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Defining, Measuring, and Recording Professional Skills: An Explication of a Professional Skills Certification Framework and Assessment Rubric

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Abstract
The lack of professional skills in engineers, a skill gap long recognized by employers, has created a demand for student development processes that facilitate the acquisition of technical and professional skills. In contrast to typical course-based learning, technical and professional skills are best acquired through experiential learning activities such as internships, research projects, and other co- and extra-curriculars. The purpose of this paper is to explicate the development of a professional skills certification framework for undergraduate students in a microelectronics engineering workforce development program and creation of the mechanism(s) to assess professional skill development. The framework facilitates students' acquisition of professional skills through experiential learning as viewed through the overarching theoretical lens of both social cognitive career theory and self-determination theory. The certification framework, rubric, and assessment development are described, and the implications are discussed.

Tags: professional skills definitions, implementation, portfolio, professional skills, microelectronics, reflections, rubric

Introduction

Employers and educators alike have recognized a lack of professional skills in burgeoning engineers [1], [2]. Thus, there is a demand for student development processes and experiences that facilitate the acquisition of both technical and professional skills. For this project, professional skills, often referred to as "soft skills," include a variety of competencies such as communication, teamwork, professional and ethical responsibility, and more as determined by ABET and delineated in the results of this paper. Unlike technical skills, professional skills take more time to develop and sharpen [3]. Additionally, they are not as amenable to course-based learning often due to their "untestable" nature. Whereas a chemistry class might be able to teach technical skills and then assess the outcomes by way of measuring student knowledge gained, professional skills are not as easily assessed. Additionally, previous scholarship found that professional skills are best acquired through experiential learning activities such as internships, research projects, leadership roles, and other co- and extra-curricular activities [3] - [8]. These factors demonstrate the need to develop professional skills in students and create a mechanism that assesses the skills. Thus, this certification framework aims to facilitate and track the acquisition of professional skills through an academic structure that encourages experiential learning activities that will provide students with the skills required upon graduation.

Therefore, to address the demand for well-rounded, career-ready engineers, our team created a certification framework that defines critical professional skills and supplies an accompanying rubric to assess students' progression through the completion of certification. The purpose of this paper is to expand upon Linvill et al.'s [1] work to further explicate the theoretical background and implementation practices of a professional skills certification framework for undergraduate students in SCALE, which is a DOD-funded microelectronics workforce development center that encompasses 20 universities. Our team utilized experiential learning theory, social cognitive career theory, and self-determination theory to describe how the framework is successfully developed, refined, and implemented.

Certification Background

The certification framework addresses the need for a structured microelectronics engineering educational curriculum that aids in both the technical and professional skill development of microelectronics engineers. Linvill et al.'s [1] previous work utilized Bloom's taxonomy [9] - [12] to create a toolkit of learning outcomes to measure students' successful skill development. The certification framework is split into technical and professional skills that are then divided into "components" that incorporate the skills necessary for a student to be career-ready upon graduation. Each component includes essential "themes" developed to break each skill into fine-grained elements for student development [1]. Essentially, each component is made up of predetermined competencies, defined as "specific skills that students can achieve to have a stronger understanding of the Theme" [1, p. 6].

Using Bloom's taxonomy resulted in four levels of preferred verbs that describe the acquisition of skills and the application, analysis, and creation of knowledge [1]. The levels provide a tangible way to measure successful completion of each competency. Each level can be completed by providing evidence of and reflection upon various scholarly activities that allowed students to gain understanding and experience in the competencies including: coursework, internship, club, leadership positions, etc. As students progress through the rubric, they will demonstrate completion of the certification framework.

Importantly, the framework is designed to be completed as part of a mentorship or curricular programmatic activity. As such, while students work to complete the framework, they also engage in a mentoring relationship with a faculty member. The mentoring relationship is designed to allow each student to receive guidance on both professional and technical skills and related activities while reflecting with a mentor who can provide additional perspective.

This paper focuses on the professional skills within the framework, which are divided into the following components: teamwork, communication, engineering habits of mind, solutions and impact, professional ethics, lifelong learning, leadership, and diversity, equity, and inclusion (DEI). Importantly, the current work extends Linvill et al.'s [1] previous work to develop a professional skills certification framework to develop career-ready microelectronics engineers by 1) explicating how the definitions for the professional skills in the framework were refined, and 2) determining how professional skills are assessed for each individual student. Implementation of the certification framework for faculty and student use is also discussed. Thus, the research questions this study employed provide further understanding of the work done to develop and refine the certification framework:

RQ1: How are professional skills defined for use in the certification framework?
RQ2: How are professional skills in the certification framework assessed?

