Board 68: WIP: Development of a Certification Framework for a Microelectronics Workforce Development Program

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Abstract

With the current shortage of employees entering the microelectronics workforce, the U.S. defense industrial base (DIB) is faced with the growing challenge of where to obtain qualified workers. The challenge for engineering educators is how best to educate and train a workforce for the DIB's specific technical and professional skill requirements to meet the growing demand for technicians and engineers in microelectronics. As workforce development programs grow and expand in the engineering education space, there is a need to ensure that students are developing both technical and professional skills. The purpose of this Work in Progress Paper is to describe the initial development of a certification framework for students in a microelectronics engineering program. The primary goals of developing the framework are that it be straightforward to use by faculty and students at any university and easily transferable to other domains. The research questions for this paper are: (1) what are the high-level technical and professional knowledge, skills, and abilities that students in a microelectronics workforce development program need to be certified? (2) What are the overall framework components for certification, and what is the supporting literature? (3) What is a current example of the framework applied to professional skills for undergraduate students, and what are the next steps for technical skills? This paper includes detailed examples of the framework and supporting literature for professional skills (i.e., teamwork, lifelong learning), and how technical skills (i.e., circuits, quantum mechanics, quantum computing) are developed.

Tags: workforce development, microelectronics, lifelong learning, professional development, radiation hardened technologies, teamwork

1 Introduction

The microelectronics industry has been in the national and global news, particularly with the shortage of microchips and the passage of the CHIPS and Science Act of 2022. These shortages have significantly impacted the automotive industry and consumer electronics and, more importantly, caused a rethinking of global supply chains [1]. In the U.S., the Defense Industrial Base (DIB), consisting of "Department of Defense (DoD) components, and more than 100,000 companies and their subcontractors who perform under contract to the DoD" [2], is facing similar but additional challenges with microelectronics. These challenges include how to secure the supply chain and where to get enough qualified workers in microelectronics [3].

In order to meet the immediate needs and challenges of a highly trained microelectronics workforce, in 2020, the DoD funded 17 universities to engage in a workforce development program called SCALE. This program provides distinctive curricula, mentoring, internship opportunities, and directed research projects for 2-year, 4-year, and graduate students interested in various microelectronics specialty areas across multiple disciplines. With the recent passing of the CHIPS and Science Act [4], more companies are increasing their investments in microelectronics in the U.S., helping the supply chain issues, but putting more demands on the U.S. labor force [3].

The challenge for engineering educators, specifically those educators within this specific workforce development program, is twofold. One challenge is ensuring that students learn and retain the unique technical and professional skills and abilities needed for the microelectronics workforce, which can be lost if not properly taught and reinforced [5]. The other challenge is setting students up for success as lifelong learners by instilling a sense of professional development in the students who already have a full curriculum [6]. As workforce development programs grow and expand in the engineering education space, there is a need to develop better ways of ensuring that students retain their technical and professional skills while continuously working on their professional development.

The purpose of this Work in Progress paper is to describe the initial development of a certification framework for students in a microelectronics workforce development program. The framework is designed to identify the skills and abilities that students should have in technical and professional skill areas so that faculty can help students certify that they are appropriately trained. The primary goals of developing the framework are for it to be straightforward for faculty and students at any university to use and easily transferable to any other technical or professional skills domains. The research questions for this paper are: (1) what are the high-level technical and professional knowledge, skills, and abilities that students in a microelectronics workforce development program need to be certified? (2) What are the overall framework components for certification, and how were those synthesized from the literature? (3) What is a current example of the framework applied to professional skills for undergraduate students, and what are the next steps for technical skills?

2 Background Literature

The need for engineering students to be trained and proficient in skills outside of the traditional engineering degree is a well-discussed idea in engineering education. Students wishing to specialize within their desired field, and employers needing specialized workers, often look for certifications that put emphasis on in-demand knowledge, skills, and abilities [7]. The Accreditation Board for Engineering and Technology (ABET) and other agencies have provided guidelines for educational institutions [8], through accreditation processes, to provide students with the professional and technical skills they need, but programs then need to have an explicit plan for implementation [9].

