ENGINEERING WORK-AND-LEARN

IMPERATIVES FOR INNOVATION

SEPTEMBER 2018

LIFT, operated by the American Lightweight Materials Manufacturing Innovation Institute (ALMMII), is a Detroit-based, public-private partnership committed to the development and deployment of advanced lightweight metal manufacturing technologies, and implementing education and training initiatives to better prepare the workforce today and in the future. LIFT is one of the founding institutes of Manufacturing USA and is funded in part by the Department of Defense with management through the Office of Naval Research.

The Association of Public and Land-grant Universities (APLU) is a research, policy, and advocacy organization dedicated to strengthening and advancing the work of public universities in the U.S., Canada, and Mexico. With a membership of 237 public research universities, land-grant institutions, state university systems, and affiliated organizations, APLU's agenda is built on the three pillars of increasing degree completion and academic success, advancing scientific research, and expanding engagement. The association's work is furthered by an active and effective advocacy arm that works with Congress and the administration as well as the media to advance federal policies that strengthen public universities and benefit the students they serve.

National Center for Manufacturing Sciences (NCMS) is a cross-industry technology development consortium, dedicated to improving the strength and competitiveness of American manufacturing. As a member-based organization, NCMS leverages its network of industry, government, and higher education partners to develop, demonstrate, and deploy innovative technologies, leveraging the advantages of collaboration across sectors to increase efficiency and optimize performance. NCMS is committed to helping meet U.S. manufacturers' demand for skilled workers through its ongoing support for workforce development, training, and STEM education.

TABLE OF CONTENTS

FORWARD

Reports from industry suggest that, while students are graduating from university engineering programs with substantial theoretical knowledge, they often lack in problem-solving, context for real-world applications, and critical employability skills needed to thrive in the workplace.

A crucial role of the university engineering program, whether at an undergraduate or graduate level, is to prepare future engineers for success in the workplace, not just success in the classroom. It is our belief that work-and-learn models provide an effective way to round out students' education experiences and prepare them for the workplace. When done well, work-and-learn programs have been shown to:

- Enhance learning through application of knowledge to real-world problems;
- Increase problem-solving and data analysis skills, enable more effective teamwork, and improve adaptability to new venues, tools, and technologies;
- Improve student preparedness for screening and hiring processes;
- Expose students to individuals from different backgrounds, generations, and skillsets.

A quick scan of university programs in the U.S. would likely find that most universities offer *some* level of work-and-learn experiences to students as part of, or as a supplement to, their engineering education. If work-and-learn models are indeed already reasonably prevalent in engineering education, then why do industry leaders and students alike report concern over recent engineering graduates' lack of preparedness for the workplace? Is it merely a matter of implementing more work-and-learn opportunities into university engineering education? Or do traditional models of engineering work-and-learn programs need to be reimagined to better prepare students for the rapidly changing workplace?

These questions prompted LIFT, APLU, and NCMS, in partnership with Manufacturing USA, to convene a group of nearly 50 representatives of university engineering programs and industry, in June 2018, to discuss the critical need for innovation in engineering work-and-learn models at universities. Over the course of the two-day workshop—entitled "Advancing University Engineering and Manufacturing Education: The New, Innovative, and Re-Imagined World of Employer-Engaged 'Work-and-Learn'"— the participants were charged with identifying critical imperatives to innovating university engineering work-and-learn models; drivers for doing so; barriers to innovating work-and-learn models; and potential solutions and innovations that universities can employ to better prepare their engineering students for the workplace.

Through these discussions, we identified four key imperatives and accompanying recommendations that would innovate existing engineering work-and-learn models to better prepare engineers for successful careers in industry. While the participants of this workshop were primarily focused on engineering programs relevant to careers in manufacturing, these imperatives and recommendations can be applied to a broad array of engineering disciplines, programs, and levels of education. We are pleased to report these findings, imperatives and recommendations in the following pages, and we hope they stimulate innovation in university engineering work-and-learn programming across the country.

Emily DeRocco
Vice President, Education & Workforce Development, LIFT

Jim Woodell
Vice President, Economic Development and Community Engagement, APLU

Defining 'Work-and-Learn'

Work-and-learn models are educational strategies that enhance academic learning with practical workplace experience through engagement with an employer. Work-and-learn models equip students with both technical skills and employability skills (see page 8) necessary to make a more seamless transition to industry upon graduation.

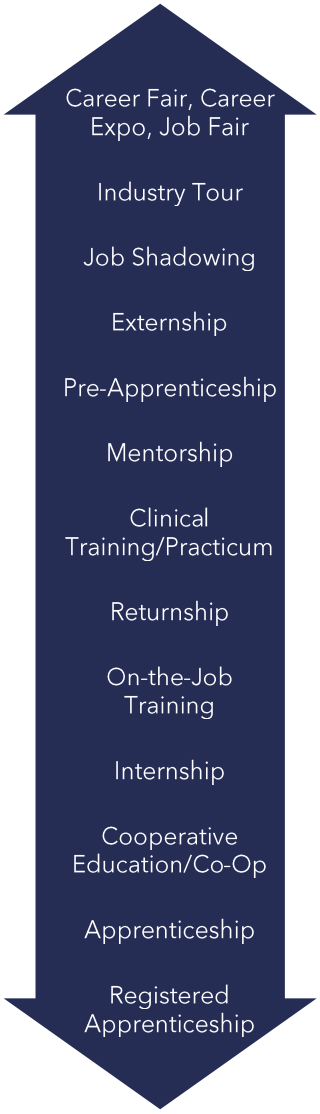
Work-and-learn is an umbrella term for a multitude of different strategies that provide industry experience. Work-and-learn models can take on various forms, some of the most common being internships and co-ops, and may range from relatively simple 'low touch' experiences to longer-term and more robust 'high touch' experiences as shown in the continuum, developed by the National Network of Business and Industry Associations (National Network), to the right.

It's important to note that, while many educators may be more familiar with the term experiential learning to describe hands-on educational experiences, experiential learning may, but does not necessarily, result in skills gain directly linked to workplace readiness. Conversely, work-and-learn models are specifically designed to develop workplace skills, albeit to varying degrees. For that reason, this publication specifically focuses on expanding and innovating work-and-learn models to prepare students for success in industry.

Work-and-Learn Continuum

LOW TOUCH
Work-and-Learn

- Less structured
- Low engagement and resources needed from the employer
- General career



HIGH TOUCH
Work-and-Learn

- Very structured
- High engagement and resources needed from the employer
- Full immersion and career and industry

Source: National Network

Executive Summary

The following imperatives and recommendations for reimagining engineering work-and-learn models resulted from the *Advancing University Engineering and Manufacturing Education: The New, Innovative, and Re-Imagined World of Employer-Engaged "Work-and-Learn"* workshop held in Washington D.C. in June 2018.

