Bridging the Gap: A Course Comparison Study of Graduate Semiconductor Education Through Traditional Coursework, Internship, and Novel Role-Playing Work Experience

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Abstract:

With a high demand to fill graduate level jobs in the semiconductor manufacturing industry there is a need to increase job readiness and ease the transition from academia to industry. Traditionally, graduate academic education pedagogy does an excellent job of providing students with theoretical knowledge and scientific research skills, such as technical writing, communication, and research and development. However, the typical graduate research experience does not fully prepare students for industry work experience. To overcome this challenge, the authors developed a novel two course curriculum that mimics an internship and startup company work experience in the semiconductor manufacturing area. This is accomplished through "role-playing" courses where students act as internships in the 1st semester (onboarding) and then they transition to employees in the second semester. A self-study survey was used to compare students in three categories i) mock work experience courses, ii) students with previous real-world internship or work experience, and iii) students who took traditional semiconductor manufacturing courses with no work experience. Results of the survey indicate that students with internships and students in our new mock work experience courses scored higher in 71% and 69% of the topics compared to students taking traditional courses respectively. In addition, the students participating in our "mock" work experience scored higher than the students with actual work experience in 63% of the categories. These results indicate that this new role-playing work experience pedagogy is more efficient at providing key knowledge, skills, and abilities (KSA) than typical academic courses and is at least equal if not a little better than an actual internship over a range of topics.

1. Introduction and Literature Review:

With high demands to rapidly advance semiconductor and microsystems manufacturing there is a need to increase the quality of MS/PhD students by increasing job readiness in this field. Advanced manufacturing jobs are in high demand for all levels including technicians (High school or associate degree level), engineers (undergraduate level) and engineers with graduate degrees. Technicians or students with undergraduate degrees are easier to hire as companies expect longer onboarding efforts. However, students with a MS or PhD's are expected to add value to the company at a much faster rate and have increased technical and essential skills. Industry members often complain that new hires do not possess the knowledge, skills, and abilities (KSA) needed to make an impact to the company in the time frame that they desire [1, 2]. Therefore, there is a high demand to change the pedagogical methods used to teach semiconductor/microsystems engineering courses to help bridge the gap between academia and industry and increase job readiness. Methods to increase job readiness for technicians and undergraduates have been investigated [3-6] but little research has been investigated to enhance graduate education in the semiconductor area [7-9]. Most of the efforts have involved creating problem-based learning (PBL) courses which have shown enhancements in specific tasks, but students still find transitioning from academic life to industry life challenging. Other attempts include using virtual reality for universities that do not have access to cleanroom [10]. While others have focused on student self-learning methods, student-centered pedagogy, and AI methods [11-13]. However, most of these methods fail to tackle the problem from an industrial perspective including cultural differences between academia and industry.

Recent PBL based methods used to increase job readiness in microsystems manufacturing have focused on developing microfabrication training in a cleanroom environment [10, 14-16]. However, the theoretical knowledge aspect still focuses on traditional lecture methods. Results of a recent industry lead KSA survey indicates that semiconductor companies are mostly satisfied with the theoretical knowledge of graduate students, but the work environment (culture), skills and abilities are lacking [17, 18]. The trend of not having desired KSA is growing in large part due to the increased number of MS students opting for non-thesis degrees, which results in students not obtaining the desired skills or abilities [19, 20]. However, semiconductor companies are raising concerns that even thesis students often lack the KSA needed by industry as current academic thesis options often do a good job of preparing students for academic careers or R&D jobs. However, the majority of semiconductor jobs are focused on advanced manufacturing. Typical graduate academic education pedagogy does an excellent job of providing students with knowledge and scientific research skills, suitable for R&D work but not advanced manufacturing. Considering only 10-15% of PhD engineering students go on to have an academic career that means that current pedagogy is not geared towards providing students with the needed KSA to transition easily to industry. Currently the best method to provide the desired KSA to graduate students is through internships [6, 21-23]. However, internships are not always possible for graduate students due to location and time constraints, citizenship status, academic research requirements, and limited opportunities especially for international students. This results in the majority of students not opting to have industry work experience until after they graduate, which is why students are struggling with transitioning from academia to industry. This creates stress on the student/employee as well as frustration to the company [24]. Attempts to overcome this have been attempted by increasing hands-on experience in labs [25-27]. However, these are typically academic lab environments, and they provide students with fundamental skills, but they often lack the culture, high demands, and work environment often found in semiconductor industries.

An attempt to overcome this challenge is presented in this paper, which describes a novel two-course project that aims to mimic an internship and startup company work experience while in an academic setting. The two-part course is a role-playing PBL based course where students act as interns/employees and the instructors are supervisors/managers. The courses have an industrial work culture mindset rather than the traditional academic setting. The concept aims to provide students with a similar internship experience as they would get at a typical semiconductor internship or training within their 1st year with the company. The paper describes the two-course curriculum in detail, and to evaluate the novel curriculum a self-study survey was completed and compared between students with different experiences including: i) students that took the new role-playing courses, ii) students taking traditional semiconductor lecture courses, and iii) students with real-world internship and/or work experience. Previously, self-surveys have been an effective method of assessing KSA proficiency in graduate engineering student, and thus a similar evaluation process was used in this study [28, 29]. The goal of developing a new pedagogy is to increase job readiness for graduate students, which is defined as the ability to add value to the company during the 1st year of hire by understanding the fast-paced work culture, working in diverse team environment, and making company needs top priority. Industry members have indicated that students lack specific KSA, and that by having these KSA they feel students will be better prepared for the transition to industry thus increasing job-readiness. Ultimately the research question that this paper is investigating is:

- Can a role-playing work experience curriculum provide increased job-readiness compared to traditional teaching and work experiences (ie. internship and typical course lectures)?

