2023 Annual Conference & Exposition
Baltimore Convention Center, MD | June 25 - 28, 2023
The Harbor of Engineering Education for 130 Years
Paper ID #39560

Pro-Op Education: An Integrated Effort to Prioritize the ABCs of the Profession

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Pro-op education - an integrated effort to prioritize the ABCs of the profession (Work in Progress)

Introduction:
This paper reports on the research and experiences in the Mechanical Engineering Department at Ohio University's Russ College of Engineering and Technology that identified 'professionalizing' engineering education as an approach worth further investigation to significantly change the learning and professional development of engineering students. Our approach, which has been branded Pro-op education, involves prioritizing (and leading with) development of Professional Attitudes, Behaviors and Competencies (Pro-ABCs) as foundational skills, and interweaving traditional coursework with small but significant professional experiences designed to emphasize aspects of the U.S Department of Labor's engineering competency model (primarily personal and workplace effectiveness). The intention is to transform the identity and mindset of the learners in our engineering programs from 'student' to engineer in training, or engineering apprentice.

A key feature of pro-ops is that students take on professional roles in experiences intentionally designed to resemble a professional experience in all aspects, to differentiate them from just another class project. We use immersion as a measure of the level of industry-like context, with a high level of immersion being required to qualify as a pro-op. The overarching goal of Pro-op education is to create a healthy professional culture (Pro-culture) within our engineering program, where students engage in repeated professional experiences and tell stories about them through the reflective lens of the Pro-ABC model. Pro-op students interact with instructors for perspective sharing and calibration in ways that support student ownership of their development and their ability to self-evaluate. Pro-op instructors serve primarily as mentors while helping students build and demonstrate professional competencies. Student-designed professional portfolios (Pro-folios) serve to build their sense of belonging as an engineer and benefit them by making it easier to demonstrate, assess, recognize, and build on their Pro-ABCs in future work and enable better performance in competitive job and promotion interviews.

For context, our mid-size ME department is situated in Athens Ohio, a rural area with limited local industry. We have historically attracted and retained faculty who desire a balance of research and teaching and who see student development (both undergraduate and graduate) as our primary mission. Pandemic and budget-related challenges recently disrupted our historical patterns of engagement with students in ways that make the status quo an unattractive option and have created an openness among faculty and staff to change. Surveys and student focus groups about student and department culture over the past three years have revealed the prevalence of anxiety and mental health challenges among students, the influence of multiple overlapping groups (micro-cultures) on student behaviors that are well beyond our control, and the barriers to adoption of professional behaviors created by student attitudes formed in high-school and first-year non-engineering college courses such as 'school is a game,' 'being smart / being right is what matters,' and 'students are in competition for limited opportunities' [1]. This quote about identity captures our motivation to meet students where they are so we can walk together towards the light of a new educational model and pattern for instructor-student relationships: "It's never about behavior, it's about identity - versions of an old self have to die in order for a new, brilliant one to emerge and see the light [2]."

The characteristics of the desired professional culture (Pro-culture) are described by the U.S. Department of Labor's Engineering Competency Model (developed with the American Association of Engineering Societies and experts from industry, education, and business) [3]. As part of a Stacking the Deck for Career Success initiative, researchers at Ohio University have transformed the model into a student-friendly competency card deck (Figure 1, and available online) [4] and an overview foldout (Figure 2) to make the model more accessible and implementable.

Figure 1: Competency Card Deck with several pages visible

The current version of the competency card deck includes challenges and interview questions to prompt student development in the following competencies.

- Personal Effectiveness (Interpersonal Skills, Integrity, Professionalism, Initiative, Adaptability & Flexibility, Dependability & Reliability, and Lifelong Learning)
- Workplace Effectiveness (Teamwork; Client/Stakeholder Focus; Planning and Organizing; Creative Thinking; Problem Solving, Prevention and Decision Making; Seeking and Developing Opportunities; Working with Tools and Technology; Scheduling and Coordinating; Checking, Examining, and Recording; Business Fundamentals)
- Academic (Reading, Writing, Mathematics, Science and Technology, Communication, Critical and Analytical Thinking, Computer Skills)
- Industry-wide Technical (Foundations of Engineering; Design; Manufacturing and Construction; Operations and Maintenance; Professional Ethics; Business, Legal and Public Policy; Sustainability and Societal and Environmental Impact; Engineering Economics; Quality Control and Quality Assurance; Safety, Health, Security and Environment).
- Wild Cards are additions to the model from our research and employer interviews. (Wellness & Self-care; Compassion & Kindness; Curiosity & Civility; Equity & Inclusion; Humility & Humor; Leadership; Career Exploration & Advancement.)