Imperative: Engineering graduates should have deeper understanding of how their role intersects with other processes and individuals in the workplace.

- Create inter-disciplinary and multi-level innovation groups to develop new curricula and learning modules.
- Partner with local community and technical colleges to facilitate industry problem-based learning experiences involving both technician and engineering students.

Imperative: All engineering students should participate in high-quality and innovative work-and-learn experiences during their undergraduate and graduate programs.

- Develop multiple pathways for engineering education including research and applied pathways.
- Push for more flexibility in completion times, allowing extended programs of study and incorporating more work-and-learn opportunities for students.

Imperative: Engineering curriculum must be responsive to evolving industry needs, including the needs of small, medium, and large employers.

- Assess, at the local level, the extent to which accreditation and curriculum review present barriers to change and identify strategies for working within or adapting systems to maximize opportunities to innovate.
- Create facilities shared by both academia and industry to facilitate industry problem-based learning and ongoing work-and-learn experiences.
- Establish stronger partnerships with small and medium-sized enterprises (SMEs) to allow for more diverse inputs into curricula and work-and-learn experiences.
- Partner with Manufacturing USA Institutes to send students and faculty to emerging technology workshops and courses.
- Hire professors of practice and equip the next generation of faculty members with industry experiences.

Imperative: Work-and-learn models should be more widely implemented in university engineering programs and not reliant on a small group of 'champion' professors or administrators.

- Encourage adoption of work-and-learn models by including employment readiness as part of the institutional-level definition of student success.
- Create 'Engineering Work-and-Learn' communities of practice.
- Capitalize on the ongoing evolution in promotion and tenure practices, including greater recognition of community and industry engagement, and increased emphasis on community-engaged learning, to provide incentives for faculty to develop and implement work-and-learn models.

A Case for Innovation in University Engineering Work-and-Learn Models

The work environment of professional engineers continues to evolve rapidly and will require new approaches to prepare students for the challenges of industry. The pace of technological innovation continues to accelerate and requires the ability to think critically, react quickly, and interact with an increasingly diverse group of colleagues. Historically, engineers have been tasked with developing deep expertise in their area of study, whether mechanical, electrical, chemical, or other, and perhaps rarely interacting with other disciplines and roles within a manufacturing environment. Conversely, engineers are now increasingly being expected to develop a breadth of engineering knowledge, in addition to deep expertise in their chosen discipline, so they can interact with, and understand, how other engineering disciplines and roles intersect within a manufacturing organization.[i] While many engineering students spend at least part of their education working with other engineering disciplines, they rarely interact with students and professionals who represent other aspects of the workplace environment—from the business analysts who will allocate resources for their project to the technicians who will build their designs. Further, industry is rapidly shifting to become more agile to quickly respond to market shifts both in technology development and production techniques, which will require engineers to develop a systems perspective to more effectively collaborate with colleagues across their organization. Quite simply, engineers can no longer live in silos, and neither can universities and industry.

At the same time, the demand for skilled engineers is projected to grow 4%, adding 65,000 new jobs through 2024.[ii] Fortunately, engineering program enrollment has remained steady, and has even seen growth in recent years, with many programs often reaching maximum capacity. In 2016, universities in the United States graduated 124,009 students with bachelor's in engineering and engineering technologies.[iii]

Although universities are educating engineers in relatively large numbers, there appears to be a mismatch in how well these students are being prepared for the jobs of today, let alone the engineering jobs of tomorrow. While 96% of chief academic officers of colleges and universities believe that their institutions are very or somewhat effective at preparing students for the workforce, only 11% of business leaders strongly agree. [iv]

Workshop attendees reported that dissatisfaction from industry appears to be growing, and newly graduated engineers are not adequately prepared for today's work environment. Workshop participants reported that the average employer must spend 1-2 years upskilling a recent university graduate before they can begin functioning as an entry-level engineer. While some training is expected to prepare engineers for company-specific processes and technologies, industry is finding that students aren't prepared for basic requirements of a manufacturing environment. In one survey, employers indicated that employability skills, not technical skills, were the most lacking in recent college graduates. When asked about employability skills, 60% of managers felt critical thinking and problem-solving were most lacking.[v]

Employability Skills

Employability skills are those critical competencies that are difficult to measure but are essential to successful employment regardless of industry or career level.

Common employability skills include:

- Personal Skills, like integrity
- People Skills, like teamwork
- Applied Knowledge, like critical thinking
- Workplace Skills, like working with tools and technology.

See the "Resources and Acknowledgements" section for more Employability Skills resources.

Likewise, engineering students themselves are feeling unprepared for the workplace despite completing rigorous programs of study.[vi] In a study of engineering Ph.D. students, those who were pursuing careers in industry perceived gaps in their preparedness to succeed in industry, particularly related to their ability to: interface with industry, tailor communication to their audience, work across disciplines, work in teams, and manage multiple projects.

Lack of readiness for work isn't limited to engineers. National conversations like the Future of Work (See the "Resources and Acknowledgements" section for more resources) are highlighting the ways the workplace is evolving—not just because of technology shifts, but also because of social and cultural shifts across industries. One recent study surveyed graduates regarding the relevance of their education to their jobs and the skills needed in day-to-day work. In its survey of college freshman, 85% report pursuing post-secondary education as a means to obtain a good job. However, the study found that only 36% of students enrolled in STEM (science, technology, engineering, and math) are confident their program of study will prepare them for success in the workplace.[vii]

Work-and-learn models offer a solution for preparing students for careers after graduation, however simply implementing more of the same models will not keep up with shifting industry demands. New innovative approaches are needed, and engineering educators should be at the forefront of preparing their students to adapt, by steering shifts both in the classroom and in the workplace through innovative, reimagined work-and-learn models.

How to Use This Publication

This publication:

- Captures imperatives for preparing engineering graduates for the workforce.
- Identifies potential barriers to meeting these imperatives by innovating and expanding work-and-learns.
- Provides tangible ideas for how universities can design and implement even more effective forms of work-and-learn programs.

The challenges or barriers that have been identified in this publication are not necessarily present at every university or within every engineering program but are representative of the most common issues identified in the *Advancing University Engineering and Manufacturing Education: The New, Innovative, and Re-Imagined World of Employer-Engaged "Work-and-Learn"* workshop organized by Lightweight Innovations for Tomorrow, Association of Public and Land-grant Universities, and the National Center for Manufacturing Sciences in June 2018.

For individuals who are looking to implement one or several of the recommendations made here, this publication can be used to provide ideas on how to:

For Faculty

- Build a case for why existing work-and-learn models at your institution need new innovative approaches.
- Embed new innovative work-and-learn experiences into your coursework and programming.
- Design quality industry engagement opportunities for students.

For Administrators

- Champion innovative work-and-learn models and look for ways to incentivize their expansion.
- Lead institution-wide efforts to further engage industry.