The next few sections describe the aforementioned theoretical frameworks that aid in understanding skill acquisition, and both inform and relate to the certification framework development stages. The processes and results of defining and assessing professional skills are explained. The last section then puts the process of certification framework development, including defining and assessing skills, into conversation with its theoretical and pragmatic contributions.

Theoretical Frameworks

Experiential Learning Theory

Kolb's [13] experiential learning theory (ELT) proposes a four-stage cycle to explicate the learning process. Kolb [13] describes the cycle as beginning with a concrete experience, followed by reflective observation, abstract conceptualization, and active experimentation, all of which are necessary for learning. Kolb notes that while students may begin this cycle at any stage, they still follow the same progressive stages [14]. In an alternative explanation, Durkin describes this as "a process by which students purposefully acquire knowledge by doing, reflecting upon what was done, applying insight, and improving the result" [14, p. 22]. Utilizing experiential learning places the student in an active role within their learning process, allowing the material to be more memorable and easily transferred to other contexts [15] - [17] outside of the classroom.

Literature suggests that experiential learning is particularly effective for the acquisition of professional skills, as these types of skills generally take more time to develop [3] - [8] than typically available through classroom learning. In other words, it is the experience of applying professional skills within a certain context (i.e., as they relate to engineering problems/scenarios) that provide more intentional and meaningful learning outcomes. Experiential learning is also effective in solidifying technical skills for engineering students. Notably, Litchfield, Javernick-Will, and Maul [18] found that students involved in service-learning engineering activities were comparable in perceived technical skills but had higher perceived professional skills. Therefore, allowing students opportunities to engage in experiential learning can assist in the acquisition of technical and professional skills, both of which are necessary for students' development and success. Thus, we utilized ELT in determining implementation options designed to allow students to gain professional skills "by doing" through curricular, co-curricular, and extra-curricular activities [14]. Experiential learning has been used to inform the creation of reflective prompts, similar to the ones in this certification framework, within previous research [19]. Reflections are a form of assessment for experiential learning [20] and are used in the certification framework as students describe and apply their various scholarly activities that contributed to their professional skill growth.

Social Cognitive Career Theory

Social cognitive career theory (SCCT), also known as the social cognitive model of career development, was founded by Robert Lent, Steven Brown, and Gail Hackett [21]. The theory is based on Bandura's general social cognitive theory and self-efficacy theory [22], [23]. Bandura [24] describes self-efficacy as dependent on four main factors: personal performance accomplishments, vicarious learning, social persuasion, and physiological and affective states. SCCT draws on Bandura's theories to argue that interests develop from outcomes expectations and self-efficacy and acknowledges the dynamic nature of interests and expectations as individuals have new experiences [25]. SCCT is often utilized to understand "why people choose and persist in their career paths" [26, p. 4]. Additionally, SCCT considers both environmental and individual factors that shape one's decisions in relation to career development and provides a basis for explaining and predicting career development [21], [23].

Our team applied SCCT to the development of students' professional skills by designing the framework to require students to engage with SCCT's three-factor interaction model of career. The model can be understood through questions of self-efficacy (i.e., "Can I do this?"), outcome expectations (i.e., "What will happen if I do this"), and personal goals (i.e., "How much do I want to do this?") [25], [27]. As students interact with the professional skills development framework, they are required to intentionally identify the steps needed to accomplish their learning goals, be aware of the opportunities for successfully obtaining each professional skill by level, understand the skills they will gain, and evaluate their desire to complete the framework based upon the available information. Framing this study within the context of SCCT aided in the creation of a professional skills certification framework that considers students' dynamic interaction with learning while engaging with their individual needs throughout the process.

Self-Determination Theory

In consideration of students' individual needs, we also utilized Self-Determination Theory (SDT) as a theoretical lens through which to view this study. SDT is a macro-level theory of "motivation and personality development" [28, p. 4] and an "investigation of people's inherent growth tendencies" [29, p. 68]. In other words, SDT is a theory that was created to examine why humans are consistently motivated to grow and how this is impacted by their personality, making the theory well-suited to apply to the context of student motivation to learning. Specifically, SDT posits that an individual's task performance and well-being change based on the motivation they have for that task.