This project was developed to supplement already existing university and DIB efforts to produce students with robust and specialized knowledge to work in the microelectronics industry. This certification program was developed using prior examples, such as the Six Sigma manufacturing quality certification, a multi-disciplinary certification that is accepted by a variety of fields and companies [10]. Non-technical professional skills, such as teamwork and lifelong learning, were also identified during the certification design process as competencies that are in high demand by employers. These skills were outlined in the Researcher's Development Framework (RDF) [11], which divided competencies (i.e., components) into domains and subdomains, with phases of mastery ranging from 1-5. Each component of the RDF was also given a descriptor, and compiled into a table to be used by researchers in their professional development [11]. These attributes would later inspire the organizational structure of the microelectronics certification.

2.1 Theoretical Framework

The Taxonomy of Educational Objectives, originally created by Benjamin Bloom in 1956 [12] and often referred to as Bloom's Taxonomy, was utilized as the overarching theoretical framework to guide the work of creating a Certification Framework for Microelectronics Engineering workforce development. Bloom's Taxonomy, herein referred to as Bloom's, is important in learning contexts because it allows educators to identify and classify learning objectives and create relevant assessment rubrics [13]. Additionally, Bloom's serves to guide students by allowing them to engage with anticipated learning outcomes and have an awareness of the relevant categories for course assignments that serve as assessments [13].

Of interest for this specific project, Bloom's categorizes and classifies categories of learning by levels of complexity [13]. The original version of Bloom's utilized nouns, including the following categories: knowledge, comprehension, application, analysis, synthesis, and evaluation. Bloom's has evolved over time, with a notable revision in 2001 by Anderson and colleagues [13] [14]. Importantly, one of the changes that the 2001 revision [13] made was to reorder the categories and utilize verbs, including the following revised categories: remember, understand, apply, analyze, evaluate, and create.

Following this revision, Newton and colleagues [15] created a master list of action verbs for Bloom's by utilizing a "simple majority consensus method" [15]. This method sought to bring consensus to the verbs being utilized by forty-seven separate and publicly available lists of verbs that had been created, sometimes without a rationale for why the verbs were chosen [15]. This master list of action verbs includes preferred verbs and verbs to avoid for use in writing learning outcomes and creating assessments [15].

3 Methods/Results

As multiple methods and results are presented that show how the framework was built and applied, the authors present the methods and results for each section together, rather than presenting all of the methods followed by the results separately. This type of formatting is often used when multiple methods are employed [16], and the authors found it the most straightforward way to help the reader understand the methods and results that followed.

The first section briefly presents the work of another team that worked with DIB members to identify their workforce needs, which helped distinguish the high-level technical and non-technical professional skills students need for certification. The second section explains how the framework was developed from the literature discussed in the literature review section (hence, there are results only) and includes an overview of the framework. The third section applies the framework to two examples of professional skills, including the background literature: teamwork and lifelong learning. The fourth and final section applies the framework to some initial areas in the technical area of Radiation Hardened Technologies.

3.1 Workforce Needs

A workforce needs assessment was conducted as part of the larger workforce development project [17]. This workforce needs assessment informed the work that the certification group completed as described within this paper. The workforce needs assessment project goal was to assess the needs of the DIB workforce to better prepare students for success in the microelectronics industry. The methods and results from the workforce needs assessment will be explored briefly in section 3.1 to provide the necessary background context for the work of the certification project. The technical and professional skills that emerged from the workforce needs assessment project served to inform the certification project.

3.1.1 Methods

The workforce needs assessment team interviewed six members of the DIB. These individuals were from a unique group of professionals who are difficult to access based on their roles and security clearances. Demographics included 2 women and 4 men. Individuals were from a variety of job sectors, including government agencies, government contractors, government research laboratories, and private industry (e.g., aerospace and engineering technology solutions). These individuals all had extensive experience hiring and managing microelectronics engineers. Participants were asked questions related to the needs for developing a microelectronics workforce. For example, participants were asked what technical and professional skills they look for in an intern or new professional. They were asked to consider broad technical skills, microelectronics specific skills, specialty microelectronics skills, and professional skills needed. Additionally, participants were asked what skills and abilities they expect a microelectronics engineer to learn on the job. The workforce needs assessment team then performed an iterative qualitative data analysis to determine highly-desired technical and non-technical professional skills that entry-level professionals must possess. The full data collection and analysis process is described further by Linvill et al. [17]. The microelectronics technical areas were generated through iterative collaboration between members of the DIB and content-area specialists from academia. These high-level technical areas serve as broad categories which encompass more specific microelectronics Knowledge, Skills, and Abilities (KSAs).