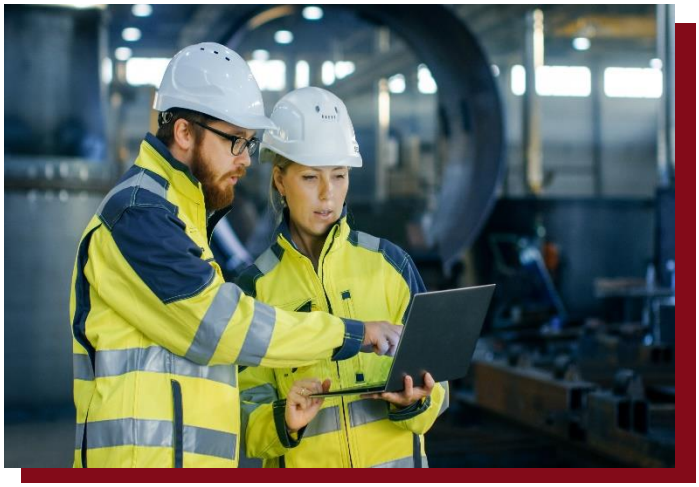
For Industry:

- Advocate for, and partner with educators on, and contribute (both time and monetary resources) to expanding and innovating work-and-learn opportunities for students.

Imperatives for Reimagining Engineering Work-and-Learn Models

Imperative: Engineering graduates should have deeper understanding of how their role intersects with other processes and individuals in the workplace.

The typical engineering student begins his or her education with a broad liberal arts foundation followed by core engineering coursework that ideally cuts across multiple engineering subdisciplines. By the time students reach sophomore status, they typically select a specialty discipline, like mechanical engineering or chemical engineering, at which point they complete the bulk of their remaining coursework with other students in the same discipline.



While many universities have attempted to encourage some cross-specialty interaction, this is not a widespread practice, and when it is pursued, such interaction relies on a single course or project to foster cross-pollination. While a step in the right direction, the approach surely doesn't provide adequate exposure to prepare students for the workplace, where they will undoubtedly need to interact with individuals from different levels of technical background, knowledge, and capability.

In addition to needing the ability to communicate with other engineers from different disciplines, engineers will also need to be able to regularly interact with technicians, production staff, budget and financial analysts, and many other functions in the business and workplace environment. Workshop participants indicated that, all too often, while engineering students understand their piece of the manufacturing process well, they do not necessarily understand how it fits within the broader picture of a manufacturing environment. One industry participant asserted, *'As an engineer, my work is only as good as the technician I work with*,' underscoring the importance of a work environment where engineers and technicians can effectively communicate and collaborate with one another. Rather than waiting for engineers and technicians to encounter one another for the first time in the workplace, universities should foster learning environments in which these interactions take place much more frequently throughout the education process.

Recommendation: Create inter-disciplinary and multi-level innovation groups in universities to develop new curricula and work-and-learn modules.

Rather than relying on *ad hoc* faculty relationships across departments to spur innovation in curriculum development, universities should establish more formal interdisciplinary and multi-

level workgroups. Such groups can include faculty across disciplines within the university and include a cross-section of faculty from engineering disciplines as well as other critical majors, including, but not limited to, business, engineering, management, technology, and accounting. The workgroups should also include inputs from local community and technical colleges as well as regional employers. The groups can collaborate to develop new curriculum, industry problem-based learning modules, capstone projects, and work-and-learn modalities that will expose engineering students to other disciplines, roles, and functions within the manufacturing environment.

Whenever possible, these workgroups should integrate industry problem-based learning (see below) into work-and-learn opportunities to ensure that projects are representative of real-world scenarios. While some engineering programs undoubtedly collaborate with industry to develop projects around real-world industry problems, this practice needs to be more widespread and grounded in industry context than what is currently the norm.

Industry Problem-Based vs. Project-Based Learning

Project-based learning is a common occurrence in most university programs, where students are provided with a prompt describing hypothetical parameters and expected outcomes to work individually or as a team to complete a short or long-term project. While this approach undoubtedly helps foster teamwork and problem-solving skills, these experiences can have even greater impact by integrating real-world industry problems.

Industry problem-based learning integrates real-world examples of challenges faced by industry into curriculum and project work. Rather than try to craft hypothetical case studies based solely on their own experience, university faculty can partner with local industry members to solve a current or prior real-world problem faced by engineers. Exposing students to a real-world problem from industry provides insight into issues and constraints they are likely to approach in the workplace.

This type of partnership with industry also provides a natural opportunity to allow engineers working for the partner company to mentor students and provides companies with new perspectives from the fresh eyes of engineering students.

Recommendation: Partner with local community and technical colleges to facilitate industry problem-based learning experiences involving both technician and engineering students.

While engineers and technicians are sometimes still siloed in the workplace, it is becoming increasingly necessary for both to understand the interaction and interdependency of these two critical roles in the manufacturing environment. Rather than wait for engineers and technicians to encounter one another for the first time on the job, students in two-year technician and four-year engineering programs stand to benefit significantly from more frequent interactions while still in school.

Industry problem-based learning presents a great opportunity to facilitate these interactions. Many universities are located near a career, technical, or community college, institutions that are vital to the education of the manufacturing sector's future technician workforce. Through collaboration with these institutions on industry problem-based learning, engineering and technician students can work through challenges, either in a lab setting, or ideally, in a real manufacturing facility. Such a collaborative work-and-learn model will expose students to diverse workstyles, perspectives, and approaches to problem-solving processes in the manufacturing environment.

Imperative: All engineering students should participate in high-quality and innovative work-and-learn experiences during their undergraduate and graduate programs.

While many engineering students have some exposure to work-and-learn experiences, workshop participants acknowledged that the quality of such experiences can vary greatly. Workshop participants cited compliance with accreditation standards and stringent graduation requirements as barriers to the flexibility necessary for increased 'high-touch' work-and-learn opportunities, such as co-ops, internships, and even apprenticeships that count for program credits, without increasing credit requirements. Students are burdened with full course loads, and universities are often pressured to encourage students to finish their programs of study within a certain timeframe.[viii] These burdens act as additional barriers to innovation in curriculum and work-and-learn models that would allow programs to better prepare students for the workplace and their long-term careers.

While perspectives differed and didn't lead to consensus, several workshop participants asserted that engineering curricula, by and large, is imbalanced, favoring theory over application. For example, one set of opinions noted that math coursework—calculus, in particular—may be superfluous for some engineers wishing to work in industry. While it was generally acknowledged that such courses are valuable for teaching the theoretical or scientific aspects of engineering, there may be room for allowing other valuable experiences, such as more high-touch work-and-learn, to be provided to prepare students intent on working in industry.