Through rigorous empirical testing, three innate and fundamental psychological needs have been identified for all human beings. Needs are "the nutriments that are essential for optimal human development and integrity" [30, p. 337], [31], including competence, autonomy, and relatedness [30] - [32]. Competence is the feeling of acting or performing effectively within an environment or task [32]. In the classroom context, competence would include mastering course content and translating the ability into success in course assessments. Competence has been identified as leading to increased student motivation and achievement [33]. Autonomy as a psychological need is the feeling of acting for oneself or enacting agency over one's own behavior or "provision of choice" [28, p. 13], [32]. Autonomy can still be achieved by a traditional classroom environment through a student internalizing the importance of being in class and seeing the value in completing coursework [33]. Relatedness includes the need to feel emotionally connected, attached, or related to others [32], [34]. Relatedness has been viewed as an outcome of a student experiencing a connected classroom climate [33] and has been linked to positive student learning outcomes [34]. Students who have these psychological needs met perform better academically, which contributes to a deeper learning outcome [35] and are actively motivated to engage in learning tasks [36].

Our team utilized SDT to structure the framework through meeting the vital needs of competence, autonomy, and relatedness for students. Students gain competence in professional skill development as they engage in experiential learning to complete the required competencies of the framework. Their need for autonomy is met as they choose what activities they will participate in to complete the competencies. Finally, relatedness is addressed by the mentor-mentee relationships that develop as students work with their assigned mentor during their time completing the certification framework. Similarly, students will learn alongside one another and develop relationships as they complete activities both in and out of the classroom. By ensuring that SDT's competence, autonomy, and relatedness needs are met, the framework encourages students to maintain motivation and growth throughout the duration of the certification process.

Methods/Results

Multiple methods and results were produced through refining the certification framework and developing an assessment process. As a result, the following sections are split to address each research question individually and make it more clear for readers how both the professional definition and assessment tasks were worked through methodologically and the results they provided. First, the professional skill definition development methods and results are described, followed by the professional skill framework assessment methods and results. Then the two are discussed in tandem alongside the theoretical and practical implications. Study limitations are noted.

Professional Skill Definition Methods

Linvill et al.'s [1] previously conducted a workforce needs assessment to identify nine essential professional skills needed to equip and develop career-ready microelectronics engineers, including teamwork, communication, engineering habits of mind, solutions and impact, professional ethics, lifelong learning, leadership, and diversity, equity, and inclusion (DEI). Engineering accreditation entities, such as the Accreditation Board for Engineering and Technology (ABET), relevant professional organizations, such as the National Association of Colleges and Employers (NACE), the National Science Foundation, the National Communication Association, and the National Society for Professional Engineers, and a variety of scholarly articles were reviewed to create holistic definitions for each of the nine essential professional skills [37]. As previously described, the identified professional skills were then compiled into the certification framework that provides structured guidance to students pursuing applicable curricular, co-curricular, and extra-curricular activities to develop necessary professional skills.

Professional Skill Definition Results

Expanding on the work of Linvill et al.'s [1], holistic definitions of each of the nine critical professional skills were composed using existing scholarship and are shown in Table 1 below, with an emphasis on definitions already well utilized by both ABET and NACE.

Table 1. ***Professional Skill Definitions Refined***

Professional Skill	Definition	Definition Source(s)
Teamwork	Building and maintaining a collaborative environment by appreciating diverse viewpoints, creating an inclusive environment, and sharing responsibilities in order to effectively meet objectives.	NACE [39], ABET [40]

Communication	Using both verbal and nonverbal messages to generate meaning and exchange information, ideas, and perspectives across various contexts and audiences.	NACE [39], ABET [40], NCA [41]
Engineering Habits of Mind	The distinctive thought processes, actions, and development of engineers who employ systems thinking, adapting, problem finding, creative problem solving, visualizing, and improving.	Lucas & Hanson [42]
Professional and Ethical Responsibility	The ability to understand and analyze professional and ethical responsibilities in the decision-making process to ensure that global, economic, environmental, health, and societal impacts have been thoughtfully considered.	NACE [39], ABET [40], NSPE [43]
Understanding Solutions, Impacts, and Issues	The ability to recognize problems, understand and analyze potential consequences, and work to produce solutions that consider global, societal, economic, and environmental welfare.	ABET [40], [3]
Lifelong Learning	Continuously identifying and addressing personal educational needs by acquiring necessary knowledge or training in order to maintain competence and consistently contribute to the field.	ABET [40], [44]
Leadership	Supporting an inclusive and collaborative environment that encourages team members to acquire tasks that utilize their strengths in order to work toward a shared goal.	NACE [39], ABET [40]
Multi-Disciplinary Problem-Solving	Utilizing a multi-disciplinary approach to problem-solving by using knowledge, information, and resources from diverse academic backgrounds. Recognizes structural disparities in professional and social contexts, understands the value of diverse perspectives and cultures, and actively supports diversity, equity, and inclusion initiatives.	NSF [45]
Diversity	Acknowledging, recognizing, and appreciating the range of human differences, encompassing the characteristics that make one individual or group different from another. Diversity includes, but is not limited to, the following characteristics: race, ethnicity, culture, gender identity and expression, age, national origin, religious beliefs, work sector, physical ability, sexual orientation, socioeconomic status, education, marital status, language, physical appearance, and cognitive differences.	NACE [39], [46], ABET [40]
Equity	The fair treatment, access, opportunity, advancement, and justice for all people, achieved by intentional focus on their disparate needs, conditions and abilities.	NACE [39], [46], ABET [40]