3.1.2 Results

Interviews with members of the DIB and meetings with content-area experts led to the discovery of five technical areas and nine non-technical professional skills that are highly desired in entry-level microelectronics engineers. The five technical areas include Radiation Hardening, System-On-Chip, Heterogeneous Integration and Advanced Packaging, Supply Chain, and Trusted AI. These technical areas represent high-need pathways and gaps in the existing microelectronics workforce. Additionally, nine professional skills were documented, including communication; diversity, equity, and inclusion; engineering habits of mind; leadership; lifelong learning; multi-disciplinary problem solving; professional and ethical responsibility; teamwork; and understanding solutions, impacts, and issues. The initial workforce needs assessment study showed that professional skills are critical to the development of microelectronics engineering professionals because, as identified by industry professionals, professional skills are inextricably intertwined with and serve to advance technical skills [17]. These professional skills helped inform the certification team and are embedded in the comprehensive set of professional skills for certification, which will be introduced in section 4.3. It is important to note that a key finding of the workforce needs assessment is the nature in which the professional and technical skills were identified by the DIB. The microelectronics experts often combined technical knowledge with non-technical professional skills, to the point where the two seemed to be inseparable.

3.2 Certification Framework Explanation

A review of current scholarship and engineering curriculum led to an initial framework focusing on four levels of microelectronics students' attainment as they progress through their studies.

The Certification Framework identified both technical and non-technical professional skills that students must possess to be career-ready for internships and professional positions in microelectronics and to determine levels of competency related to those skills. Within this project, a *Component* is defined as an element of the larger engineering program curriculum (e.g., teamwork). Components are well-defined based on relevant scholarship, and, where applicable, components may have varying *Themes* to serve as umbrella categories. For example, "individual conduct" and "interpersonal conduct" are Themes within the teamwork component. The Certification Framework also utilizes *Competencies*, which are defined as specific skills that students can achieve to have a stronger understanding of the Theme. For example, a Competency within teamwork's Theme of "individual conduct" is "self-management."

Building on the evolution of Bloom's Taxonomy and the work of Newton and colleagues [15], this project sought to create a further refined master list of verbs for use in the Certification Framework. Verbs were paired with a corresponding Level to evaluate student mastery of each Certification Framework Competency (Table 1). *Levels* within the Certification Framework then serve to provide a mechanism to measure students' mastery of each Competency.

Table 1 *Certification Framework Master Verb List*

Modified Bloom's Category	Certification Level	Verbs				
Create	4	create	compose	argue	design	plan
		support	revise	formulate	write	
Evaluate	4	rate	evaluate	assess	judge	justify
		manage				
Analyze	3	analyze	question	differentiate	experiment	examine
		test	categorize	distinguish	calculate	contrast
		outline	infer	discriminate	compare	
Apply	2	operate	apply	use	demonstrate	solve
		produce	prepare			
Understand	1	translate	paraphrase	discuss	report	locate
		generalize	classify	summarize		
Remember	1	list	define	recall	state	label
		repeat	name			
Avoid List		appreciate	know	familiar	aware	understand
		select	explain	relate	arrange	choose

Table applied from Newton and colleagues [15]

Visually, the hierarchy defined above is translated into a framework rubric. The layout of the rubric is universal so that it serves as a basic framework for the certification of both technical and professional skills (Table 2).

Table 2 *Framework Rubric*

	Component			
Competency	Level 1	Level 2	Level 3	Level 4
		Theme 1		
	Remember, Understand verbs (*)	Apply verbs (*)	Analyze verbs (*)	Evaluate, Create verbs (*)
		Theme 2		
	Remember, Understand verbs (*)	Apply verbs (*)	Analyze verbs (*)	Evaluate, Create verbs (*)

(*) Indicates the modified Bloom's category

At the Component level of the framework, the high-level KSA is identified (for example, teamwork, or a specific technical skill). At the Theme level, sub-skills and experiences are identified within that particular Component, for example, the types of teamwork experiences, or aspects of a particular technical skill. Then, the Themes are further broken down into an individual Competency for student attainment through certification. Each Competency has a level of progression, Levels 1 through 4, that a student can progress through as their knowledge, skills, and abilities in that Competency grow.