Some workshop attendees asserted that while having a strong foundational knowledge of theory is critical for success in engineering, students seeking careers in industry sometimes lack the ability to apply theory in a pragmatic, functional way. Even in Ph.D. programs, where it is assumed that at least some graduates will spend their careers largely in academia or in research labs, as many as 80% of these engineering graduates will work in industry at some point in their career.[ix] It stands to reason that adjusting curricula to engage students in relevant work-and-learn experiences which reinforce their disciplinary knowledge in actual manufacturing settings may be the most practical option to prepare them for career opportunities with industry.

Recommendation: Develop multiple pathways for engineering education, including research and applied pathways.

One innovative approach could be to allow students to select 'tracks' of their four-year engineering programs designed to prepare them for their career goals. For students wishing to work primarily in developing products and manufacturing solutions in industry, universities could establish an 'applied' track, complete with an educational pathway that places emphasis on the manufacturing environment and workplace skills. This track would need to feature, at a minimum, one innovative work-and-learn experience, and preferably multiple work-and-learn experiences. And it should be remembered that the focus here is on providing relevant work experience for a fully-trained engineer, as opposed to an engineering technologist or technician.

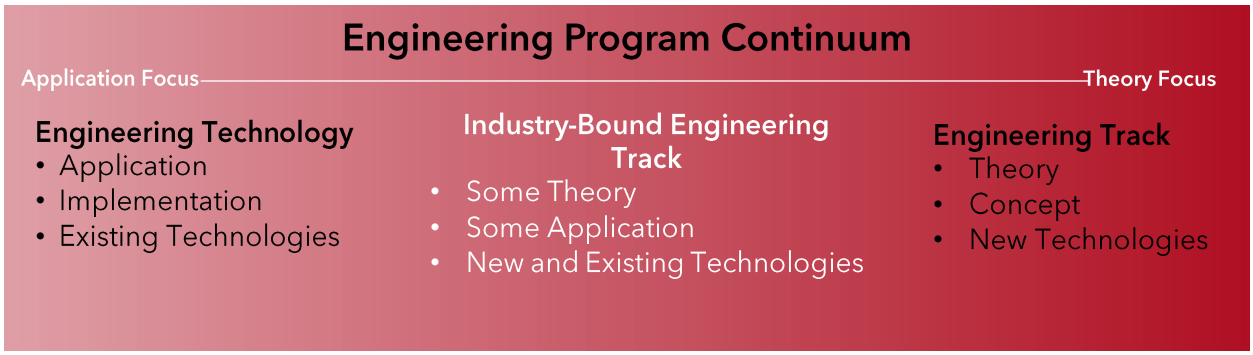
Alternatively, students wishing to pursue a career primarily in academia, or industry research labs, could take more traditional academic pathways and spend more of their coursework in research and academic settings. However, even for these students, some exposure to industry via a work-and-learn experience should still be integrated into their program to at least have some context for industry.

A complementary approach could include the development of a 'Technology Liberal Arts' curriculum for engineering students that integrates soft skills, business principals, and economics with foundational engineering coursework. The purpose of such a curriculum would be to provide engineering students with a foundation for understanding technology with broad enough knowledge to equip them with the capability to 'learn on the fly.' Rather than 'teaching them the answer,' they would be prepared to *find* the answer regardless of their specific career pathway.

The Ohio State University's Center for Design and Manufacturing Excellence has developed its Experiential Entrepreneurship Education (E3) to provide students with this kind of cross-functional education to build both technical engineering skills and business and entrepreneurial skills. See Innovation in Action # 1 (below) for more detail on their program.

It is important to emphasize that this recommendation is not suggesting that more students should be directed toward engineering technology programs, which tend to prepare students more for application of *existing* technologies as opposed to engineering programs which teach concept and theory to allow the development of *new* technologies. While engineering technology programs fill a very important need, they are not designed to prepare students to be fully functional engineers.

With that being said, there appears to be a gap between traditional engineering programs and engineering technology programs that needs to be filled, perhaps by creating these 'industry-bound' tracks for students as represented by the continuum below. These would allow students flexibility to integrate more knowledge of practical application to complement theoretical coursework through work-and-learn opportunities that provide more practical application within an industry setting. As represented in the continuum below, there may be an opportunity for engineering programs to integrate some topics traditionally taught in engineering technology programs to more effectively prepare students who want to work in industry.



Innovation in Action #1

E3, Center for Design and Manufacturing Excellence, Ohio State University

Model: The Experiential Entrepreneurship Education (E3) program immerses students in the manufacturing innovation and commercialization process by framing their academic learning around industry-problem based projects or student-led start-up ventures. Students are eligible to apply beginning in their sophomore year and can continue through graduate study. Once admitted, students form cross-disciplinary teams and pursue one of two tracks depending on their career goals:

- **Year 1**- All students complete a common track with an emphasis on product development. Sample topics include business analysis and development, product design and market deployment, and agile design.
- **Year 2 through Graduation**- Students choose one of the following:
  - Industry Track- Students engage with industry on industry problem-based projects during which they learn project management, technology development, and commercialization
  - Start-Up Track- Students engage in start-up business activities on their own student-led venture, learning to develop a business plan, assess the viability of their innovation, pitch to investors, and develop a go-to-market strategy.

Innovation Factor: Work-and-learn is embedded throughout students' entire academic program and exposes them to a wide-range of business processes in manufacturing while also developing entrepreneurial skill sets.

Learn More at: https://cdme.osu.edu/

Recommendation: Push for more flexibility in completion times, allowing extended programs of study and incorporating more work-and-learn opportunities for students.

Whether pursuing the alternative pathway recommendation described previously or simply adding work-and-learn experiences to traditional pathways, doing so may require alternative timelines for program completion. It is worth noting that the average time for an undergraduate to complete an engineering degree is already around 4.8 years.[x] Pursuing a quality work-and-learn experience, in addition to completing all required coursework, may require longer than the standard completion time. Workshop participants recommended considering flexible and extended programs that would allow work-and-learn experiences to be embedded into the program of study. One suggestion was to design programs in 'sprints' of alternating coursework and work-and-learn experiences over six years, in two-year increments: two years in school, two years in a work-and-learn experience, and two final years in school. Such a program would allow students to build foundational knowledge, apply it in an extended work-and-learn experience, and then finish their coursework complete with context from the manufacturing environment.

The New Jersey Institute of Technology implements a variation of this concept, a five-year model that allows for extended co-op experiences that are embedded into the engineering curriculum. See Innovation in Action # 2 (below) for more detail.

Innovation in Action #2

New Jersey Institute of Technology

Model: At New Jersey Institute of Technology (NJIT), students are prepared for engineering careers through collaboration, hands-on experience, and classroom learning that allows students the flexibility to extend their academic program beyond four years. This extended timeline provides for more robust work-and-learn experiences.

The NJIT Co-op Program is a five-year program that connects students with work experiences that are specifically structured to allow students to rotate between in-classroom academic learning and on-the-job experience with their host company. These rotations allow for longer, more-engaging work-and-learn experiences of at least 25 weeks of work experience per co-op.