Inclusion and Belonging	The proactive and continuous intent to respect and value others in support of inclusivity and belonging.	NACE [39], [46], ABET [40]

Professional Skill Assessment Methods

Linvill et al.'s [1] work was created to determine what professional skills are necessary for microelectronics engineers and how those skills could be gained through the structure of a certification framework using Bloom's Taxonomy. In this paper, the previous framework is expanded to include further theoretical background and implementation practices. As previously discussed, the framework is structured utilizing ELT to establish competencies based on the career and learning development of SCCT and SDT as well as the standardization of Bloom's Taxonomy. ELT is also used to determine the implementation practices of reflection, portfolio, and mentorship.

Definitions for the skills were determined by researching and compiling definitions, descriptions, and uses of the terms from key sources such as NACE, ABET, NCA, Lucas and Hanson, NSPE, and NSF [3], [39] - [45]. Definitions were designed to create an active understanding of what the skills are and how they can be applied practically. Each skill was then further broken down into components, levels, and competencies. By not only creating a definition for the skill but breaking down what makes a student certified in the skill, our framework provides a more thorough understanding of what professional skills are and how to obtain them.

Professional Skill Assessment Results

Importantly, the framework guides students through the learning processes that include participation in the associated curricular, co-curricular, and extra-curricular activities. As students progress through each level of the certification, they will provide evidence of their skill development and reflect upon their experiences through writing prompts (see Table 2), which are then reviewed by teaching or research assistants to verify. Reflection requires the student to indicate the competency (professional skill) they have achieved, the relevant skill level, and the curricular, co-curricular, and/or extra-curricular activities completed. Students are then asked reflective questions specifically designed to allow for the reflective observation as called for by ELT. Then, if applicable, the student uploads evidence (i.e., such as a paper or project) to showcase their learning outcome(s).

Table 2. ***Example Reflection for Teamwork: Level 1***

Competency	Prompt
Initial Prompt	What activity (course, club, sports team, etc.) did you use to complete "Level 1: Teamwork"?
Self-Management	Reflect on how individuals can work together to contribute to group outcomes. Include observations that you have made from your curricular, extra-curricular, and/or co-curricular experience.
Multi-disciplinary Experience	Discuss what collaborative skills are needed to work with multi-disciplinary teams. What steps will you take to gain those collaborative skills?

Communication (Within Team)	Reflect on your experience discussing project-related content with team members. What qualities were demonstrated by your team? What qualities can be implemented on the team to improve communication in the future?
Team Culture	Reflect on your experience of reporting to leaders and other team members. What strategies do you use to show respect to others on your team?
Strategic Planning	Discuss how you label tasks and deadlines. How would you describe your organization process? How could your organization process be improved?
Ensuring Fair Work Distribution	Discuss your teammates' strengths, positions, and workload. How was work divided amongst the team? Do you think that the workload was fair? Why or why not?
Closing Prompt	Please upload any applicable files from your "Level 1: Teamwork" activity that can be contributed to your portfolio. Include documents such as completed papers, projects, class instructions, etc.

Discussion

This paper expands the previous work of Linvill et al.'s [1] to establish holistic and robust definitions of the following professional skills: teamwork, communication, engineering habits of mind, professional and ethical responsibility, understanding solutions, impacts, and issues lifelong learning, leadership, multi-disciplinary problem solving, and diversity, equity, inclusion, and belonging. By establishing these refined definitions, the framework can be utilized to effectively measure students' development of professional skills that have often been viewed as abstract concepts rather than measurable outcomes.