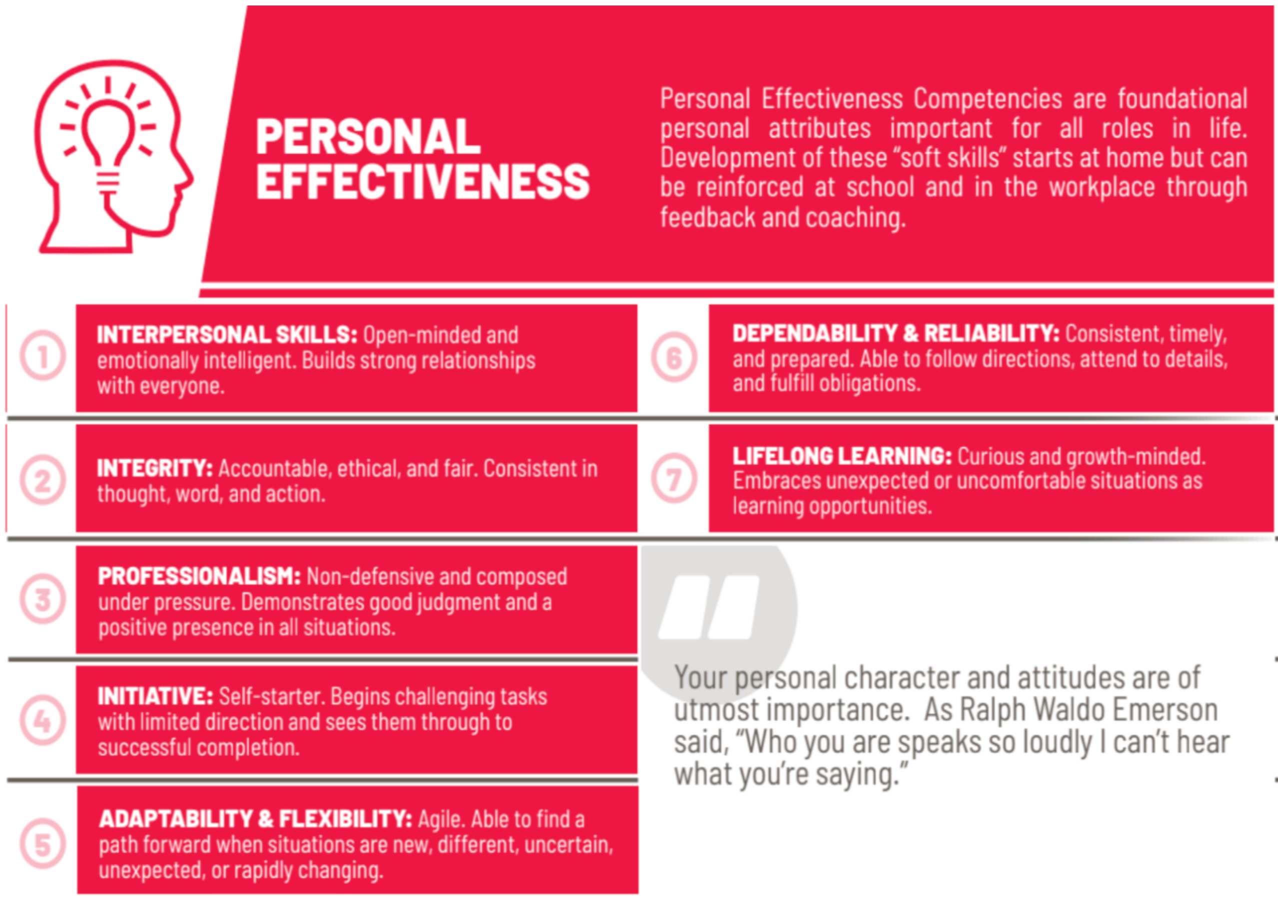

Figure 2: An example page from the Competency Model Overview foldout

In pilot studies to date the card that has resonated with the most students is the Wellness and Self care card. Including it as a competency integrated into the model seems to have had a positive impact on engineering students' openness to talking about and practicing wellness and self-care. This is an area for additional research. The need for ongoing development of materials that address the attitudes and behaviors needed to build professional competencies is reinforced by recent employer perspectives on desired attitudes or mindsets lacking in recent grads (including humility, initiative, and professionalism) [5], and studies on professional mindsets [6],[7] and mindset shifts [8] [9].