Sample Rotation Schedule:

- Year 1: Two Semesters of Classes at NJIT
- Year 2: Two Semesters of Classes at NJIT
- Year 3: One Semester at NJIT, Seven Months in Co-op Placement
- Year 4: One Semester at NJIT, Seven Months in Co-op Placement
- Year 5: Two Semesters of Classes at NJIT

Innovation Factor: Flexibility for extended academic programs with embedded work-and-learn models.

Learn More at: http://engineering.njit.edu/

Imperative: Engineering curriculum must be responsive to evolving industry needs, including the needs of small, medium, and large employers.

Universities often form industry advisory boards to provide input into engineering curriculum. While these boards are designed to guide academic departments on current industry trends and necessary skills for students to excel in the workplace, these groups often meet only a few times per year and are limited to the inputs of the representatives on the advisory board. Workshop participants reported that, while many schools try to get a representative group from industry, their participant selections are often limited to personal connections or companies invested in the institution through development efforts or alumni.

Additionally, larger employers seem to be disproportionally represented, as they often have the financial means and staffing resources to invest. This may result in the needs of larger employers being met, but those of small and medium-sized enterprises—particularly those based in the regions in which university graduates will work and live—remaining unknown or being left out of consideration.

Workshop participants also reported that curriculum review and program accreditation processes, which play an important role in maintaining quality standards among engineering programs, are potential barriers in modifying curriculum at the pace that industry responsiveness requires. Workshop participants reported that these processes can inhibit innovation in curriculum because curriculum standards are thought to be limiting and/or review and approval processes are cumbersome.

Recommendation: Assess, at the local level, the extent to which accreditation and curriculum review present barriers to change and identify strategies for working within or adapting systems to maximize opportunities to innovate.

For universities to be able to implement innovative, high-touch work-and-learn opportunities, they will need the flexibility to modify curriculum and allow multiple educational pathways. For example, departments and programs may need to exchange work-and-learn experiences for some coursework. An assessment of what is possible within the boundaries of program accreditation and curriculum review—and what is possible in terms of adapting program review processes—is needed to help academic leaders push for more responsiveness and innovation.

While concerns about accreditation and curriculum review processes were prevalent in the feedback offered by workshop attendees, there was also a sense that these processes might be used by some academics as scapegoats. Faculty and academic leaders might simply be

resistant to change, or unsure of the best ways to be more responsive to student and industry needs. Engineering programs and departments should undertake assessments of curriculum development processes and include honest conversations about where the real barriers are. Such assessments should conclude with the development of strategies for maximizing opportunities to innovate within the constraints of current systems, and ideas for improving the systems to make them less constraining.

These discussions should also include an assessment of whether current standards and processes are consistent with current industry needs and whether they consider future industry needs. Ideas should be generated about addressing and improving the long timelines for change that are created by accreditation and curriculum review processes, and how these processes can be improved to create more agility and responsiveness in curriculum innovation.

Accreditors should also be engaged in these discussions to ensure feasibility of new innovations. Accreditation bodies like the Accreditation Board for Engineering and Technology (ABET) have recently made public calls for innovation in engineering programs, and especially around supporting the inclusion of work-and-learn models, suggesting a willingness to work with universities to develop innovative approaches to preparing students for careers in industry while still complying with accreditation standards.[xi] [xii]

Some schools have already found ways to innovate within the confines of accreditation by utilizing 'topics' courses to include work-and-learn experiences so long as quality measures are implemented to measure outcomes of the courses and ensure those experiences are of the highest quality.

Recommendation: Create facilities on campus shared by both academia and industry to facilitate industry problem-based learning and ongoing work-and-learn experiences.

Students often need to travel off campus to engage in work-and-learn experiences; however, some universities are beginning to invite industry to campus to interact with students in the classroom. Beyond the classroom, industry engagement could also include use of shared facilities where academics, students, and industry representatives work side-by-side. While these facilities require substantial capital investment, universities that have implemented them are seeing significant results. Often, shared facilities can grow out of existing university research and development assets, yielding benefits for, not only teaching and learning, but also for research as well.

If such shared facilities are not an option in the short-term, universities can still implement this concept by inviting industry representatives to campus and into the classroom as guest lecturers and mentors for an industry problem-based project or assignment.

The Haley Barbour Center for Manufacturing Excellence at the University of Mississippi is a prime example of how universities can link classroom learning with hands-on experience in a factory setting that involves real-life industry equipment and processes right on campus. See Innovation in Action # 3 (below) for more details.

Innovation in Action #3

The Haley Barbour Center for Manufacturing Excellence, University of Mississippi

Model: The Center for Manufacturing Excellence (CME) features a 12,000 square foot working factory that provides students with a work-and-learn experience without ever needing to leave campus. The CME program is open to students with majors in engineering, accountancy, and business, all with a manufacturing focus, allowing students to interact with, and learn about, both technical and business sides of the manufacturing industry. Students can take classes at the CME facility, allowing them to rapidly apply what they learn in the classroom to what they see and do on the factory floor. The curriculum combines theory, academics, and hands-on learning, with industry partners engaged throughout the learning process.

Innovation Factor: Realistic work-and-learn experience on-campus, equipped with a working factory and multiple touchpoints for industry/student interaction.

Learn More at: http://www.cme.ms/

Recommendation: Establish stronger partnerships with small and medium-sized enterprises (SMEs) to allow for more diverse inputs into curricula and work-and-learn experiences.

Small and medium-sized enterprises (SMEs), companies with under 500 employees, make up almost 45% of the job market in manufacturing but are underrepresented when it comes to providing inputs into university curriculum and in offering work-and-learn opportunities. [xiii]

Establishing connections with smaller entities may sometimes be more difficult than larger companies, but universities can leverage organizations like industry associations and their local Manufacturing Extension Partnerships (MEPs) to reach these employers. These entities regularly convene SMEs and may be able to serve in a coordinating role. Universities can also tap their alumni networks, who are actively working in industry, often in SMEs, to provide inputs and facilitate connections to their employers.

Universities can also extend opportunities specially designed for SMEs to engage in work-and-learn models and on the curriculum input process. One example would be to hold workshops especially focused on small and medium-sized enterprises to provide input on curriculum and programming. This would allow them to contribute in a forum and engage with universities without having to compete with larger entities.

Recommendation: Partner with Manufacturing USA Institutes to send students and faculty to emerging technology workshops and courses.

Even if universities can develop more agile curriculum development processes to respond to industry needs, technology development is moving at such a rapid pace that universities will always face challenges in keeping up with industry expectations.

Rather than attempting to integrate all emerging technologies into university coursework and work-and-learn opportunities, universities can partner with the 14 Manufacturing USA institutes to develop programming around technologies that are emerging from their research and development efforts to supplement classroom learning. Examples of partnership opportunities with the Manufacturing USA institutes could include holding coursework onsite in institute labs or developing capstone experiences for internships or co-ops hosted by the institutes. By leveraging the institutes' facilities and in-house expertise to provide these work-and-learn opportunities, universities can make emerging technology development accessible to engineering students, and ultimately better prepare them for technologies that will be prevalent in their future careers.