The framework was constructed considering SDT's three psychological needs of competence, autonomy, and relatedness, to increase "high quality motivation" [32, p. 151] of students throughout their learning activities. Students will gain competence through the regular completion of activities related to gaining professional skills. The structure of the framework was created with autonomy in mind, allowing students to choose curricular, co-curricular, and extra-curricular activities that best fit their needs and interests. The certification framework also integrates SCCT's three-factor interaction model of career as the structured levels clearly demonstrate to students what they need to do to accomplish each component, competency, and level, aiding in self-efficacy, outcome expectations, and completion of personal goals. Doing so aligns with SDT's competence, autonomy, and relatedness motivations to be met as students move through the program, completing levels, choosing courses and activities that meet their specific interests, and building relationships with mentors as well as others in their program [30] - [34].

Additionally, the certification framework utilizes ELT as students engage in a cycle of experiential learning. With the flexibility to engage in content through a concrete experience, whether in the classroom, through an internship, or through a variety of curricular and co-curricular activities, students are able to take the time to learn and reflect on their observations both individually and with their peers. Thus, they are able to "grasp" concepts and engage in the "transformation of experience" that takes place through experiential learning in ways that would be difficult in only a traditional classroom setting [13, p. 41]. For example, students may learn an abstract concept like "leadership" or a technical concept in the classroom. Then, they will engage in an extra-curricular activity like a club or an internship where they witness others leading or using a technical concept. As they reflect on their observations of their experience and conceptualize what leadership means to them or how to use a technical skill or thought process, they will be able to actually engage in active experimentation of their own leadership style or technical skills through further activities like leadership roles or skill application in clubs, teams, group projects, or further work experiences. In this way, the certification framework provides a structure to ensure that students are not only learning about, but actively engaging in the development of key professional and technical skills.

The next step for the research team will be implementation, which is currently in progress. The implementation process utilizes an online collaboration platform to pilot the certification framework, rubric, and assessments with a group of engineering students and faculty. The certification framework pilot includes one faculty member at a university who mentors multiple undergraduates as part of a microelectronics engineering workforce development program. The online platform will be used to gather student responses to the reflection questions as they progress through certification levels (limited to two competencies for pilot purposes). Students will also use the online platform to provide evidence for meeting each competency. Student evidence will be reviewed by a teaching or research assistant to verify that the student appropriately met the competency requirements. Following the pilot, the research team will conduct a review of the student and faculty experiences in a mixed-method format by utilizing both a survey and focus group. This information will inform how the certification framework might be improved upon to ensure that the desired outcomes are met, including adequate acquisition of student skills and a framework that is accessible and adaptable for faculty to utilize with students for professional skill building and subsequent assessment.

Implications

This paper further extends the use of SCCT, SDT, and ELT by utilizing all three theories for the development of the certification framework. Bringing all three theoretical frameworks into conversation with one another within the context of engineering education provides an overarching framework for engineering educators to consider for further developing students who possess the professional skills necessary to be a career-ready engineers. These considerations include SCCT's structure of how students develop and maintain their career interests through self-efficacy, outcome expectations, and personal goals, SDT's call to consider student's motivations in terms of their competence, autonomy, and connectedness, and ELT's cycle and structure of learning.

First, utilizing SCCT as a lens for the creation of the certification created a process that requires students to interact with the professional skills development framework and intentionally identify the steps needed to accomplish their learning goals, be aware of the opportunities for successfully obtaining each professional skill by level, understand the skills they will gain, and evaluate their desire to complete the framework based upon the available information. Framing this study within the context of SCCT takes students' dynamic interaction with learning into account while engaging students' individual needs throughout the process.

Second, the certification framework builds on existing evidence of the three fundamental psychological needs of competence, autonomy, and relatedness within SDT. Much of previous research that utilized SDT in a higher education context includes an application to the traditional classroom. This project applies SDT to the development of a robust skill acquisition tool and therefore expands our understanding of the use of SDT that breaks the bounds of coursework. Completion of the framework not only produces a certified student, but also a well-refined employee once that student enters the workforce. In other words, the benefits of a student with satisfied psychological needs go beyond the classroom, and potentially extend into the workplace.

Third, the application of ELT within this project suggests that experiential learning does not need to be limited to traditional coursework. Experiential learning can be included outside of the typical course curriculum. Because the traditional university classroom environment still lacks experiential learning, it is important for educators to consider another way for students to gain crucial experiential learning experiences, such as through a skill acquisition framework.

