Designing Coursework and Culture: Toward a Bachelor's Degree in Engineering Technology

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Kathryn Kelley serves as executive director of OMI; she has more than 20 years' experience in program leadership and strategic communications at industry-oriented higher education, economic development and statewide technology organizations. She collaborates with state and national partners to develop regional and national public policy to support manufacturing innovation, advocate for small- and medium-sized manufacturing needs within the supply chains and remove barriers between academia and industry.

Activities include: • Managed Ohio Development Services Agency Ohio MEP funded program on "Manufacturing 5.0" to develop a framework and set of tools to guide MEP staff assisting small- and medium-sized manufacturing firms in their journey toward digital integration. • Completed ODSA-funded project on Ohio Advanced Manufacturing Technical Resource Network roadmaps organized by manufacturing processes to determine manufacturing needs and technical solutions for machining, molding, joining/forming, additive manufacturing. • Served as lead coordinator of a Bachelor of Science in Engineering Technology degree program at The Ohio State University focused on curriculum development and approval, securing industry support and promoting program to internal/external audiences. • Collaborated with the Ohio Manufacturers' Association, Ohio TechNet, and others to develop a framework and implementation of regional industry sector workforce partnerships and a statewide image campaign, Making Ohio, to spur manufacturing job growth • Administrated Ohio Department of Higher Education (ODHE) Ohio Means Internships & Co-ops program for the Central Ohio region, including area community colleges, to increase advanced manufacturing experiential learning • Served as Ohio principal investigator on a $2.24M US Department of Defense Office of Economic Adjustment Defense Manufacturing Assistance Program and $300K Defense Cybersecurity Assurance Program

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Aimee Ulstad, P.E is an Associate Professor (Clinical) in the Integrated Systems Engineering Department at The Ohio State University. Prior to joining the faculty at OSU, Aimee was an industry professional in various engineering roles for over 30 years. Aimee received her degrees in Mechanical Engineering and Masters in Business Administration from Ohio State. She began her career as a packaging equipment engineer at Procter and Gamble, then moved to Anheuser-Busch where she worked for over 27 years. She worked as project manager, engineering manager, utility manager, maintenance manager, and finally as the Resident Engineer managing all technical areas of the facility. During her tenure, the brewery saw dramatic increases in productivity improvement, increased use of automation systems, and significant cost reductions in all areas including utilities where they received the internal award for having the best utility usage reduction for 2014. Since joining Ohio State, Aimee has joined the American Society of Engineering Educators and has served in all leadership capacities in the Engineering Economy division (treasurer, program chair, division chair, and past chair). Aimee is also part of a core group of Ohio State faculty working on a BSET degree at the Regional Campuses and is passionate about teaching engineering using application and wicked problem methodologies.

Work in Progress: Lessons Learned in Creating a new BSET Program in Year Two to Design Coursework and Culture

Premise:

This paper is the second of multi-year analysis of a new degree program for a Bachelor of Science in Engineering Technology (BSET) degree at an established higher education institution that has previously only granted Bachelor of Science in Engineering degrees. This new degree will be fully offered at regional campuses, which have traditionally offered a feeder program into an engineering program with severe capacity constraints. The purpose is to share the lessons learned from this program development with others in the engineering education and technology space as a joint learning exercise. Last year's paper was written when the degree proposal was being submitted. This year's paper covers what has happened since the proposal was approved and the program launch date set for three regional campus locations in autumn semester 2020.

Research – Coursework Development and Curriculum Alignment

In the first year, the BSET steering committee took a mindful approach in developing a four-year engineering technology degree for students that was manufacturing focused and leaned toward management and leadership skills. The approach was undergirded by research collected from regional focus group results and US Bureau of Labor O*NET occupational data to determine current and future engineering technology skills needed by manufacturers.[1] As Paul Nutter et al states, "Academic programs can benefit by assessing their effectiveness to fulfill the needs and expectations of manufacturing industries, gaining insights for appropriate curriculum revisions to enhance the job-readiness of students to serve these 'customers' of our academic services." [2] The committee supported the viewpoint that many students will find engineering technology a better educational fit than the existing engineering degree program offered at the university.