One such model is currently in development through a partnership between University of Michigan, The Ohio State University, Lockheed Martin, and Lightweight Innovations for Tomorrow (LIFT). While not yet deployed, this concept provides a promising model for how universities can work with Manufacturing USA Institutes and industry to develop work-and-learn models around emerging technologies. See Innovation in Action # 4 (below) for more information.

Innovation in Action #4

University of Michigan, The Ohio State University, Lockheed Martin and Lightweight Innovations for Tomorrow (LIFT) Multi-Environment Engineering Work-and Learn

Model: This model, currently in development, will involve work-and-learn participants completing experiences in 1) **emerging tools and technologies** in the university research and development environment; 2) **developing tools and technologies** at the Manufacturing Readiness Levels 4-7 in the Manufacturing Innovation Institutes; and, 3) **application-ready tools and technologies** in advanced manufacturing workplaces.

Students will start their work-and-learn program with a one-week cornerstone experience at LIFT, followed by multi-week practicums on campus in a university research lab and at an employer's worksite. Students will round out their experience with a one-week capstone project back at LIFT. The pilot program will focus on Integrated Computational Materials Engineering (ICME).

Innovation Factor: Collaborative model to expose engineering students to the entire innovation and technology development ecosystem around an emerging technology, from basic research to commercial production.

Learn More at: www.lift.technology

Recommendation: Hire professors of practice and equip the next generation of faculty members with industry experience.

Many universities already hire engineers working in industry to teach engineering coursework on a part-time basis. These individuals bring valuable insight into the classroom, often being able to integrate real-life problems and situations they encounter in their jobs in industry in their classes. Despite the value they bring, many of these individuals are considered adjunct instructors, a status that often does not allow them to advance in their teaching careers or become a core member of the faculty. Engineering programs should consider establishing a non-tenure track for instructors who also work in industry to allow for career advancement and retention of this valuable source of talent. Engineering programs can look to disciplines like nursing as a model of how to set up such a track. Nursing programs often heavily rely on a non-tenure track of instructors to ensure nursing students are properly prepared for the workforce. While these individuals have real status in the nursing industry, they also have a pathway to advance in their teaching careers over time, making them an intrinsic part of every nursing program. Typically, non-tenure track nursing faculty start as assistant clinical professors, can be promoted to associate clinical professors, and eventually, can become full clinical professors.

In addition to simply hiring part-time professors who also work in industry, universities should consider providing industry experience to current and future full-time professors. One opportunity to do so is to develop faculty work-and-learn programs that allow professors to complete temporary work assignments, similar to a student internship or co-ops, within a company.

This model can also be applied to future professors by encouraging an industry rotation for Ph.D. candidates, many of whom go on to become professors. Providing them with exposure to industry during their education gives them critical context for what their students will eventually encounter in the workplace.

It is worth noting that these same approaches can be applied to career services staff in engineering departments. While sometimes trained in human resources or workforce development, career services professionals do not always have extensive knowledge of industry context, yet they are tasked with helping to guide engineering students toward their future careers. Extending these meaningful industry work-and-learn experiences to career services staff will provide them with an understanding of the workplace so they are more informed when working with students.

Imperative: Work-and-learn models should be more widely implemented in university engineering programs and not reliant on a small group of 'champion' professors or administrators.

While there are faculty members and administrators at universities who value work-and-learn experiences, champion these approaches, and strive to develop innovative models, far too many university programs view work-and-learn experiences as a 'nice to have' component in engineering education rather than a necessity. When those champions leave the university or retire, their work-and-learn program often fades without them.

The reasons for the lack of work-and-learn model uptake vary by institution, but workshop participants reported that some institutions don't have a culture that promotes employment readiness, and that faculty and departments do not include it as a measure of student success. Other workshop participants reported that many of their university colleagues simply did not know where to start when developing innovative work-and-learn programming and found the process of integrating those models into their courses overwhelming.

University policies and practices related to promotion and tenure were also identified as possible barriers to widespread adoption of innovative work-and-learn models. Participants noted that as promotion and tenure policies continue to evolve—as they must—to better recognize and encourage industry and community engagement, in addition to the traditional emphases on teaching and research, more incentives will be created to advance the implementation of work-and-learn models.

Recommendation: Encourage adoption of work-and-learn models by including employment readiness as part of the institutional-level definition of student success.

Workshop participants asserted that one of the most effective means of encouraging innovative work-and-learn model adoption is to implement student employment readiness policies and initiatives at the university-wide level. Essentially, student employment readiness must become part of how universities define student success. Doing so would remove reliance on individual departments and champions for adoption of work-and-learn models and drive institutional change. Institutional initiatives could range from simple awareness campaigns; to professional development workshops on how to innovate and implement work-and-learn models; to incorporating completion of work-and-learn experiences into graduation requirements. Regardless of the approach a university takes, workshop participants recommended crafting attainable, yet robust metrics to measure both work-and-learn activities and the employment readiness of students engaging in these models. Quite simply, what gets measured gets done, and measuring both activity and outcomes should encourage adoption and provide necessary data to review the impact of the employment readiness initiatives.

The University of Louisville has already integrated work-and-learn experiences across their engineering programs by requiring co-op experiences for all students that are supplemented by a shared innovation facility that allows both students and industry to work side-by-side. See Innovation in Action # 5 (on page 21) for more details on their model.

Innovation in Action #5

University of Louisville, J.B. Speed School of Engineering and FirstBuild

Model: All engineering students at University of Louisville are required to complete a co-op experience. Each co-op includes three semesters of full-time work and is built into the curriculum to ensure that their academic education complements and prepares them for their co-op experience.

The program is scheduled year-round, starting after students complete their freshman year, engaging students in either academic learning or a co-op experience throughout the summer, fall and spring semesters for the remainder of their program. These rotations allow students the opportunity to apply their academic coursework in an industry setting and then share those experiences with instructors and fellow students.

University of Louisville further integrates innovative work-and-learn experiences for their students through FirstBuild, a co-creation center, makerspace, and micro factory that brings students, community, and industry together to address real-world industry problems. The FirstBuild center provides students with additional hands-on experience and early exposure to industry partners in their community.

Innovation Factor: School-wide integration of work-and-learn model complemented by an innovation facility shared with industry.

Learn More at: Louisville.edu/speed and https://firstbuild.com/about/

Recommendation: Create 'Engineering Work-and-Learn' communities of practice.