2. Methodology

2.1 Description of New Course Curriculum:

The instructors have previous experience in enhancing job readiness for technicians and undergraduates in the semiconductor industry [30, 31] and have significant experience in developing novel hands-on labs for semiconductor/microsystem graduate education [32] as well as developing online videos on microfabrication on various platforms such as YouTube designed to supplement lectures [33]. The goal of this study was to develop a novel pedagogy to increase job readiness for graduate engineering students in the field of semiconductor manufacturing. The authors developed role-playing courses that allow students to gain industrial experience in an academic course. The courses use problem and project-based learning (PBL) but enhance it by also including an industrial culture environment. For instance, the situations required rapid problem solving, teamwork, and getting students to not think about grades but consider what is best for the company, and with the thought that they could be fired.

The first course in the two-course project aims at mimicking an internship experience (onboarding) at a semiconductor company where instructors run the course as if they were bosses/supervisors instead of professors, which includes being harsher having higher demands to solve problems now instead of waiting. It also included not tolerating students being late, making them call in sick etc…Other methods included punching in their time, keeping travelers and notebooks, presenting on yield and statistical process control parameters. The hierarchy of the courses is shown in Figure 1. The instructors have >20 years of industry experience in semiconductor/MEMS manufacturing and thus use their prior experience to create an industrial environment. One instructor acted as the supervisor while the other was their boss, and sometimes the “boss” instructor would yell at the other instructor/supervisor, which then trickled down to the student/employees. In addition, several industry members were consultants to help form the curriculum and provide feedback to the instructors, and they acted as the board of directors.

The courses consisted of 1 hour of “lecture” which was run like a weekly project meeting and 10 hours of “lab” which occurred in a cleanroom each week. The first semester consisted of onboarding activities to allow the students/interns to obtain training on equipment in the cleanroom, and then they had to use their training to fabricate devices including diodes, art wafers as a product for a customer, and develop bimorph actuators. During the 1st course the students obtained training on equipment, methodology, product development, communication skills (written and oral), statistics, and various other KSA identified below. They learned about standard operating procedures, statistical analysis related to semiconductor manufacturing, tracking wafers etc…The instructors created a setting that mimicked an industrial culture. The "lecture" time was used to allow students to give oral presentations status of work completed, problems they encountered, suggested methods to solve the problem, followed by group discussions. One instructor ran the "labs" section and acted as the supervisor/trainer, while the other instructor acted as the project manager (PM) and attended weekly meetings and both gave feedback to the students to train them on industrial practices and professionalism. In the course students had to make real-world devices for customers and had to perform testing to make sure they met specifications along with failure analysis, yield engineering, and time/team management. The course did not contain any typical lectures but instead the instructors taught through PBL performed in the cleanroom through real-world scenarios. For example, on multiple occasions the fabrication process failed, and the instructors used that to allow students to develop problem solving skills and to perform failure analysis on future runs.

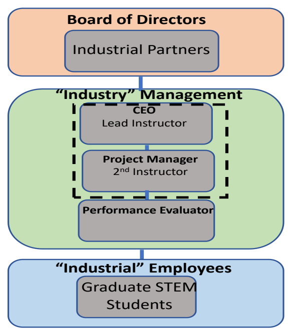

Figure 1- Schematic representation of the hierarchy developed in the courses

As part of the role-playing scenario instructors tried to get students to not think about grades but instead think of grades as a promotion scenario. For instance, a B in the course would be equal to getting hired or transitioning from intern to an employee and an A would be similar to getting promoted to a lead position, and a C would represent being fired. Overall, this was a success as students did not ask about grades during the semester instead, they focused on the job at hand and doing a good job to help the company. Instead of grades we gave evaluations to students, which is routinely done in industry. Some students struggled with not having submitted assignments and grades, but the instructors kept reiterating the company work culture. Overall, the courses aim to 1) enhance students' multidisciplinary knowledge in semiconductor area, 2) gain experience in an industry environment to enhance professional abilities 3) develop hands-on applied "hard skills", 4) develop essential skills and 5) develop systematic industrial-based problem-solving skills. The brief course descriptions of both courses are given below:

- **Course 1 (internship)- Microfabrication Training and Education**: This course was equivalent to an "internship" or training for new hires, where the focus was on introducing microsystems technology, along with hands on training with the various equipment in the cleanroom such as photolithography, thin film deposition, plasma and wet etching, characterization, and CAD design. Unlike traditional courses (theoretical); this course focused on learning how to use the equipment and the inner workings of the equipment. As challenges or failures occurred the students had to develop a systematic approach to solving the problems.