The steering committee aligned BSET goals, outcomes and proficiencies to ABET accreditation guidelines, which will be used to track students' mastery of the subject matter. SME guidelines will also be used for the manufacturing concentration. The goals, outcomes and proficiencies of the program were fully developed and approved before beginning curriculum development. The next step undertaken in Summer 2019 was to prepare goals, outcomes and proficiencies for each course as well as develop course content, syllabi, assignments and testing. These will be uploaded into an online master course that will connect the ABET and SME outcomes to the course elements.

With the goal of developing courses for this program, faculty members, industry advisers and students formed a team to support this program. Because the regional campuses will be delivering this program and the central campus groups will be approving the curriculum through their current curriculum oversight committees, both central campus and regional campus faculty were selected. The three sub-teams were staffed as follows:

- Math: Team members from math included one full professor who teaches at the regional campus, one associated faculty at the central campus who is the coordinator for engineering calculus, and one associated faculty at another regional campus.
- Physics: The physics team included two full professors who teach at regional campuses and one emeritus professor from central campus who has a deep history of conducting hands-on learning pedagogical research.
- Engineering: The engineering team included two faculty from the regional campus, one associated faculty from central campus, and one graduate student who had worked extensively as a teaching assistant and a senior in the current engineering program.

At the outset of this program, we expected that new courses would be developed for calculus, physics, and engineering technology separate from those delivered to traditional engineering students, but this goal morphed over the summer. A major priority for the team was to ensure that the courses were integrated to support the goals of making math and physics complementary. Students' development of communications and critical-thinking skills were emphasized by manufacturers as an important priority, so presentational and team-building assignments were included in all subject areas.

We held a kick-off meeting with the appointed faculty to develop the first year of the BSET coursework. In this meeting, they learned about the initial research and jobs data used to determine skills required by industry nationally and regionally as well as the process that the steering committee undertook to during the overall development of the BSET program. This overview included the outcomes and proficiencies that were developed for each of the following educational goals established by the steering committee for the program:

1. Systems Thinking & Problem Solving: The successful student will be able to effectively solve problems by applying the appropriate engineering technologies, tools, and techniques within systems of equipment, controls, and people.
2. Professional Skills/Communication: A successful student will be able to demonstrate, appreciate, and master interpersonal communications skills in the modern workplace.
3. Business: A successful student will be able to understand business terminology, analyze value of alternatives, and communicate the business, societal and global impacts effectively.
4. Continuous Improvement: The successful student will be able to optimize processes and systems with respect to quality, timeliness, and continuous improvement.

The faculty team began their course development process by touring several manufacturing plants in the region and by asking engineering staff what types of skills

Figure 1: Faculty touring regional manufacturing plants

they use during their daily work and the proficiencies they look for when hiring new graduates. They also investigated pedagogical practices that could serve as a guiding mechanism for course development.

During the tours of automotive, home appliance, and industrial metals manufacturers, questions faculty posed questions about how math, physics and engineering skills are used on the plant floor. Below are the questions asked during the tours with responses from the manufacturing engineers:

- How do you use physics in your role? Do you have examples of its use in engineering positions at the plant?
  - Manufacturing engineers indicated that they used physics to understand forces at play between components, kinematic simulations, process layouts
  - Use to work on how machines function
  - Angle, momentum is needed
  - Manufacturability is where the physics comes in
  - Tolerance and tolerance stamping are important
  - Don’t use it much anymore, other than spec’ing equipment to fit certain parameters
- How do you use math in your role?
  - Math is used to calculate run rates, process times as well as managing budgets and preparing cost stories and statistical analysis.
  - Paint engineers calculate heat transfer, material flow, atomization, application
  - Quality uses math and geometry/trig for stack-up studies
  - Force calculations, length of line measurements, component wear analysis
- How have you used calculus?
  - Most plant engineers do not; only for high-level research