Participants acknowledged that events like the *Advancing University Engineering and Manufacturing Education: The New, Innovative, and Re-Imagined World of Employer-Engaged "Work-and-Learn"* workshop are helpful for both exchanging information on work-and-learn models and brainstorming innovations and improvements. However, they also recognized that these types of forums were frequented most often by existing champions of work-and-learn programs, and therefore, were less likely to reach individuals and programs that need the most guidance. Furthermore, such workshops tend to be convened around special events or for a specific one-time purpose. This episodic approach makes it particularly difficult to gain real momentum among faculty to develop and implement innovative work-and-learn models. For those reasons, workshop participants indicated a need to establish ongoing online and in-person forums and workgroups for educators and industry to share ideas and blueprints for how to implement innovative work-and-learn models.

Ideally, such an ongoing forum would be developed as a partnership between education and industry, for instance, between university associations and industry associations which already convene large groups of the key stakeholders in work-and-learn models.

One early task an ongoing forum could tackle is establishing and sharing common partnership principles and models to help universities follow best practices in developing closer

relationships to industry. For example, The Ohio State University has developed a set of partnership principles. The National Network of Business and Industry Associations has also released publications specifically designed to help universities design quality work-and-learn partnerships with industry that may be helpful in the development of such partnership principles. Future engineering work-and-learn communities of practice should review these resources as a starting point. See the "Resources and Acknowledgements" section for these and additional resources.

Recommendation: Capitalize on the ongoing evolution in promotion and tenure practices, including greater recognition of community and industry engagement, and increased emphasis on community-engaged learning, to provide incentives for faculty to develop and implement work-and-learn models.

Similar to allowing multiple tracks for students to pursue academic and research or industry-focused pathways, faculty should also be granted the opportunity to be recognized for both their research and their contributions toward promoting applied learning. Promotion and tenure practices are evolving and will continue to evolve as disciplines themselves change over time, and disciplinary practices change. This evolution can be leveraged to encourage faculty to develop and implement industry-engaged work-and-learn activities. Some institutions are developing parallel promotion and tenure processes for research and teaching faculty as well as for 'professors of practice', whose work focuses on teaching and/or collaborations with industry. Such multi-track promotion and tenure systems provide obvious opportunities to encourage faculty to focus on work-and-learn experiences and employment readiness. As noted above, employment readiness ought to increasingly become part of how student success is defined, and when it does, promotion and tenure policies will need to acknowledge and define the implementation of innovative work-and-learn experiences as part of the definition of high-quality teaching.

RESOURCES AND ACKNOWLEDGEMENTS

ACKNOWLEDGMENTS

We would like to thank all the participants in the June 2018 workshop entitled *Advancing University Engineering and Manufacturing Education: The New, Innovative, and Re-Imagined World of Employer-Engaged "Work-and-Learn."* These individuals all made significant contributions to this publication. The universities and organizations represented included:

- Arizona State University
- ARM Manufacturing Institute
- American Society of Mechanical Engineers
- Auburn University
- Association of Public and Land-grant Universities
- Binghamton University
- Bowling Green State University
- California State University, Northridge
- Case Western Reserve University
- Central State University
- Clemson University
- Cleveland State University
- Colorado School of Mines
- Colorado State University
- U.S. Department of Defense
- Florida International University
- High Value Manufacturing Catapult, UK
- Indiana University
- Indiana University-Purdue Indianapolis
- Iowa State University
- Kettering University
- LIFT Manufacturing Institute
- Lorain Community College
- MForesight
- Massachusetts Institute of Technology
- Montana State University
- National Center for Manufacturing Sciences
- New Jersey Institute for Technology
- U.S. National Institutes of Standards and Technology
- North Carolina State University/Power America
- Ohio State University
- Ohio University
- Oklahoma State University
- Penn State University
- Purdue University
- Shape Corp.
- Siemens
- Tennessee State University
- Thomas P. Miller and Associates
- University of Akron
- University of Cincinnati
- University of Houston
- University of Louisville
- University of Maryland
- University of Michigan
- University of Mississippi
- University of Toledo
- Virginia Commonwealth University
- Virginia Tech

We also want to thank and Shalin Jyotishi, of APLU, and Jacqui Miecksztyn, of Thomas P. Miller & Associates for their extraordinary work in helping to conduct the workshop and manage this important publication.

Workshop Agenda

In partnership with

Advancing University Engineering and Manufacturing Education: The New, Innovative, and Re-Imagined World of Employer-Engaged "Work-and-Learn"

First Floor, APLU, 1307 New York Ave NW, Washington, DC 20005
Monday, June 4 – Tuesday, June 5

Workshop Overview & Purpose: Brought about by an evolving industry landscape and by the many and varied contributions of the Manufacturing USA® Institutes—and their university and industry partners—***technological innovation*** continues to change the engineering and advanced manufacturing workplace at a rapid rate. In turn, the needs of the nation's engineering and advanced manufacturing workforce are also changing.

As a key component of LIFT's Education & Workforce Development portfolio, the Institute partnered with APLU in a broad-based initiative to align technology and talent development, with focus on both the engineering and technician workforce. LIFT's investments in replicable and scalable workforce development solutions put special emphasis on work-and-learn models.

As highlighted in APLU's 2017 report, *Ready for Jobs, Careers & a Lifetime: Public Research Universities and Credentials that Count*, universities will need to embrace their role in talent and workforce development in order to transform into more agile and responsive institutions that can address employer and student needs. Universities can no longer rest on the laurels of traditional internships, co-ops and forms of problem-based learning. These **"Work-and-Learn"** educational strategies must be reinvigorated, enhanced, and scaled. They must also engage employers to an even greater extent than ever before. These new models for university-level Work-and-Learn will be essential to meeting the demands of a 21st century workforce and the modern global economy.

To that end, **LIFT, APLU**, and **NCMS**—in partnership with **MForesight** and **Manufacturing USA**—have organized this workshop to disseminate pathbreaking and innovative strategies for Work-and-Learn with a specific focus on ***university-level*** engineering and manufacturing education. Following the workshop, the organizers will produce a brief publication that underscores the impetus for these new, innovative and employer-engaged work-and-learn strategies in engineering/manufacturing and present recommendations for their effective design and implementation.

The workshop audience will be comprised of faculty members, department chairs, associate deans, industry workforce managers, and other university economic and workforce development

administrators interested in learning about and implementing the most effective forms of Work-and-Learn in engineering/manufacturing education.

DAY 1 – MONDAY, JUNE 4

8:30-9:00 **Breakfast**

9:00-9:15 **Welcome by APLU President Peter McPherson**

9:15-10:00 **Opening Keynote: Rallying for University-Industry Partnerships and Work-and-Learn**

Description: The time for the nation's public research universities to embrace their rightful role in talent and workforce development is now. The call to "rally" is around new models for Work-and-Learn and the critical role universities can play in partnering with employers to design and implement re-imagined, innovative, bleeding edge work-and-learn educational strategies being discussed over the course of the workshop.