Occasionally instructors purposely created a process that they knew had a high likelihood of failing to teach students troubleshooting skills. This also taught students the need to do failure analysis and plan for possible mitigation steps, so in future planning they could anticipate potential high-risk processes. The students were required to develop standard operating procedures for their tools and processes, and cross train other students as needed. This course aimed to teach students statistical analysis, design of experiments, and yield from a hands-on approach. The requirement of a high yield process was designed to teach "interns" about risk analysis and decision making.

- **Course 2 (employed)- Microsystems Device Development**: Students that passed the 1st course were "promoted" to employee status, where the 2nd course focused on manufacturing multiple microsystems devices. Students were placed into teams with a focus of creating a product for the company as outlined by the "companies" device development plan. Employees had input on what type of device the company targeted, which aided them in learning decision-making. Students designed and developed their devices to meet specifications. Design and process/integration engineers worked in parallel, and students were given leadership roles in specific areas. Students utilized project management systems such as Gantt charts, fishbone diagrams, action items, special work requests and engineering change notices. They also performed failure mode and effects analysis (FMEA) and contingency planning to predict failures. This is standard practice in industry where if one person falls behind schedule, it impacts the entire chain. The instructor/PM gave guidance and motivation, and suggestions to systematically solve problems as they developed. The project leaders had responsibilities to manage their team and make sure all specs were met. Students had larger leadership roles in this course compared to course 1.

2.2 Survey Evaluation:

The objective of the study was to determine the effectiveness of the new mock work experience courses at easing the transition of graduate students from academic to industrial careers. To investigate the effectiveness the authors conducted a self-study survey given to various graduate students which consisted of 49 questions based on key KSA (that were previously identified by a semiconducting industrial panel) [17, 18]. All survey questions were based on input from a panel of industry members about real-world needs. Therefore, the KSA represents the average industry members' opinion on how to increase job-readiness as they acknowledged that students with the desired KSA would have reduced onboarding and add value to the company much sooner. The questions were grouped into categories illustrated in Table 1. Students gave each KSA a score of 1-4 where 4 represented mastery level and 1 represented no knowledge of the KSA. The survey was carried out by the students in the mock course at the beginning of the 1st course and at the end of the 2nd course to determine how many of the KSA students improved during the two-course project. To compare the effectiveness of the courses compared to other traditional methods, the survey was given to various groups of students including:

1. Students participating in the mock courses had no previous semiconductor work experience and they had not taken any previous semiconductor engineering courses (students had a diverse academic background such as (mechanical, electrical, chemical, materials engineering).
2. Graduate students who have taken previous traditional semiconductor engineering courses but have not had any work experience in the area. This consisted of students who had taken 1, 2, and 3 or more courses in the semiconductor/microsystem area. Traditional courses would cover all the technical subjects within the KSA such as photolithography, deposition, design, oxidation, doping etc… However, the material is given to students via hands-on labs and traditional chalk talk lectures.
3. Graduate students who have had previous internship/work experience at a semiconductor company for at least 6 months. Many of the students in this category also had also taken at least one traditional course but that was not a requirement for this grouping.

Table 1: Survey Questions and Categories

Question (#)	Sample Questions (shortened)
	ESSENTIAL SKILLS
1	Verbal Communication: Ability to communicate effectively with your team or supervisor.
2	Presentation Skills: Ability to present technical work clearly to a team or supervisor.
3	Written Communication: Proficiency in writing reports, emails, and other professional documents.
4	Respect for Others: Do you treat colleagues and supervisors with respect?
5	Trustworthiness: Do you foster a supportive environment where colleagues can trust you?
6	Conflict Resolution: Ability to manage and resolve conflicts in a professional manner.
7	Team Leadership: Ability to lead a team, assign tasks, and ensure timely completion.
8	Time Management: How effectively do you manage your time and balance multiple tasks?
9	Multi-tasking: Ability to manage multiple tasks simultaneously.
10	Creativity and Innovation: Ability to think outside the box and develop solutions to problems.
	GENERAL TECHNICAL SKILLS
11	Equipment Maintenance and Calibration: Comfort with maintaining and calibrating cleanroom equipment.
12	Troubleshooting: Ability to identify, diagnose, and fix problems.
13	Quality Control: Skills in implementing and monitoring control measures for consistency.
14	Process Optimization: Ability to continuously improve processes
15	Cleanroom Operations: Understanding of the inner workings of a cleanroom.
16	Safety and Chemical Handling: Knowledge of safety protocols and chemical handling.
	PROCESS FABRICATION SKILLS
17	Photolithography
18	Spin Coating
19	Soft Lithography
20	Wet Etching
21	Dry Etching
22	Metrology: Thin Film Measurement, Profilometry, Optical Metrology, Scanning Electron Microscopy (SEM)
23	Chemical Vapor Deposition
24	Physical Vapor Deposition
25	Oxidation Growth
26	Doping
27	Dicing
28	Packaging
	SOFTWARE SKILLS
29	Design of Microsystems Devices
30	Mask Design (CAD)
31	Finite Element Analysis of Microsystems
32	Following Design Rules in Mask Designs
	STATISTICS, DOE, FAILURE ANALYSIS
33	Device Testing (e.g., probe testing to measure resistance or device performance)
34	Statistical Process Control (SPC)
35	Process Capability Index (Cp) and Process Performance Index (Cpk)
36	Design of Experiments (DOE)
37	Cause and Effect Analysis
38	Pareto Analysis
39	Failure Modes and Effects Analysis (FMEA)
	GENERAL KNOWLEDGE TOPICS
40	Chemistry: Understanding of chemical processes in fabrication, such as photoresist and etching.
41	Thermal Processes: Understanding of thermal processes and their effects.
42	Solid-State Physics and Semiconductors
43	MEMS: Basic understanding of MEMS devices and their fabrication.
44	Photonics
45	Vacuum Science
	MANAGEMENT & MISC
46	Intellectual Property (IP): Ability to read, write, and understand patents.
47	Cultural Differences: Awareness of the cultural differences between industry and academia.
48	Project Management: Ability to manage projects, including task delegation and progress tracking.
49	Gantt Charts: Experience with creating and using Gantt charts for project planning and time management.