    - Used more for optimization
    - Don’t need matrix differentiation
    - Ask engineers to learn torque, electrical circuits, differential equations
    - Adjusting the proportion, integral and derivative
    - Wish my classes would have been more of an integration of what you can do with calculus, not just math problems.
- What math do you think engineering technology workers need to know?
    - Geometry, coordinate systems, algebra, trigonometry, statistical analysis
- What computer software do you use?
    - CATIA, DELMIA, AutoCAD
    - We do not use MATLAB here
- How proficient do workers need to be in Excel?
    - Very proficient; able to manipulate, analyze, summarize, and interpret large amounts of data
    - Use databases from which to analyze data

The engineers at one of the manufacturing firms outlined three essential skills that graduates should have include: critical thinking - to be able to adapt to every changing environment; the ability to communicate - when to use an email versus text versus face to face; and flexibility, as technology changes every two years.

The faculty team then were engaged in a short curriculum design camp to outline goals and outcomes of new courses that would fit an engineering technology focus, with an overarching purpose to integrate coursework in math, physics and engineering as well as present content through a project-based approach. Not only did the new courses receive this treatment but also courses that were adapted from the existing curriculum.

Beginning with the overarching goals, objectives and proficiencies developed by the BSET steering committee, the Course Design Institute (CDI) introduced faculty course developers to the “Backward Design” process, a concept advanced by educators Grant Wiggins and Jay McTighe in their book *Understanding by Design* [3]. While it is tempting to begin designing a course by deciding what content to cover, backward design facilitators ask instructors to start by identifying specific, student-centered goals and objectives before touching any other elements of the course. Participants follow this process to finish the workshop with an "Integrated Course Plan" that will best enable student learning.

The university coordinator for assessment and curriculum design commented about leading the course design process:

> The instructors really wanted to start with lengthy conversations about content and who was going to teach what, when. They struggled to see the reason for backing up and starting off with articulating goals and outcomes. But when they started to see how the goals and outcomes guided their thinking and allowed them to better work together to coordinate the various courses and align student learning they seemed to really embrace the process. I was so impressed with the conversations they had, working in such detail to bring the courses together, both

concurrent courses and longitudinally to make sure that both skills and topics would be learned in a consistent order. They also worked diligently to come to agreement about vocabulary and designed assignments that would fit together across multiple concurrent courses.

Six entirely new courses for the engineering technology degree program were submitted for approval by multiple colleges and universities as well as adaptations of existing courses that will include content and lab work were connected more squarely with engineering technology skills development.

New courses include:

Introduction to Engineering Technology	Manufacturing Processes I	Manufacturing Processes 2
Calculus for Engineering Technology 1	Engineering Graphics 1	Engineering Graphics 2
Calculus for Engineering Technology 2	Electrical Circuits 1	Physics 2

We also negotiated with the respective colleges to offer special sections of physics, engineering fundamentals, Excel and chemistry to engineering technology students. The extent of the adaptation ranged from changing a final assignment to offering an entire section geared toward engineering technology students.

In addition to math, science, and engineering, ABET requires that students accomplish “soft” skills upon graduation so that they have the ability and understanding to do the following: work as a member of a team, communicate in written, oral and visual formats, participate in professional development activities, uphold professional and ethical standards, realize their work exists in a diverse, global context, and focus their efforts on continuous improvement. that will teach them team leaders and management skills that are crucial in the mid- to high-level roles needed in modern manufacturing plants. [4] The faculty infused these requirements through individual and team assignments in each of the math, physics and engineering courses.

At the end of the summer, the faculty built much of the first two years of the bachelor’s degree program; approximately 70% of the course development of content matter was completed within five months. At the end of the summer, faculty presented to the industry representatives whom they interviewed earlier in the summer the coursework that was developed, with positive reviews. Figure 2 provides an example of the curriculum details provided to the industry representatives.

