “Nanotechnology Applications and Career Knowledge Center.” Accessed: Jan. 25, 2024. [Online]. Available: https://www.cneu.psu.edu/nano4me/
[18] E. Sciaky, “CC-PRIME Needs Assessment Interviews with Industry Advisory Board Members,” Center for Science and Engineering Partnerships, Spring 2022.
[19] T. J. McCue, “Microsystems Process Technician: Knowledge, Skills & Abilities,” Micro Nano Technology Education Center, Jun. 2023. Accessed: Jan. 25, 2024. [Online]. Available: https://micronanoeducation.org/semiconductor-jobs-knowledge-skills-and-abilities/
[20] “All About Allan Hancock College.” Allan Hancock College. Accessed: Jan. 29, 2024. [Online]. Available: https://www.hancockcollege.edu/about/index.php
[21] E. Sciaky, A. Leak, and L. Lenaburg, “CC-PRIME Post-Training Focus Group Report 2022,” Center for Science and Engineering Partnerships, Apr. 2023.
[22] “STEM Transfer Program.” Santa Barbara City College. Accessed: Jan. 29, 2024. [Online]. Available: https://www.sbcc.edu/stem/stemtransferprogram.php
[23] E. Sciaky and L. Lenaburg, “CC-PRIME Post-Training Focus Group Report 2023,” Center for Science and Engineering Partnerships, Oct. 2023.
[24] E. Shein, “Global Chip Shortage: Everything You Need to Know.” TechRepublic, Oct. 19, 2023. Accessed: Jan. 25, 2024. [Online]. Available: https://www.techrepublic.com/article/global-chip-shortage-cheat-sheet/
[25] “National Talent Hub: Connecting Industry, Talent, and Training Like Never Before.” National Institute for Innovation and Technology. Accessed: Jan. 10, 2024. [Online]. Available: https://nationaltalenthub.com/
[26] “About the Workforce Development Board.” County of Santa Barbara: Workforce Development Board. Accessed: Jan. 12, 2024. [Online]. Available: https://www.countyofsb.org/1947/About-the-Workforce-Development-Board