The results of the online surveys were collected and grouped based on students' response to prior experiences. Then the results for each KSA question were averaged and the standard deviation was determined within the group. The results of each question were analyzed and compared to the various categories of students using a student t-test to determine significance. To validate that students were being honest in their answers some KSA questions such as #31 (Finite element modelling) and #44 (photonics) were never discussed in the new role-playing course, evaluators would expect these to have <2 averages. The instructors also looked at the results to make sure the expertise level identified by the students was reasonable based on what instructors observed during the two courses. The overall average score per KSA was calculated based on the scores of each of the 49 KSA questions, and the average overall scores were compared between groups. Demographics of students were not evaluated but students participating in the survey included both national and international students as well as male and female students, but the exact breakdown was not determined as that was not the purpose of the study. However, the graduate student demographics in the school of engineering include: 40% Caucasian, 35% Hispanic, 12% international, and approximately 20% female.

3. Results and Discussion:

The surveys were completed by n=65 students, which consisted of (n=10 students in the role-playing courses), (n=15 with previous work/intern experience), and n=40 students from traditional lectures which was further divided into (n=12 students who took 3 courses), (n=11 students who had taken 2 courses), and (n=17 students who took 1 course). Group 1 had the lowest number students due to limitations on class size for safety reasons. Survey results from the mock internship courses at the beginning and the end of the two-course project are shown in Figure 2 and Figure 3(a). The results show a significant improvement in almost all KSA categories with the largest improvement being in the "fabrication skills" and "general skills" categories. Some categories (modelling and photonics) showed no improvement, which is understandable since the role-playing courses did not discuss these. This further validates the credibility of the survey as it shows honesty from the students. Figure 2c on fabrication skills also validates the honesty of the students as initial scores had values between 1-2 (no knowledge) at the beginning of course, which would be expected from students with no prior experience. As for essential skills most questions showed an improvement but overall students thought they already had a good understanding of essential skills prior to the course, which agrees with previous KSA surveys [17, 18].

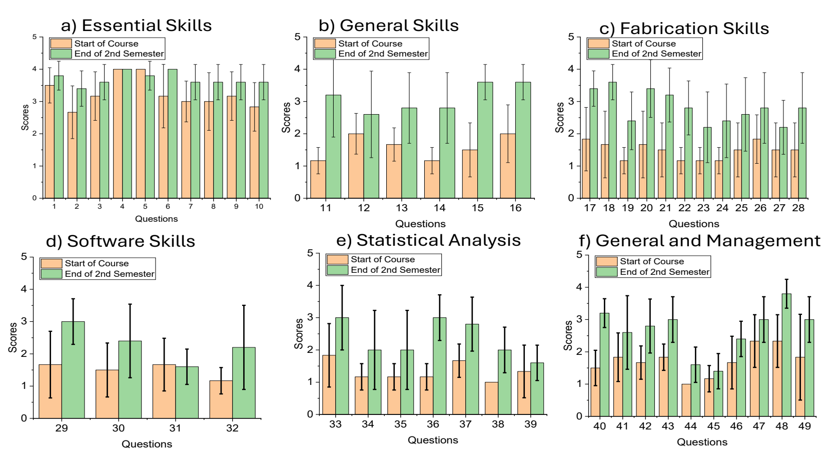

Figure 2- Self-study survey results from students in the "Mock" Internship course, error bars represent a standard deviation.

Figure 3(a) illustrates the average KSA score for the entire 49 KSA that were evaluated. Before students began the role-playing courses students had an average KSA score of 1.76 meaning they had levels between no experience and basic knowledge. The average score was >1, because students gave high values in the essential skills category. However, after completing the two courses the average overall KSA score increased to 3.24, which was in the adequate to mastery range. This significant increase demonstrates that students believed they had adequately learned the majority of the KSA to the level that industry was interested in hiring new employees.