The certification framework is still being developed as the research team continues to identify the specific ways that students may obtain the required professional and technical skills through their formal academic curriculum, internships, capstone projects, research, and other co-curricular and extra-curricular activities. Discovering the relevant and accessible options for acquiring each level of the certification framework is in process and will be completed in the coming year through the research team's work with the assistance of subject matter experts.

3.3 Professional Skills

The workforce needs assessment findings informed the professional skills used for the certification project. The full list of professional skills is shown in Table 3 below, along with the core sources, such as ABET, the National Association of Colleges and Employers (NACE), etc., that served to define each Component.

Table 3 *Professional Skills for Certification*

Certification Component	**Contributing Source(s) for Definitions**
Communication	ABET [18], NACE [19]
Diversity, Equity, and Inclusion	NACE [19]
Engineering Habits of Mind	Lucas and Hanson [20]
Leadership	ABET [18], NACE [19]
Lifelong Learning	ABET [18, 21]
Multidisciplinary Problem Solving	National Science Foundation [22]
Professional and Ethical Responsibility	ABET [18] NACE [19], National Society of Professional Engineers [23]
Teamwork	ABET [18], NACE [19]
Understanding Solutions, Impacts, and Issues	ABET [18]

Although the certification framework has been outlined for each of the professional skills in Table 3 above, in this WIP paper, we focus on two professional skills in the certification framework, teamwork (see section 4.3.2) and lifelong learning (see section 4.3.3).

3.3.1 Methods

The professional skill certification framework development was similar in process for each Component of their competencies. The researchers used the workforce needs assessment findings and literature on the specific Component to brainstorm corresponding core Themes and Competencies. The researchers then collaborated to establish a baseline that all students in an ABET-accredited engineering program should be able to achieve in their first year of university coursework or extra-curricular involvement. The four levels were intended to be achievable through a four-year undergraduate program with the competencies becoming more difficult to obtain through the curriculum at higher levels of certification. After drafting the content within each Competency, we applied verbs, derived from Bloom's Taxonomy and Newton and colleagues' [15] "pragmatic master list of action verbs" to the levels to create an actionable rubric for certification for use in measuring students' mastery of each Competency.

3.3.2 Results – Teamwork

The researchers combined the ABET [18] and NACE [19] definitions for teamwork to derive a robust definition of the Component: "Building and maintaining a collaborative environment by appreciating diverse viewpoints, creating an inclusive environment, and sharing responsibilities in order to effectively meet objectives." Themes were then developed to encompass subsets of teamwork competencies. Those Themes included individual conduct, interpersonal conduct, and project management (Table 4). The content within each Level was built upon existing evaluation criteria for teamwork experience.

Table 4 *Teamwork Certification Component*

Competency	Level 1	Level 2	Level 3	Level 4
		Theme 1: Individual Conduct		
Self-Management	Discusses how individuals influence one another and contribute to group outcomes	Demonstrates responsibility and trust in individual work and behavior	Analyzes individual behavior to improve success of the group	Plans opportunities to improve individual work and behavior for the success of the group
		Theme 2: Interpersonal Conduct		
Multi-disciplinary Experience	Discusses collaborative skills needed to work with multi-disciplinary teams	Operates on a team with at least one member of a different discipline	Tests collaborative skills within a multi-disciplinary team	Manages collaboration within at least 2 multi-disciplinary teams

Competency	Level 1	Level 2	Level 3	Level 4
Communication (within team)	Discusses project-related content with team members in a professional and honest manner	Prepares schedules for meetings that are mindful of all team members	Analyzes alternative solutions to teammates' work in a respectful manner	Manages conflict in a professional manner
		Theme 3: Project Management		
Team Culture	Reports to leaders and other team members with respect	Demonstrates timeliness in professional matters	Analyzes team needs to maximize effective contributions	Supports the team culture through respect, timeliness, sensitivity, etc.
Strategic Planning	Labels tasks and deadlines in an organized fashion	Produces work ahead of deadlines	Distinguishes between priorities and additional work to cater to approaching team deadlines	Plans deadlines to flexibly and effectively reach team goals
Ensuring Fair Work Distribution	Recalls teammates' strengths, positions, and workload	Uses teammates' professional strengths to assign them to particular project components	Analyzes teammates' strengths, positions, and workload throughout the project	Evaluates and revises workload as project needs change

3.3.3 Results – Lifelong Learning

The development of the lifelong learning certification Component followed a process that was very similar to teamwork, as described above. The definition of the lifelong learning component was developed by combining definitions from ABET [18, 21]: "Continuously identifying and addressing personal educational needs by acquiring necessary knowledge or training in order to maintain competence and consistently contribute to the field." Of note for this Component, there are currently no broad Themes that served as umbrellas for the Competencies (Table 5).