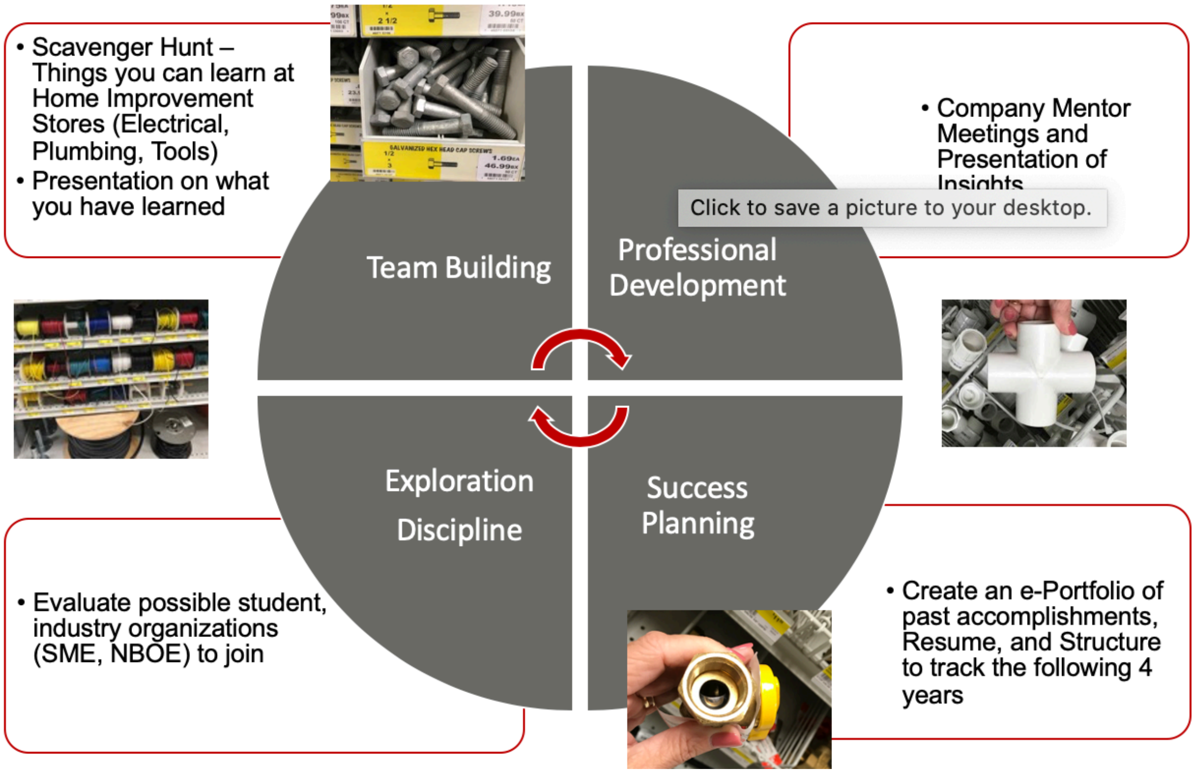

Figure 2: Course skills and content presented at BSET industry report-out

The integration of math, physics and engineering was one of the major accomplishments of the faculty during and after the intensive CDI, with the goal of providing students with an understanding that the lessons they learn in math is connected to what they learn in physics and engineering.

Ultimately, the goal to educate students by combining systems thinking, business and communication skills and a dedication to continuous improvement was achieved. In their 2012 report, "Industry-University Partnerships Work: Lessons from successful collaborations," by the Science | Business Innovation Board, Alan Begg, senior vice president, at the SKF Group, indicated, "It is individuals who understand both worlds – academia and business – that are the driving force behind successful partnerships."[5] We are confident that the faculty have developed a strong start for BSET students who will play a valuable leadership role in the next generation of manufacturing.

Another unintended benefit is that the faculty, especially those at the regional campuses, have become champions of the degree program. During regularly held meetings during the school year, they have reported how they have promoted the program to their classes. One faculty member led a regional MakerFest challenge to promote the new degree to high school students. The faculty have supported the program during regional meetings to inform other faculty and staff about the BSET degree. In addition, they have been instrumental in recommending and recruiting new faculty for the build out of the second two years of coursework. While the BSET faculty began the course development process with constraints and limitations, most have now embraced the process and creative approach, which is affecting their delivery of other courses. During the school year, the participating faculty have continued to experiment in advance of the BSET program launch through assignments and pedagogical approaches, such as a flipped classroom in one of the physics classes. [5]

We are recruiting faculty to work on the Year 3 team of the BSET program. Based on the lessons learned during the first years of course development, we will investigate the content expertise of each faculty member for the upper-level courses. And we will continue to vet our approach and progress with area manufacturers.

