

Expanding the Boundaries of Semiconductor Education Using Virtual Reality Content Created at the Cornell NanoScale Facility

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Summary of Research:

Recent advancements in the areas of artificial intelligence, quantum computing, Internet of Things (IoT), and a generally more connected world have led to a generational expansion of U.S. and worldwide semiconductor device fabrication capabilities. A key focus area of this expansion has been the development of a highly skilled technical workforce in semiconductor device processing. In the United States alone, workforce shortages in the semiconductor industry are projected to range between 59,000 and 146,000 workers by the year 2030 [1], [2]. This generational challenge of global semiconductor fabrication expansion and a potential workforce shortage present a unique opportunity to explore new pathways in immersive education that are scalable to a wide range of students from diverse backgrounds.

Immersive and experiential learning have been identified as important learning techniques, improving comprehension of complex topics and aiding in content retention [3], [4]. Virtual reality (VR) can allow immersive learning experiences in environments where students do not have direct access, which is critical to scalability at the level required to meet the talent demands of the growing semiconductor industry.

University cleanroom environments have been and remain a critical part of the talent pipeline for this industry and also enable critical advancements in fundamental science, discovery, and development of new technologies. These shared, open-access facilities present unique opportunities for students to engage in cutting-edge scientific equipment and make critical scientific breakthroughs that would not be possible for a single research group alone.

The Cornell NanoScale Facility (CNF) is staffed by 18 qualified experts with over 500 years of combined

experience in the areas of microfabrication and nanoscale device creation and engages in many in-person learning opportunities for students from diverse backgrounds. While fruitful, these in-person experiences are geared toward groups of 10-20 students at a time and could not scale to meet the workforce demands in our region, let alone have a national or worldwide impact.

For these reasons, we have created a series of VR educational experiences in partnership with the Cornell Center for Teaching Innovation (CTI) that focus on the core competencies of semiconductor device fabrication (i.e., gowning, safety, photolithography, etching, deposition, and metrology). To date, we have engaged over 2,000 learners from across the learning spectrum using this technology, with over 1,200 cumulative learning hours spent in the VR learning environment. Unlike typical 3D rendered VR environments, the CNF VR modules utilize high resolution 360-degree video along with embedded interactive content and quizzes to bring learners directly into the cleanroom learning environment for experiential learning using the Uptale Immersive Learning platform.

To evaluate the effectiveness of these modules, we conducted a concurrent mixed-methods study in the Spring semester of 2025 in a chemical engineering course that used modules on photolithography. Surveys were administered to all students ($n = 62$) immediately after experiencing the modules, and 24 students were interviewed for feedback on the learning experience. The data indicate that the VR photolithography modules were highly engaging and motivating for students, with strong satisfaction, sustained attention, and perceived value for learning. Students reported substantial learning gains, particularly through the immersive visualization of complex processes, which effectively connected lecture concepts to real-world applications and, in some cases, increased confidence for industry-related

career paths. VR also improved access to otherwise restricted laboratory environments and was viewed as more effective than traditional videos or readings for experiential learning. The results of this work will be used in future iterations of this technology.

Question No.	Please rate your agreement with the following statement:	Code
1	I enjoyed this lab.	enjoyed
2	I see the value in participating in this lab.	seeValue
3	I tried my hardest to do well in this lab.	triedHard
4	I am more interested in a career in the semiconductor industry now that I have completed this lab.	career
5	I learned something new from this lab.	learnedNew
6	Concepts I learned in lecture were reinforced by this lab.	concepts
7	I recommend this lab be instituted next year.	recommend
8	I felt safe while participating in this lab.	feltSafe
9	This was my first experience with VR.	firstVR
10	The VR modules were easy to navigate.	navigate
11	The VR modules were too lengthy.	tooLengthy
12	The VR equipment was comfortable and user-friendly.	comfortable
13	The VR experience was immersive.	immersive
14	I am interested in an in-person tour of the CNF labs.	tour

Table 1: Lab Feedback Survey Items.

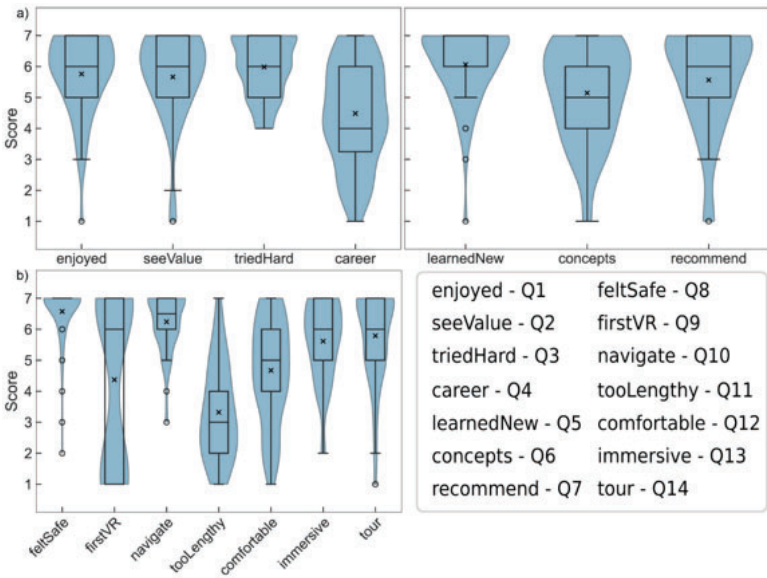


Figure 1: Quantitative lab feedback survey results. Student responses to (a) motivation and learning and (b) VR-specific items are shown as violin and box plots.

Conclusions and Future Steps:

We have demonstrated the potential of VR modules to meet the growing demand for scalable, informative, and enjoyable cleanroom instruction to support the expanding US semiconductor industry. Through both quantitative survey responses and qualitative interviews, our students expressed a perception of the photolithography modules we have developed as enjoyable, effective for teaching, and satisfactory alternatives to touring the lab in-person. Future work in this area should prioritize module interactivity to fully leverage the capabilities of the VR environment. Subsequent implementations of the existing modules should also emphasize the importance of eye breaks to avoid possible detrimental physical effects. Overall, VR instruction remains a promising avenue to expand access to laboratory content to meet growing workforce development needs.

References:

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[2] Semiconductor Industry Association, “Chipping Away: Assessing and addressing the Labor Market Gap Facing the U.S. Semiconductor Industry.” Jul.2023.[Online] Available:<https://www.semiconductors.org/chipping-away-assessing-and-addressing-the-labor-market-gap-facing-the-u-s-semiconductor-industry/>.

[3] D. Beck, “Special Issue: Augmented and Virtual Reality in Education: Immersive Learning Research,” Journal of Educational Computing Research, vol. 57, no. 7, pp 1619-1625, Dec. 2019, doi: 10.1177/0735633119854035.

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