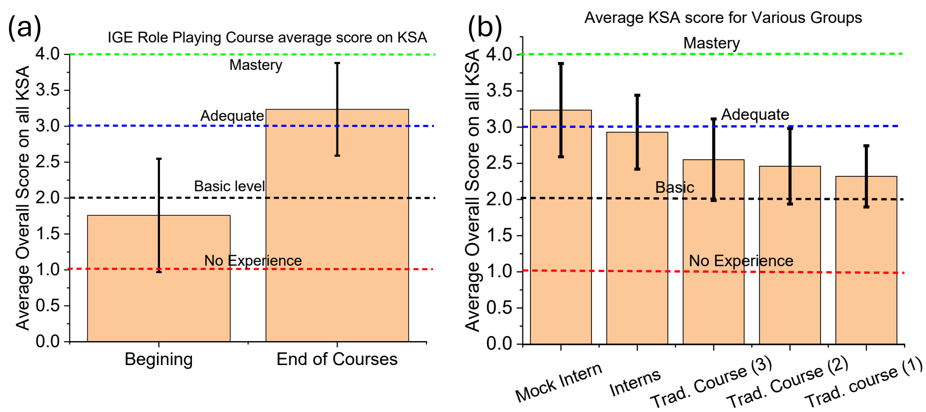

Figure 3- Results of the average KSA score for various groups (a) for the role-playing mock course (beginning and end of the project) and (b) for all groups surveyed.

Figure 4 shows the results from graduate students who have taken traditional lecture/lab-based semiconductor/microsystems courses. The authors university currently offers three traditional courses on the topic [8], the analysis of the results shown in Figure 4 compare students who have taken 1, 2, or 3 of the courses. The results show significant improvements in most categories when students took 3 courses versus 1 course. Students taking 2 courses scored higher in 67% of the questions compared to students who took only 1 traditional course. This demonstrates that repetitive learning helps students' retention, which agrees with previous studies [34, 35]. Students who took all 3 courses only scored higher in 40% of the questions compared to students taking 2 courses which indicates there was not a significant improvement in KSA from taking 3 courses in the topic vs 2 courses. There appears to be a saturation, where taking 3 courses did not significantly enhance the students KSA compared to 2 courses. Figure 3(b) illustrates the same results by averaging all 49 KSA resulting in an average score of 2.32, 2.46, and 2.55 for students taking 1 course, 2 courses, and 3 courses. There was a slight benefit in taking three courses over two courses which increased the broad knowledge of students. The courses were taught by various instructors so some of the material was repeated but all three courses had a different objective and topics.

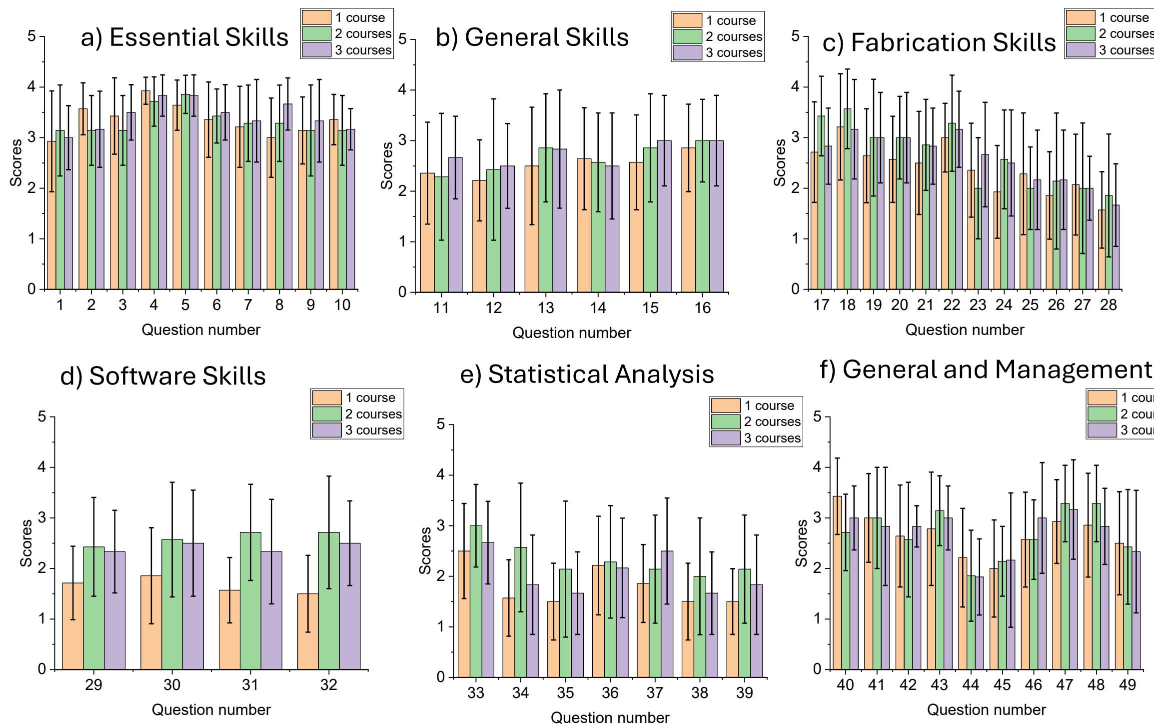

Figure 4- Self-study survey results from students taking traditional semiconductor or microsystems engineering courses with error bars representing a standard deviation.