Pro-op Education:
Table 1 lays out the basic structure and defines the terms used in the Pro-op education model. The entire model is presented here for a general overview. This work in progress paper will focus on specific aspects of the model with interesting background research and/or pilot test results.

Table 1: Pro-op Educational Model – Interweaving a critical mass of professional experiences throughout an engineering program to move learners' mindsets, identity and behavior from student towards engineering apprentice. The first Pro-op prototype embeds most professional experiences within traditional course structures, with the semester-spanning Pro-Days as the signature experience. Future iterations envision one Pro-Day per week for at least four semesters.

<table>
<tr>
<td>Course-embedded Pro-op experiences
* $\geq$25% of course credits in middle years prominently feature Pro-ops. Includes fundamental (Dynamics, Thermo, etc.) and applied (CAD, Machine Design, etc.) courses.
*Pro-op semester - At least one semester in middle years will have 100% of courses (> 12 credits) with Pro-op experiences.</td>
<td>Open-structured Pro-Days
*Pro-Days are full-day Pro-op work experiences
*The 1st prototype is a 3-credit Pro-op lab course requiring 15 Pro-Days of ‘on-site professional work’ to be completed in a minimum of 3 diverse locations. The open-structure allows students to complete the Pro-Days over their middle years (not required to be in one semester), choosing experiences and roles based on development needs.</td>
</tr>
<tr>
<td colspan="2">Common Characteristics for all Pro-op experiences:
Pro-Roles: Students placed in varying professional roles, with role reflection as a form of career exploration. Students own the schedule and time/cost are tracked and evaluated.
Pro-ABCs as defined in the competency model guide student engagement in experiences and provide a frame for reflection and feedback for experiential learning cycles.
Pro-Cycles are personalized forms of an experiential development cycle (Adapted from Kolb [10] and CPREE [11]) that provide a repeatable structure for supporting learning, development, and connection. They are co-developed with students, so the terms and steps resonate with them.
Pro-feedback methods are structured around Pro-ABCs and respect student choice and voice on feedback styles that support their development and mental health. Role-reversals and ‘do-overs’ are used to explore power dynamics and how interactions could have been different. Positive connections (you belong) are made when students demonstrate Pro-ABC behaviors.
Pro-grading transparently places a large percentage of the total grade on the use and self-evaluation of proper engineering process, full engagement in the Pro-cycle/ Pro-feedback process, and demonstration of relevant Pro-ABCs.
Pro-stories are similar to behavioral interview (tell me about a time…) responses, told about professional experiences through the reflective lens of the Pro-ABC model. The story converts the Pro-ABC into a shareable artifact used for building/demonstrating/evaluating professional competencies. When compiled in a Pro-folio they tell the student’s professional development story.
Pro-folios are a meta-structure in the Pro-op model, pulling the diverse experiences and stories together in a way that shows connections and development over time, aids development that transfers into other situations [12] and supports a follow-up structure where students can select future experiences to fill in gaps identified in earlier stories and instructors can require prerequisite competencies to be demonstrated in the Pro-folio. The format of the Pro-folio will be co-developed with students to take advantage of the important prior work on e-portfolios [13] and research that shows positive impacts on shifting mindsets [14], building a professional identity [15], and an increase in self-assessment skills [16], but also recognizes that different formats are needed to reduce the frictions that act as barriers to student use of portfolio systems. Pro-folios support learner-owned records and sharing in ways that employers can use to evaluate job candidates.</td>
</tr>
</table>