Table 5 *Lifelong Learning Certification Component*

Competency	Level 1	Level 2	Level 3	Level 4
Change and Learning	States preferred style of learning and discusses high levels of engineering knowledge	Uses preferred learning mediums for basic application of knowledge	Examines old and new knowledge from diverse sources	Assesses knowledge from a variety of sources and mediums to evaluate unique and creative solutions

Competency	Level 1	Level 2	Level 3	Level 4
Critical Curiosity	States formal engineering technical area to independently expand knowledge	Prepares critical questions in technical area that require creative and/or dynamic solutions	Analyzes when to voice questions or dissonant opinions towards established practices of the technical field	Creates a balance between established knowledge and challenging the status quo to continuously improve the field
Meaning Making	Summarizes how technical area connects to and influences other specialties in engineering	Demonstrates interconnecting relationships between engineering, society, and personal life	Analyzes methods of connecting old and new knowledge	Designs a 'web of knowledge' that connects technical and non-technical topic areas
Creativity	Discusses various brainstorming methods	Applies personal creativity to brainstorming process	Analyzes various brainstorming methods for creative problem-solving	Designs projects with well-established brainstorming methods and a willingness to take risks on creative solutions
Resilience	Discusses components and strategies of resilience	Demonstrates maintenance of communication network during a challenge	Analyzes problems/solutions with alternative logics	Evaluates complex and long-term problems with perseverance and determination
Strategic Awareness	Classifies necessary and unnecessary information when learning	Uses various methods of collecting knowledge for future use	Analyzes new knowledge with big picture thinking.	Assesses relevancy of old knowledge and ideas in the current, ever-changing world
Learning Relationships	States effective strategies for individual and interpersonal learning	Applies individual learning strategies to meet project needs	Experiments with individual and interpersonal learning for problem-solving	Plans individual work with consideration of previous learning experiences
Mentee/Mentor Relationship	Discusses mentor/mentee relationships and the expectations that go along with them	Applies knowledge of mentor/mentee relationship to choose a mentor	Analyzes relationship with mentor to determine best mentoring practices	Manages a mentee as an active mentor using previous experience

3.4 Technical Skills

The certification of technical skills was generated based on the KSAs that are in demand for students entering the microelectronics workforce. These desired KSAs were defined by project stakeholders through the workforce needs assessment process. Students will gain technical experience through a formal academic curriculum, internships, capstone projects, research, and co-curricular and extra-curricular activities. All of these accomplishments will be tracked through the technical skills certification.

3.4.1 Methods

The development of a certification rubric for technical skills was a similar process to that of the professional skills certification discussed above. The first KSA was identified as electronic circuitry, coming from the technical area of Radiation Hardening. First, KSAs related to circuits were "ranked" in chronological order and difficulty that the typical microelectronics engineering student would acquire them. The purpose of Themes and Competencies act differently than professional skills due to the chronological nature of technical courses. The Themes act as placemarks for the timing of the subject and the competencies that are covered in the material that students would acquire during that time period. For example, circuit theory, analysis, and simulation are the first three subjects that a student would be introduced to during a first-year course (Table 6). These would act as competencies within the technical skill and would be placed under the "first-year" Theme. The Levels of technical skills are dependent on the Level of the microelectronics engineering student in order to achieve competencies within the given Theme. For example, a microelectronics engineering student who is a Level 3 in circuit theory would be unable to achieve past Level 2 of analysis because they lack adequate knowledge to apply to circuit analysis.

Table 6 *Circuitry Certification Component*

Competency	Level 1	Level 2	Level 3	Level 4
		Theme 1: Basic Circuits (First-year)		
Circuit Theory	Name voltage sources, current sources, resistors, capacitors, and inductors on a schematic. Understands the units associated with each part.	Demonstrate the meaning of resistance, voltage, current, impedance, and produce (draw) nodes onto a schematic.	Distinguish the behavior of an ideal op-amp. Increased comfort with distinguishing complex circuit behavior.	Evaluate the difference between time domain and frequency domain circuits.