Practical implications for this study can also be considered. First, the certification framework addresses the need for professional skill development in the microelectronics engineering industry by providing definitions, competencies, a framework, and an assessment rubric for the certification program. The structure of the certification framework addresses the "untestable" nature of professional skills, providing a direct benefit not only to microelectronics engineering educators, but to educators in other areas searching for a way to teach and assess professional skills. Additionally, the certification framework provides a streamlined and consistent way for students and faculty to track development throughout students' academic careers. The certification framework and assessment rubric will provide students with a space to reflect on the professional skills they have developed, which will allow them to articulate those skills in interviews and be aware of areas in which they have grown and still need to grow. Ensuring that professional skills are developed and tracked during this time will also allow employers to clearly identify what skills new employees have. The certification tools can easily be adapted by other engineering educators to facilitate the acquisition and assessment of professional skills. Assigned mentors, such as faculty members or advisors, may use this certification framework to help students choose the best path for their plan of study while aligning with student interests. Additionally, employers may benefit from the certification framework as a tool to verify student competencies related to professional skill development, particularly if student reflections and evidence are transferred into a portfolio view for use during the hiring process.

A second practical implication is that while assisting students to acquire professional skills, the framework contributes to student "well-being and facilitate(s) effective functioning in social settings" through ensuring their basic psychological needs are met [47, p. 22], [48]. Because professional skills are best gained through experiential learning activities such as internships or group projects, it is highly likely that students will be working on teams or in groups, which contributes to feelings of relatedness or connection [3] - [8]. Additionally, participation in mentoring relationships and reflective practices will allow students to develop key interpersonal relationships and relational interaction practices that will aid them not only in their formal schooling, but throughout their career as they engage in lifelong learning.

Third, the structure of the framework allows for not only flexibility, but also personal responsibility as students must take initiative to develop their professional and technical skills in settings and spaces that are engaging and applicable to their own fields and interests. The framework also provides both the structure and flexibility to adapt to other areas of engineering. In other words, this framework can translate to a multitude of student outcomes that will lead to success upon entry into the workforce. For organizations, this success might translate to higher rates of employee retention and satisfaction as newcomers will arrive with a robust toolkit of professional skills to utilize in the workplace.

Limitations

The authors of this work acknowledge that no definition can be perfect and that literature, as well as social and cultural developments, must be continuously examined to ensure conscientious and effective definitions of the professional skills: teamwork, communication, engineering habits of mind, professional and ethical responsibility, understanding solutions, impacts, and issues, lifelong learning, leadership, multi-disciplinary problem solving, and diversity, equity, inclusion, and belonging. Additionally, the framework is currently in its implementation stage and will be subject to adaptation as student and faculty feedback is obtained.

Conclusion

The professional skill gap in engineers, long recognized by employers, creates a crucial demand for student development processes that allow for successful acquisition of professional skills. This project expands on previous work in which holistic definitions of professional skills were previously determined. The research team utilized the predetermined professional skills and created a certification framework that tracks and facilitates skill development through experiential learning. Through this process, students can both showcase their skill development with tangible evidence and gain vital professional and technical skills structured through the certification framework.

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References

[1] J. S. Linvill et al., "Development of a Certification Framework for a Microelectronics Workforce Development Program," Accepted for presentation as part of a competitively selected panel at the ASEE Annual Conference & Exposition, Baltimore, MD, June 2023.

[2] J. S. Linvill, I. Adams, E. Haluschak, B. Quezada, and T. J. Moore, "'Good communication skills are super, super important': Developing students' professional communication skills for career-ready engineers," Accepted for presentation as part of a competitively selected panel at the ASEE Annual Conference & Exposition, Baltimore, MD, June 2023.

[3] L. J. Shuman, M. Besterfield-Sacre, and J. McGourty, "The ABET 'professional skills'—Can they be taught? Can they be assessed?," *Journal of engineering education*, vol. 94, no. 1, pp. 41-55, 2005.

[4] E. W. Ernst, "Workplace changes and engineering education reform," in *Technology-Based Re-Engineering Engineering Education Proceedings of Frontiers in Education FIE'96 26th Annual Conference*, vol. 2, pp. 882-885, IEEE, 1996.

[5] National Research Council, "Engineering education: Designing an adaptive system," National Academies Press, 1995.