Figure 5 shows the results comparing the survey responses for all three categories of students. The results show that students with work experience scored higher on 71% of KSA questions compared to students taking the traditional courses. Which verifies that internships or work experience is superior at preparing students for industrial careers when compared to traditional academic course lectures, as students meet more of the KSA desired by industry [15, 17, 27]. However, work experience students scored lower in 63% of the KSA questions compared to students in our novel mock role-playing courses. This is believed to be because traditional internships positions focus on a single area (ie. photonics) thus limiting their broad range of KSA, instead they become an expert in one particular semiconducting area. Whereas our two-course program focused more on broader knowledge as it was meant to mock a small start-up company, which requires a wider range of KSA. Figure 3(b) illustrates this further by looking at the average KSA value amongst all 49 KSA evaluated, and students from the work experience group had an average value of 2.93 slightly below adequate level whereas the mock role-playing students scored 3.24, which is significantly higher. Based on these results it appears that internships help students gain depth in specific areas while getting the cultural training, while the role-playing courses gave students a wider range of KSA while still providing the industrial cultural experience.

The results of the comparison study indicate that both an internship/work experience and our new mock role-playing course resulted in higher expertise in key KSA compared to traditional lecture/lab-based courses. Initial results from the role-playing courses indicate that it was slightly better than a real-world internship experience because it resulted in higher scores in a wider range of KSA compared to internships. However, the responses from the work experience group had a high deviation due to every company having different training methods and different demands for specific skills.

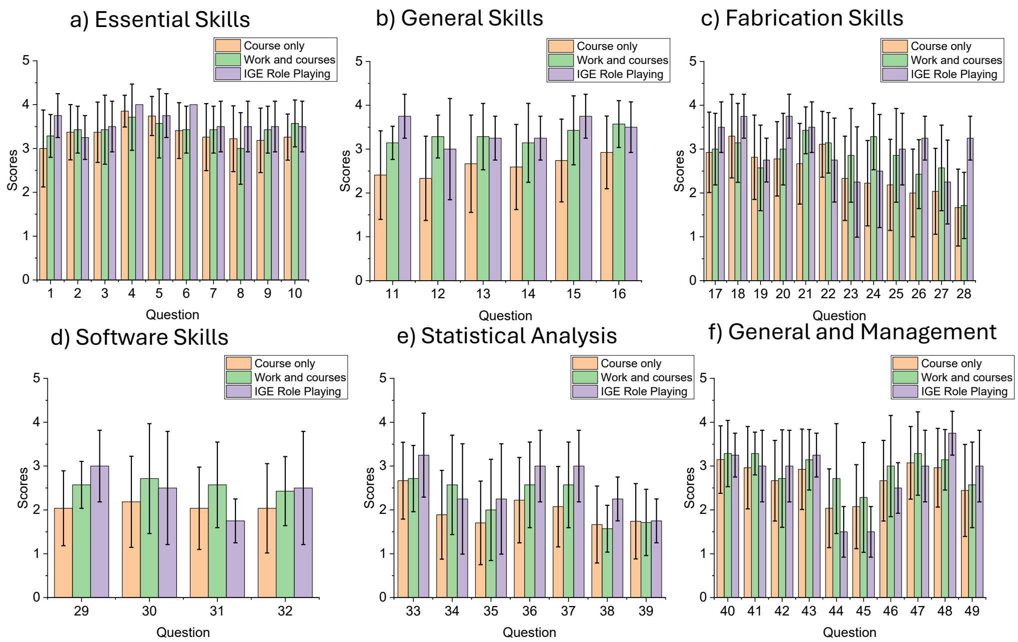

Figure 5- Self-study survey comparison results from graduate students in all three categories i) course work only (3 courses), ii) work experience, and iii) mock or role-playing course (end of the two courses).

To further evaluate the potential impact of the courses, a mock interview was performed by a semiconducting hiring industrial member. The industrial members were asked to give students an interview as if they were hiring them, and to let us know based on their interview if they would have considered them for hire. Hiring consideration was at the discretion of the industry interviewer, which was based on KSA. However, due to time constraints only a few students could be interviewed from each category (n=6 from the role-playing) (n=4 from the traditional course work), and (n=3 with prior experience). The interviewer did not know which student was in which category and selected a total of 9 out 13 students that they would hire based on the interview. All 6 of the role-playing students were selected for hire, 2 out 3 students with prior work experience and only 1 out of 4 students with traditional courses were selected. This agrees with the average KSA scores in Figure 3(b), illustrating that companies liked students with overall higher KSA scores and broad knowledge. This illustrates that both role playing and prior work experience had a significant impact on hiring students compared to traditional courses, and initial results showed the role-playing course outperformed the work experience, although a larger study would provide more statistical significance.