Circuit Analysis	Discuss basic nodal and mesh analysis	Use mesh and nodal analysis, apply the most efficient method. Apply Norton and Thevenin Transformations	Differentiates between linear, inverting op-amp, non-inverting op-amp, lowpass, highpass, and bandpass circuits. Begins to design using these circuits	Evaluates given design requirements to design the best circuit for the task at hand. Assesses the circuit throughout the design process
Circuit Simulation	Summarize the basic tools and instructions on LTSpice	Demonstrates the purpose of the different types of simulations on LTSpice (AC, Transient, Octave, etc.) and when it is best to use each	Test schematics on LTSpice, is able to correctly load op-amps and label nets	Create simulated circuits and can clearly assess the behavior of the simulation results

4 Discussion

This study set out with the goal of developing an overall certification framework for microelectronics students that is straightforward for faculty and students to use and easily transferable to any other technical or professional skills domains. The criteria for evaluating the framework were: (1) what are the high-level technical and professional knowledge, skills, and abilities that students in a microelectronics workforce development program need to be certified? (2) What are the overall framework components for certification, and how were those synthesized from the literature? (3) What is a current example of the framework applied to professional skills for undergraduate students, and what are the next steps for technical skills?

Evidence was presented from a workforce needs study [17] of the nine high-level professional skills that the DIB desires in students, including communication; diversity, equity, and inclusion; engineering habits of mind; leadership; lifelong learning; multi-disciplinary problem solving; professional and ethical responsibility; teamwork; and understanding solutions, impacts, and issue. Evidence was also presented from a workforce needs study that identified the technical skills students need for certification within five main technical areas previously specified by the DIB: Radiation Hardened Technologies, Heterogeneous Integration/Advanced Packaging, System on Chip, Trusted AI, and Supply Chain Awareness.

Evidence was presented about the overall certification framework components consisting of a Definition, Component, Theme, Competency, and four Levels of progression. These were developed and synthesized from many literature sources, including ABET, NACE, and other widely cited engineering scholarship, to create robust Component definitions and indicate Themes and Competencies that students need to be career ready. The certification framework utilized Bloom's Taxonomy [13, 14] as the guiding principle for Level progression, and developed a Certification Framework Master Verb List based on previous work of Newton and colleagues [15].

Evidence was presented for how the framework applied to the professional skills of teamwork and lifelong learning, including the background literature, and for some initial technical areas in Radiation Hardened Technologies. While only teamwork and lifelong learning were presented and completed herein, the other professional skills were also completed for the certification framework. The technical skills are still a work in progress, and will be developed over the coming year with the assistance of subject matter experts.

5 Implications/Limitations/Conclusions

First, this workforce development certification framework begins to address the challenges that engineering educators face in assessing how to best educate and train a workforce for the DIB's specific technical and professional skill requirements and ensuring that students are career ready when leaving microelectronics engineering programs to enter the workforce. The certification framework provides a universal rubric that is straightforward to use and easily transferable to other domains to ensure that students in microelectronics engineering programs develop both technical and professional skills and that mastery of those skills is measurable. Focusing on four levels of students' attainment as they progress through their program of study provides engineering educators with clear information that can be used to identify support efforts targeted at developing students' professional and technical skills, including the necessary and relevant academic curriculum, internships, capstone projects, research, and other co-curricular and extra-curricular activities.

Second, the certification framework can be easily utilized by students to understand the goals they need to set in order to develop the professional and technical skills that make them career ready within the microelectronics engineering field. The certification framework may assist students in planning the activities that they must engage in, both inside and outside of the classroom, in order to become career ready. Finally, the certification framework may serve as a way for students to demonstrate that they are well-qualified for internships or professional employment to potential employers in the microelectronics engineering field.

A limitation of this work is that the certification framework was informed by information gleaned from managers and supervisors in the DIB within the United States. This population has a specific interest in developing students who are career-ready for entry into the DIB. Though the framework is intended to be transferable to other domains, it may be less relevant to other sectors, including non-defense industry that fuels the U.S. economy. Future research related to non-defense sectors may further inform microelectronics engineering workforce development projects. Additionally, limiting the framework to a small subset of specific action verbs for technical skills may make the framework less transferable to certain domains. The use of a broader selection of verbs specifically related to additional technical areas would allow more opportunities to capture the nuances of those technical areas.

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