[6] S. D. Garrett, J. P. Martin, and S. G. Adams, "Developing nontechnical professional skills in African American engineering majors through co-curricular activities," *IEEE Transactions on Education*, vol. 65, no. 3, pp. 394-401, 2021.

[7] D. Jackson and R. Bridgstock, "What actually works to enhance graduate employability? The relative value of curricular, co-curricular, and extra-curricular learning and paid work," *Higher Education*, vol. 81, no. 4, pp. 723-739, 2021.

[8] C. J. Finelli et al., "An assessment of engineering students' curricular and co-curricular experiences and their ethical development," *Journal of Engineering Education*, vol. 101, no. 3, pp. 469-494, 2012.

[9] B. S. Bloom, M. D. Engelhart, E. Furst, W. H. Hill, and D. R. Krathwohl, "Handbook I: cognitive domain," New York: David McKay, 1956.

[10] L. W. Anderson, D. R. Krathwohl, P. Airasian, K. Cruikshank, R. Mayer, and P. Pintrich, "A revision of Bloom's taxonomy of educational objectives," A Taxonomy for Learning, Teaching and Assessing. Longman, New York, 2001.

[11] D. R. Krathwohl, "A Revision of Bloom's Taxonomy: An Overview," Theory Into Practice, vol. 41, no. 4, pp. 212-218, 2002/11/01 2002, doi: 10.1207/s15430421tip4104_2.

[12] P. M. Newton, A. Da Silva, and L. G. Peters, "A pragmatic master list of action verbs for bloom's taxonomy," in Frontiers in Education, 2020, vol. 5: Frontiers, p. 107, doi: 10.3389/feduc.2020.00107.

[13] D. Kolb, "Experiential Learning: Experience as the Source of Learning and Development," Upper Saddle River, NJ: Prentice Hall, 1984.

[14] R. J. Durkin, "Experiential Learning in Engineering Technology: A Case Study on Problem Solving in Project-Based Learning at the Undergraduate Level," *Journal of Engineering Technology*, vol. 33, no. 1, 2016.

[15] R. Moreno and A. Valdez, "Immediate and delayed effects of using a classroom case exemplar in teacher education: The role of presentation format," *Journal of educational psychology*, vol. 99, no. 1, pp. 194, 2007.

[16] E. Bartle, "Experiential learning: an overview," Institute for Teaching and Learning Innovation. Australia: The University Of Queensland, 2015.

[17] R. C. Schank et al., "The design of goal-based scenarios," *The Journal of the Learning Sciences*, vol. 3, no. 4, pp. 305-345, 1993.

[18] K. Litchfield, A. Javernick-Will, and A. Maul, "Technical and professional skills of engineers involved and not involved in engineering service," *Journal of Engineering Education*, vol. 105, no. 1, pp. 70-92, 2016

[19] Woodcock, C. S. E., Callewaert, J., & Millunchick, J. (2021). Synthesizing Definitions of Professional Competencies Linked to Experiential Learning in Engineering Education: A Literature Review. *Journal of Higher Education Theory and Practice*, *21*(4), 4.

[20] Chan, C. K. Y. (2023). *Assessment for Experiential Learning*. Taylor & Francis.

[21] R. W. Lent, S. D. Brown, and G. Hackett, "Toward a unifying social cognitive theory of career and academic interest, choice, and performance," *Journal of Vocational Behavior*, vol. 45, pp. 79–122, 1994.

[22] A. Bandura, "Social Foundations of Thought and Action: A Social Cognitive Theory," Englewood Cliffs, NJ: Prentice Hall, 1986.

[23] R. W. Lent and S. D. Brown, "Social cognitive career theory at 25: empirical status of the interest, choice, and performance models," *Journal of Vocational Behavior*, vol. 115, pp. 103316, 2019.

[24] A. Bandura, "Self-Efficacy: The Exercise of Control," New York, NY: Freeman, 1997.

[25] D. Wang, X. Liu, and H. Deng, "The perspectives of social cognitive career theory approach in current times," *Frontiers in psychology*, vol. 13, 2022.

[26] Gentry, A. N., Bermel, P., Holloway, E. A., & Douglas, K. A. (2022). Validity evidence for exposure and motivation scales in a microelectronics workforce development program. Paper presented at 2022 ASEE Annual Conference & Exposition, Minneapolis, MN.

[27] T. Buthelezi, D. Alexander, and J. Seabi, "Adolescents' perceived career challenges and needs in a disadvantaged context in South Africa from a social cognitive career theoretical perspective," *South African Journal of Higher Education*, vol. 23, no. 3, pp. 505-520, 2009.