4. Conclusion:

In conclusion, the paper describes a novel pedagogy of role-playing in a PBL course aimed to mimic industrial experience in an academic environment to increase job readiness in the semiconductor manufacturing industry. The two-course project was briefly described in the paper which was based on key KSA that were previously identified from a semiconducting industry panel. The results indicate that the new role-playing course resulted in students increasing their KSA in areas deemed necessary by industry members at a higher rate when compared to traditional lecture courses. Students taking more than one traditional course did enhance the number of KSA gained but appeared to saturate after two courses. The new role-playing course also demonstrated significant improvement in the number of KSA gained compared to typical work experience or internships, but both internship and role-playing gave students typical industrial culture work experience. This cultural work experience will hopefully bridge the gap and ease the transition for students into the work field, but future studies would be needed to evaluate the true impact. However, categories where internship students scored higher is believed to be because most internships focus on one specific task needed for a particular job, so they often lack broad knowledge. But they had higher expertise in that specific area which we assume is the area that their internship focused on. The mock interview also illustrated that industrial hiring members were more apt to hire students that participated in the new role-playing curriculum when compared to both internship and traditional course work students. Based on this survey the results show that this new role-playing course could significantly bridge the gap between academia and industry, resulting in increased job-readiness.

Future results could focus on increasing the number of participants surveyed to reduce the standard deviation and increase significance. The study was focused on the semiconducting field, but the pedagogical methods could be implemented in other engineering fields to enhance engineering education, such as other manufacturing fields, pharmaceuticals, biomedical device manufacturing etc. In addition, we plan to follow the students' career to determine real world impact in future studies. The results demonstrated in this paper could have significant impact on students, academics, and industry. Students participating in these courses that gain key KSA will find it easier to find a job and have less stress in transitioning to industry. Industries benefit by decreasing onboarding and obtaining new hires that can add value to the company in less time.

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References:

[1] H. Gunarathne and V. Chaitanya, "Workforce Development for the Semiconductor Industry–A Perspective," *The Electrochemical Society Interface,* vol. 33, no. 4, p. 65, 2024.

[2] M. Lang, J. Kim, M. Munday, and P. Chalermsook, "Talent, skills and the semiconductor industry," *Project Report.[Online]. Cardiff University: CSconnected/Welsh Economy Research Unit,* 2025.

[3] M. A. Jackson, T. Schulte, N. Kane, E. Lewis, S. Gupta, and S. Kurinec, "Microelectronic Engineering and Nanotechnology Education for Undergraduates and Pre-College Students

through Curriculum Reform and Outreach Activities," in *American Society for Engineering Education*, 2008: INFORMATION.
[4] A. Kasimakhunova and S. Atajonova, "Increasing the creativity of the teacher in teaching students in the field of semiconductor technology," in *AIP Conference Proceedings*, 2024, vol. 3045, no. 1: AIP Publishing LLC, p. 020010.
[5] T. McCaughey *et al.*, "Registered apprenticeship for the semiconductor industry: a pipeline for technician skills critical to the industry," in *2023 34th Annual SEMI Advanced Semiconductor Manufacturing Conference (ASMC)*, 2023: IEEE, pp. 1-5.
[6] R. Pearson, K. Hirschman, S. Bolster, and D. Gross, "Semiconductor Engineering Workforce Challenges, Industry and Academia," in *2023 34th Annual SEMI Advanced Semiconductor Manufacturing Conference (ASMC)*, 2023: IEEE, pp. 1-5.
[7] R. Kirchain, E. Moore, F. Field, S. Saini, and G. Westerman, "Preparing the advanced manufacturing workforce: A study of occupation and skills demand in the photonics industry," 2021.
[8] N. Jackson, "Advanced Microfabrication Manufacturing Course Comparison of Online and In-person Teaching with Hands-on Lab Component for Interdisciplinary Graduate Education," in *2025 ASEE Annual Conference & Exposition*, 2025.
[9] M.-W. S. Chang and J. Connell, "Graduate Work-Readiness in Taiwan: Stakeholder Perspectives and Best," *The Transition from Graduation to Work: Challenges and Strategies in the Twenty-First Century Asia Pacific and Beyond,* p. 179, 2018.
[10] W. Tarng *et al.*, "Development of a virtual teaching module for advanced semiconductor fabrication and its learning effectiveness analysis," *Computer Applications in Engineering Education,* vol. 32, no. 6, p. e22802, 2024.
[11] F. Saffih, "Artificially intelligent method (AIM) for STEM-based electrical engineering education and pedagogy case study: microelectronics," in *2017 ASEE Annual Conference & Exposition*, 2017.
[12] R. Blonder and M. Dinur, "Teaching nanotechnology using student-centered pedagogy for increasing students' continuing motivation," *Journal of Nano Education,* vol. 3, no. 1-2, pp. 51-61, 2011.
[13] X. Wu, W. Deng, S. Zhao, and M. Zhou, "Course Development for “Semiconductor Device Physics” in New Engineering Education," in *Exploring Innovations in Educational Technology: The ICEIT’25 Collection: Advancing Knowledge and Practice*: Springer, 2026, pp. 215-223.
[14] H. Jung and Y. Hwang, "Exploring Ways to Operate a Semiconductor Boot Camp Program to Cultivate Practical Talent," *Journal of Practical Engineering Education,* vol. 16, no. 3_spc, pp. 379-389, 2024.
[15] Y. S. Sun, Q. Zhu, and J. M. Case, "Preparing Future Semiconductor Talent in the Global Context: A Comparative Study of the Semiconductor Engineering Curriculum in the US and Taiwan," in *2024 ASEE Annual Conference & Exposition*, 2024.
[16] J.-U. Kuhn and D. John, "Building a Micro/Nanotechnology Cleanroom Training," *Journal of Advanced Technological Education,* vol. 3, no. 1, pp. 121-128, 2024.
[17] N. Jackson and P. Kang, "Development of a Novel Graduate Pedagogy to Enhance Job Readiness in Semiconductor Education Based on Role-Playing Internship Experience," in *2025 ASEE-GSW Annual Conference*, 2025.