Next Steps – A Long-haul Drive Toward Culture

Long term, the steering committee has a lot of ground to cover to change the culture at the university, as a stigma exists about the academic rigor of a program focused on hands-on learning combined with the perceptions about offering a four-year degree program only on the regional campuses, which traditionally have mostly served as a feeder into the central campus programs. Much of the progress has occurred at the curriculum level, where the faculty developing the first two years' coursework have spoken to their colleagues across all of the campuses. Steering committee members have worked with academic departments to fine tune existing courses to better fit the goals and outcomes of the engineering technology program. And educating advisors, enrollment and recruiters on the programs distinguishing features compared to engineering to better inform current and prospective students has begun but will take some time to take hold.

Action items we continue to pursue as the BSET program is developed include:

- Determining the best approaches to standardize the curriculum and develop consistency across regional campuses will be needed. Each campus has its own distinctive culture and resources, so a "one size fits all" approach to the coursework will not work.
- The regional campuses are collaborating with area community colleges and career-technical centers on lab space, available equipment and instruction. These efforts will require constant communication and collaboration to maintain mutually beneficial relationships.
- Online education options are being investigated. Even though the first year of the program requires more face-to-face instruction, some leeway exists to offer online courses across all campuses. That approach would help to ensure

The steering committee is working with multiple teams at the university to track metrics that may offer insights into our effectiveness in changing the curriculum, and ultimately, the ecosystem. We intend to assess the following statistics: the number of companies engaged in the program through guest lectures, co-ops and internships; the number of new and current students who apply to the program; funding requests for researching teaching methods to improve the engineering technology program not only for the university but the community college and career-technical centers; number of sponsored manufacturing internships and capstone projects with an application component.

The industry relationship-building that the steering committee and faculty have integrated into the first two years include touch points involving industry mentorship of new students, manufacturing tours, and providing assignments that can be included in the course syllabi. This approach is anticipated to not only build students' manufacturing-ready skills through project-based learning, but also to increase retention rates at the regional campuses.[6] While a number of engineering and engineering technology programs offer faculty-student and peer-to-peer mentorships, the addition of industry mentorship from multiple companies surrounding the regional campuses will offer students a more in-depth understanding of the roles and expectations required in manufacturing. On the flip side, determining approaches to take with manufacturers to create a culture of flexibility so their employees can enroll in the BSET program will require additional outreach.

Lessons from the information technology field may serve as a model for university-industry educational relationships. Take for example the Microsoft-Cisco-Intel partnership with the University of Melbourne. In 2008 Microsoft, Cisco and Intel agreed to launch an industry-university partnership with the University of Melbourne with the goal of identifying the higher-order skills that students need for success in schools and in the workforce and then transforming the assessment and teaching of these 21st-century skills. "The partnership of corporations and university set out to lead the way to new forms of assessment that would drive new approaches to teaching and curriculum. A radical shift in the three pillars of education was needed," says Patrick Griffin, the project's executive director. To tackle the task, the core partners formed an executive board to manage a three-year multi-stakeholder effort, involving some 250 academics and multilateral institutions including UNESCO. The partnership identified two discrete skill sets: collaborative problem-solving and digital literacy. And the three-year research effort produced knowledge, tool sets and common standards that transfer across borders.[7]

Long term, we are working with regional campus administrators to connect the university's workforce efforts with the state's current initiatives to prepare skilled workers. This approach will ultimately increase the relevance of research universities in manufacturing workforce development and allow policymakers to gain an understanding of the larger spectrum of engineering technology education that includes multiple on- and off-ramps. The resulting industry-university collaboration will help form a mutually beneficial ecosystem that meets the needs of the state and may possibly serve as a model for the rest of the US.

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