[28] R. M. Ryan and M. Vansteenkiste, "Self-Determination Theory: Metatheory, Methods, and Meaning," *The Oxford Handbook of Self-Determination Theory*, 2023.

[29] R. M. Ryan and E. L. Deci, "Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being," *American psychologist*, vol. 55, no. 1, pp. 68, 2000.

[30] M. Gagné and E. L. Deci, "Self-determination theory and work motivation," *Journal of Organizational Behavior*, vol. 26, no. 4, pp. 331-362, 2005.

[31] R. M. Ryan, K. M. Sheldon, T. Kasser, and E. L. Deci, "All goals were not created equal: an organismic perspective on the nature of goals and their regulation," in *The psychology of action: Linking cognition and motivation to behavior*, P. M. Gollwitzer and J. A. Bargh (Eds.), New York: Guilford, 1996, pp. 7–26.

[32] J. Reeve, "A self-determination theory perspective on student engagement," in *Handbook of research on student engagement*, pp. 149-172, Springer US, 2012.

[33] L. M. Jeno, A. G. Danielsen, and A. Raaheim, "A prospective investigation of students' academic achievement and dropout in higher education: a Self-Determination Theory approach," *Educational Psychology,* vol. 38, no. 9, pp. 1163–1184, Oct. 2018. doi: 10.1080/01443410.2018.1502412.

[34] B. N. Frisby and M. M. Martin, "Instructor–Student and Student–Student Rapport in the Classroom," Communication Education, vol. 59, no. 2, pp. 146–164, Apr. 2010, doi: 10.1080/03634520903564362.

[35] R. M. Ryan and E. L. Deci, "Intrinsic and extrinsic motivation from a self-determination theory perspective: Definitions, theory, practices, and future directions," *Contemporary Educational Psychology*, vol. 61, pp. 101860-, 2020.

[36] H.-C. K. Hsu, C. V. Wang, and C. Levesque-Bristol, "Reexamining the impact of self-determination theory on learning outcomes in the online learning environment," *Education and Information Technologies*, vol. 24, no. 3, pp. 2159–2174, 2019.

[37] E. L. Deci and R. M. Ryan, "A motivational approach to self: Integration in personality," in *Nebraska symposium on motivation: Perspectives on motivation*, R. Dienstbier (Ed.), vol. 38, pp. 237–288, University of Nebraska Press, 1991.

[38] B. Lucas and J. Hanson, "Thinking Like an Engineer: Using Engineering Habits of Mind and Signature Pedagogies to Redesign Engineering Education," *International Journal of Engineering Pedagogy* (iJEP), vol. 6, no. 2, pp. 4–13, 2016.

[39] National Association of Colleges and Employers. "Career readiness defined." [Online] https://www.naceweb.org/career-readiness/competencies/career-readiness-defined/.

[40] ABET. "Criteria for Accrediting Engineering Programs, 2022 – 2023." [Online]. https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2022-2023/.

[41] National Communication Association (NCA), "What is Communication?" [Online]. Available: https://www.natcom.org/about-nca/what-communication.

[42] B. Lucas and J. Hanson, "Thinking like an engineer: Using engineering habits of mind and signature pedagogies to redesign engineering education," 2016.

[43] National Society of Professional Engineers (NSPE), "Code of Ethics," [Online]. Available: https://www.nspe.org/resources/ethics/code-ethics

[44] ABET, "Criteria for Accrediting Engineering Programs: 2016-2017," [Online]. Available: https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2016-2017/

[45] National Science Foundation (NSF), "Learn About Convergence Research," [Online]. Available: https://beta.nsf.gov/funding/learn/research-types/learn-about-convergence-research

[46] National Association of Colleges and Employers (NACE), "NACE Statement of Diversity and Inclusion," [Online]. Available: https://www.naceweb.org/about-us/nace-statement-of-diversity-and-inclusion#:~:text=Belonging%20refers%20to%20the%20perceived%20support%2C%20feeling%20of,cultivates%20the%20cornerstone%20of%20engagement%20in%20our%20community.

[47] E. L. Deci, A. H. Olafsen, and R. M. Ryan, "Self-determination theory in work organizations: The state of a science," *Annual review of organizational psychology and organizational behavior*, vol. 4, pp. 19-43, 2017.

[48] R. M. Ryan, "Psychological needs and the facilitation of integrative processes," *Journal of personality*, vol. 63, no. 3, pp. 397-427, 1995.