The Pro-op initiative is an embodiment of key principles in the publication *Educating Engineers: Designing for the future of the field*, especially the weaving of professional formation throughout the curriculum in an integrated way that encourages students to draw connections [17]. Stated another way, the Pro-op education model enhances the learning of ‘how to do engineering’ by the practice of ‘how to be’ an engineer, and follows a principle of learning theory of acting into a new way of thinking [18]. The Pro-op model also builds from prior work on integrative education and professional skill development [19] – [22], a National Academies’ report on How

People Learn that promotes connected learning models in which "learning experiences and opportunities from various settings are leveraged for each learner [23]," Savage et. al's [24] work spreading project-based activities throughout the middle years that found positive impact on student attitudes about the engineering profession, and Heinrich and Green's 'remixing' approach to more strongly connect experiential learning to theory [25]. Additional important influences more related to attitudes and behaviors include Rubin's use of an expectations framework [26], and aspects of empowerment theory related to increasing student agency and engagement [27], [28], addressing power dynamics [29], [30], and informing important decisions that impact how much ownership and responsibility students take for their development and engagement in feedback interactions [31], [32]. The book Connected Teaching [33] is particularly useful in building from these theories to generate actions relevant for working with our current students and their mental health challenges. This area of research also shows the importance of word choice (for example 'exploration' instead of 'evaluation' to emphasize the collaborative nature of healthy feedback processes) and telling stories with characters that students relate to.

The open-structure Pro-Days are designed to engage students in significant and diverse professional experiences in a way that is achievable with limited access to industry. Pro-Days are not meant to replace term-long co-ops/internships but to complement them. Our ME program does not have required co-op experiences, though over 75% of graduating seniors consistently report having completed at least one engineering work experience. A limitation we have observed with our current co-op/internship system is that a large majority of students experience only one or two types of roles and industries before making decisions about their career options. This seems to lead to bias in decision making, where either one good or one bad experience has an outsized effect on career decisions. The diversity of experiences embedded in the Pro-op model is an effort to help students experience a larger variety of roles and types of work.

Pro-Day experiences include immersive experiences in local industries (as piloted with General Mills and the campus Lausche Heating Plant), work-days in research labs, assignments on new product startup ventures in our university's Innovation Center (as being piloted in a startup for community-scale agricultural and food processing equipment) or in student design groups (mentored by a faculty advisor or professional mentor), or student-proposed and industry-supported Pro-Days within the context of a traditional co-op experience targeting development or demonstration of specific competencies. We are proposing a flexible model that allows any work experience structured to fit the Pro-op characteristics to count. A future goal (beyond our current scope) is to create a structure where all engineering students would have a Pro-Day once per week - similar to existing programs where high-school students work one day per week [34]. We will be evaluating whether the combination of Pro-Days with Pro-op experiences in disciplinary courses is different enough than the current student experience to result in student attitudes and behaviors that align more with an engineering apprentice than a college student.

The importance of storytelling for engineers has been promoted by NASA's chief learning officer [35], and Wilson [36] reveals their power to re-direct our lives and impact our development. Our four years of pilot studies of a Stacking the Deck initiative applied in multiple years in the curriculum using challenges and interview questions to prompt students to tell stories about experiences through a competency lens have shown promising results in encouraging students to engage in experiences in a different way, become more fluent with engineering competencies, and improve their interview performance. A related research study showed students who made a verbal case for a competency endorsement about one month before a scheduled interview had an increase in their ability to recall examples and apply them to other possible scenarios in that interview, showing that frequent discussion of experiences in the context of engineering competencies can have the type of developmental effect expected from narrative pedagogy [37]. Further support for the use of Pro-ABCs as a lens for reflection on competencies is provided by a study by Findlay et al. that found measurable gains when learners used a reflective inventory to guide their journaling [12]. Sullivan's research about student purpose and vocation found that integrated development and learning is most likely when "students are supported in narrating their own stories about struggle and persistence in complex environments, developing proactive knowledge in the process [38]." The use of narrative or storytelling in education has a strong multi-disciplinary foundation [39], [40], and within engineering education a study by Halada and Khost took a broad and philosophical look at the use of personal narrative pedagogy to enhance student learning in areas such as problem solving, values and ethics [41].