[18] N. Jackson, P. Kang, N. Bandara, and M. Pleil, "Identify and Compare Knowledge, Skills, and Abilities Needed in Semiconductor Graduate Education from an Academic and Industrial Perspective," in *ASEE Annual Conference & Exposition*, 2026.
[19] P. Boggs, D. B. Knight, M. Borrego, J. Deters, G. C. Fleming, and S. A. Cobb, "Understanding how skill development during graduate school can prepare students for engineering industry career pathways," in *2025 ASEE Annual Conference & Exposition*, 2025.
[20] J. M. Cramer and P. T. Hamilton, "An internship may not be enough: Enhancing bioscience industry job readiness through practicum experiences," *Journal of Microbiology & Biology Education,* vol. 18, no. 1, p. 10.1128/jmbe. v18i1. 1248, 2017.
[21] S. Cheon and H. Kang, "ChipQuest: Gamifying the Semiconductor Manufacturing Process to Inspire Future Workforce," in *Adjunct Proceedings of the 37th Annual ACM Symposium on User Interface Software and Technology*, 2024, pp. 1-3.
[22] T. Dallas *et al.*, "University-Industry Partnerships in Semiconductor Engineering," in *2014 ASEE Annual Conference & Exposition*, 2014, pp. 24.1298. 1-24.1298. 13.
[23] T. Zhang, J. He, and W. Zhou, "Learning and thoughts of how industrial internship can inspire new generation talents," *Optics Education and Outreach VII,* vol. 12213, pp. 144-148, 2022.
[24] P. McCall, W. Collins, S. Azhar, and K. Leousis, "Expectations, challenges, and motivations for early career faculty who transitioned from industry to academia: a literature review," *EPiC Series in Built Environment,* vol. 2, no. 1, pp. 542-550, 2021.
[25] S. J. Hong and T. M. Ha, "Hands-on experience-based microelectronics manufacturing engineering education," in *Proceedings of 2013 IEEE International Conference on Teaching, Assessment and Learning for Engineering (TALE)*, 2013: IEEE, pp. 277-282.
[26] H. Kim, J. Kim, and A. Clipperton, "WIP: Developing Hands-On Semiconductor Fabrication and Testing Courses Through Industry-University Partnerships in a Teaching-Focused Undergraduate School," in *2025 ASEE-GSW Annual Conference*, 2025.
[27] S. Das, B. Klein, S. J. Paik, and A. B. Frazier, "Preparing Fab-skilled Engineers for the US Chip Industry Through Hands-on Integrated Circuit Fabrication," in *2025 ASEE Annual Conference & Exposition*, 2025.
[28] S. W. Rogers and R. K. Goktas, "Exploring engineering graduate student research proficiency with student surveys," *Journal of Engineering Education,* vol. 99, no. 3, pp. 263-278, 2010.
[29] C. G. Berdanier, S. E. Branch, J. S. London, B. Ahn, and M. F. Cox, "Survey analysis of engineering graduate students' perceptions of the skills necessary for career success in industry and academia," in *2014 ASEE Annual Conference & Exposition*, 2014, pp. 24.1146. 1-24.1146. 14.
[30] M. W. Pleil, "Enhancing Engineering Interest and Skills in Community College Students through a Project Based MEMS Design Competition," in *2008 GSW*, 2021.
[31] I. Rocio Vazquez, P. Sharma, V. Law, N. Jackson, and M. Pleil, "Initial Observations of a Community College Microsystem Fabrication-focused Undergraduate Research Experience," *Journal of advanced technological education,* vol. 1, no. 1, 2022.
[32] Z. Brounstein, E. Armistead, M. Duggina, P. Sharma, and N. Jackson, "Microfabrication of MEMS Electro-Thermal Actuators for Problem-Based Learning," in *2020 Gulf Southwest Section Conference*, 2020.

[33] M. Pleil and G. Massiha, "Teach Microsystems Technology on a Tight Budget," *Tech Directions,* vol. 73, no. 8, p. 18, 2014.
[34] P. M. Santi, "Preliminary analysis of repeated testing as a method to enhance long-term retention of knowledge," in *2011 ASEE Annual Conference & Exposition*, 2011, pp. 22.1168. 1-22.1168. 10.
[35] D. McAvoy, "A repeated exposure experiment to improve knowledge retention," in *2010 Annual Conference & Exposition*, 2010, pp. 15.81. 1-15.81. 8.