From our many years of experience guiding students through reflection related to experiential learning, we recognize the challenges students face in the processing (reflective observation) step. Processing involves conscious and unconscious processes and emotions, and healthy external feedback and perspectives are needed to confirm or correct individual perspectives and reflections, help learners make connections and reveal hidden gaps [37]. Pro-cycles are envisioned as learner-friendly learning cycles designed to change learner motivations and mindsets and create conditions where external perspectives and feedback is more likely to have positive impacts. Research on feedback processes show that even in work-based learning environments students 'play the game' to avoid corrective feedback (a form of feedback which is most beneficial to learning [42]), especially if the feedback is connected to an eventual grade [43]. Other studies show that emotions must be addressed as a factor in the complex social process of workplace-based feedback [44], and cultural shifts are needed to achieve responsibility-sharing in feedback processes in higher education [45]. To further improve feedback interactions we recommend providing professional development for instructors based on the wealth of good resources on feedback [46], motivation [47], and empowering others [48] that are targeted at professionals but appear underutilized in engineering education.

Pilot studies and other Work in Progress:

One of the fundamental assumptions for the Pro-op model is that increasing the level of immersion in professional scenarios will impact levels of student engagement and behavior. To test this assumption, in the Spring semester of the 2022-23 academic year we initiated a pilot study of a full-immersion in a Tech Startup project. This project integrated curricular credit for coursework whose core competencies aligned with the tasks of forming a technology startup company. Several courses from Ohio University's Entrepreneurship Certificate Program and the Mechanical Engineering Capstone Design (semester 1) and Experimental Design courses were restructured to allow students to have a full schedule of classes immersed in real project work. A team of five students including two business students and three mechanical engineers did the footwork to form their own technology startup company with instruction, coaching, and mentoring from a faculty member from each of the two departments. The pilot study culminated in the students delivering a pitch for funding for their first prototype to potential investors. From a scheduling perspective, the integration into existing curriculum allowed this pilot to work within existing structures. One key step that made this possible was having an existing list of required outcomes/competencies for all the courses involved, such that project work could be pointed towards those outcomes. For example, the Experimental Design course has a writing component in which addressing writing to different types of audiences is a key requirement. Students wrote reflections on their own professional development, wrote executive summaries of different portions of their work to business and engineering audiences separately, and a final technical report on their engineering work over the course of the term. This direct identification of skills and correlation to real-world activities in the experience represented the most significant pedagogical work in developing the pilot.

The instructors were high-level faculty from their respective areas, with direct experience in technology startups such that they could supply whatever level of background was necessary for the students' needs over the course of the term. This was highly inefficient in terms of instructor time, but was an effective method for providing needed resources on demand. Next steps for better efficiency are to identify relevant skillsets for the different instructional activities that were involved, and determining a staffing structure using teaching assistants that properly supports the learning while maximizing the extent to which high-level faculty time can be leveraged among multiple teams, while maintaining a genuine real-world feel to the experience. The instructor team focused on changing the power dynamic, encouraging the student team to be out in front running the project and directing their own learning as much as possible. For example, when working with the first potential customer the instructors began by facilitating the conversation with the customer and calling out particular communications strategies. Once a few key points had been reinforced, the instructors physically moved to the back of the room and handed the conversation over to the students. In meetings, instructors generally participated as peers whenever possible. The primary instructional approaches were coaching and mentoring as opposed to direct instruction. The large amount of student time commitment structured into the pilot provided students the necessary flexibility to redirect their time to do formative work on a task when necessary. For example, the student team reported during a regular 'staff meeting' that their ideation process was producing poor results. Straight away, instructors facilitated and then participated in a structured ideation session, pointing out necessary or important steps as they went. Students were then able to directly extend that work for the next hour on their own, which solidified their learning on-demand. The next steps for this pilot are to further investigate which courses can be integrated into immersive experiences, how to serve multiple student generations at once, and how to make the model economically sustainable.

Another aspect of the Pro-op approach to test is the response of different levels of students to the concept of an engineering competency model, and the process of using challenges and/or interview questions to impact the experiences they engage in and how they process those experiences. In earlier studies the engineering competencies were introduced to seniors in a career colloquium (ME 4800), with a focus on using the interview questions as a means to gain advantage in job and promotion interviews. This application of competency cards was well received by students, and specific results of this study will be presented in future publications. The competency model has been used for two years in a sophomore colloquium (ME 2800) where the competencies targeted included leadership, safety, and ethics. In a final oral exam, all students (excluding a few special cases who did not complete the class) successfully responded to a question from these competency cards. We are planning follow up studies for these students in later classes (such as ME 4800) to look for signs of transfer of these engineering competencies beyond the targeted assignments.

A pilot study using the competency cards and a developmental framework in a freshman design course (ME 1010) in the Spring semester of the 2022-23 academic year represents one more step toward creating a cohort of students who have multiple integrated experiences with the professional approach of the engineering competencies, to enable longitudinal studies of the impact of repeated reinforcement of the engineering competency model throughout the engineering program. During Spring semester 2023, freshman-level ME students were asked to focus on one competency from each of the four main competency categories (personal effectiveness, workplace effectiveness, academic and industry-wide technical.) In the initial weeks, students were asked to provide insight, examples, and reasoning for why and how they chose their competencies, and to consider ways they can work towards and gain experience in the competencies selected. For each competency entry, students were asked to provide and share evidence of their competency experience, how they could work towards improvements on the competency in the future, and the final outcome of the experience. Initial responses reviewed throughout the semester show that students have excellent insight into past experiences where competency related skills were challenged, and many students commented on personal barriers they felt could hinder their progress towards these skills. Students were open and honest about the concerns they had towards making improvements in some of these competencies. Through discussion with individual students working on their entries throughout the semester, it was observed that some students were very insightful and reflective on the experiences and interactions they had with others and looked at these reflections positively. Other students disliked the activity, found little meaning in it, and overall had a negative attitude towards having to write and discuss the questions asked. This difference in reactions among students is not unexpected, and parallels some of the differences in student attitudes about college. Part of our ongoing work is focused on the culture change needed to increase the percentage of students who engage more positively with developing themselves in a broader set of engineering competencies.

We also completed a pilot study on the use of ‘uniforms’ to impact student mindsets around professional project work, to determine if ‘enclothed cognition’ had any significant impact on student attitudes and behaviors related to capstone project work. Our first iteration in Fall 2022 allowed students to choose from three different student-designed prototypes – an ME Capstone pullover shirt, an ME Capstone pen, and an ME Capstone name/photo badge. The students were provided the items that they chose and used them whenever they were in a class or lab related to the ME Capstone experience. Although most students reported liking the items they received and they did use them consistently throughout the semester, we did not observe any increase in performance or significant difference in attitudes or behaviors for any of the three uniform options compared to each other or to prior classes of students with no uniforms. When the use of uniforms became optional in the Spring semester there was no consistent continuation of their use, and no noticeable difference in attitudes compared to the prior semester. So we have no evidence that having a uniform reminded students that there were different expectations for their attitudes and behaviors when working on their capstone projects. Because of the other research that showed the impact of a uniform in situations where other factors like location and type of work were aligned, we do plan to try uniforms again in a Pro-Day or other situation where more factors can align for a combined effect.

Due to the complex nature of feedback and its critical role in student development, we are planning future work that investigates forms of feedback that are most effective for student development. This work will build on research in the field of STEM teacher education that indicates that collaborative mentoring that fosters quality interactions between mentors and mentees positively impacts learning and professional development [49]. It acculturates learners, like teacher candidates, into their profession by providing them with models for practice, feedback on planning and problem-solving, and emotional support [50], [51].

Note that the existing competency card decks described in this paper are used in two programs in the college, as a resource by advisors in the career-pathway university initiative, are featured on the U.S. Dept. of Labor's Competency Model Clearinghouse [52], and through a partnership with the Center for Occupational Research and Development [53] (whose motto is "Leading Change in Education") have been adapted for use by Forsyth Tech and other technical schools and have been featured in their Necessary Skills Now Network [4]. From prior adaptation efforts we have received positive responses that reinforce the need for materials with 'bite-size chunks' that can be implemented in a range of scenarios. We are investigating how to better facilitate community development of resources related to the engineering competency model, which may include inclusion in the Open Skills Network [54]. We are continuing our efforts to promote the use of the Pro-ABC materials to industry partners for early-career professional development, to create a "pull" from industry for more professional formation within engineering programs as regional industries set clearer professional expectations in their hiring practices.

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