Keynote by **Patrick Hillberg,** Workforce Development and Academic Outreach, Siemens

10:00-11:00 **Aligning Technology and Talent Development: The LIFT-APLU-NCMS model**

Description: Bridging the gap between technology development and education in engineering is essential for ensuring the readiness of students and working learners. LIFT, one of the national Manufacturing USA institutes, partnered with APLU and the industry-group National Center for Manufacturing Sciences (NCMS) for an initiative that aims to bring the conversation about workforce development needs upstream to place where the technology development is happening. Together, APLU, LIFT and NCMS named eight scholars and teachers to its Expert Educator Team (EET). Over the past two years, the EET has collaborated with LIFT's technology project teams to identify how colleges and universities can modify their curricula and related industry certifications to meet the knowledge, skills, and abilities workers will need. The effort will help ensure a ready workforce for jobs deploying emerging innovative lightweighting technologies, materials, and processes being developed by LIFT. In this session, participants will learn about project outcomes and takeaways for campuses who wish to engage with employers or institutes on bridging technology and talent development.

Facilitator:

- **Jim Woodell**, VP for Economic Development & Community Engagement, APLU
- **Rebecca Taylor**, Senior Vice-President, National Center for Manufacturing Sciences

Discussants:

- **Kelly Zeleznik,** Dean of Engineering, Business, and Information Technologies, Lorain County Community College; Expert Educator Team member
- **Amy Clarke,** Associate Professor and Site Director, Center for Advanced Non-Ferrous Structural Alloys, Colorado School of Mines; Expert Educator Team member

11:00-11:15 **Break**

11:15-12:15 **Breakout Discussions: Leveraging University-Industry Partnerships to Advance Work-and-Learn**

Description: During this session, we will review the impetus for this workshop, the publication to emerge from the meeting, and the organizer's efforts to promote university engagement in workforce development and work-and-learn more broadly. We will discuss how university-industry partnerships can be leveraged to develop and implement more effective work-and-learn educational strategies within and across university engineering and manufacturing programs. We will ideate solutions to existing or potential barriers to university-industry work-and-learn partnerships.

Facilitated by:

- **Jim Woodell**, Vice President for Economic Development & Community Engagement, APLU
- **Rebecca Taylor**, Senior Vice President for Strategic Partnerships, NCMS

12:15-1:00 **Lunch**

Keynote by **William Bonvillian**, Lecturer; former Director Washington Office, MIT; Author of *Advanced Manufacturing: The New American Innovation Policies*

1:00-1:20 **Overview of Work & Learn 2.0 Presentations and Activity**

Jim Woodell, VP for Economic Development and Community Engagement

1:20-3:00 **Work & Learn 2.0: Innovative University Work-and-Learn Models in Action**

Description: Presentations from institutions deploying innovative, creative, cutting-edge and employer-engaged work-and-learn educational strategies in engineering and advanced manufacturing education. Speakers will address **1)** What the 'work-and-learn 2.0' strategy/project is **2)** How did the university and employer partners come together to design and implement it and how is it different/innovative in preparing students for the workforce **3)** What student and employer outcomes have manifested or are likely to manifest from the deployment of these new work-and-learn strategies.

- **Daniel Brateris**, Director of Experiential Learning, New Jersey Institute of Technology
- **Mary Andrade Carlson,** Associate Director, Career Development Duthie Center for Engineering, University of Louisville; **John Gant**, Director of Industry Partnerships, University of Louisville
- **Glenn Daehn**, Professor of Materials Science and Engineering, The Ohio State University and **Michael Camp**, Director, Entrepreneurship and Technology Innovation, Center for Design and Manufacturing Excellence, The Ohio State University
- **Matt O'Keefe**, Executive Director of the Haley Barbour Center for Manufacturing Excellence, University of Mississippi
- **Venetia Petteway**, Program Director of the Cooperative Education Team, Kettering University

3:00-3:15 **Break**

3:15-4:45 **Small Group Ideation Session with presenters of Work & Learn education models**

Description: Presenters from Work & Learn 2.0 session will help facilitate small group ideation session around the "ideal" work-and-learn environment or program in university-level engineering and manufacturing education. Each presenter will use his or her experiences and case studies as basis for discussion and strategizing.

4:45-5:00 **Reflections on Day One**

- **Emily DeRocco,** Education & Workforce Director, LIFT
- **Jim Woodell,** VP for Economic Development & Community Engagement, APLU

5:00-6:30 **Networking Reception** (Light refreshments served)

Dinner on Your Own

DAY 2 – TUESDAY, JUNE 5

8:30-9:15 **Breakfast**

9:15-10:45 **International Models: UK-Role of Centers of Innovation in Technician Education and Workforce Development**

Description: The Catapults, centers established by the government that bring together UK's businesses, scientists and engineers to work side by side on late-stage R&D, as well as other Centers of Innovation in the UK have been established with the primary purpose of technology innovation. However, they are not systematically connected with the talent and skills development necessary for the future workforce to successfully exploit this. Integrated Work-and-Learn strategies that drive knowledge and the application of emerging technologies into a well-connected education and training landscape to meet industry needs are an essential part of correcting this. These UK centers are now conducting a study to better understand the role of centers at an early stage of technology translation, as well as at later stages to meet demand for new knowledge and skills more widely in industry. It will also look at changes necessary in the education and training system for employers, educators and individuals to work more efficiently with the centers and each other. This session will present the challenges that have been identified by the study and set out the areas to be investigated with a call for input.

Presenters:

- **Ian Collier,** Director of Operations, High Value Manufacturing Catapult UK
- **Paul Shakspeare,** Consultant for Workforce Development, High Value Manufacturing Catapult UK

10:45-11:00 **Break**

11:00-12:00 **Research Universities & Manufacturing USA: The Education Opportunity**

Description: Looking beyond university-employer work-and-learn interfaces, Manufacturing USA Institutes too are revolutionizing advanced manufacturing; manufacturing systems, processes, tools, and technologies, and the manufacturing workplace. These advancements impact the knowledge, skills and abilities required of the engineering and production workforces. Universities and Manufacturing Institutes are now faced with an important opportunity to bring the conversation of talent and

workforce development "upstream" to the point of technology development. By doing so, education and business leaders can avoid costly and disruptive skills gaps that hinder student employability outcomes and industry's competitiveness and performance. During this session, we will discuss how institutes are collaborating with universities and industry to address these challenges and foster a skilled manufacturing engineering workforce.

Facilitator: Emily DeRocco, Education & Workforce Director, LIFT

Discussants:

- **Pam Carpenter,** Director of Education and Workforce, PowerAmerica Institute
- **Rebecca Hartley,** Director of Operations, Clemson University Center for Workforce Development; ARM Institute
- **Philip Lippel**, Assistant Director, MIT Washington Office; *Representing AIM Photonics Institute*

12:00-12:15 **Wrap-up and Next Steps**

- **Emily DeRocco,** Education & Workforce Director, LIFT
- **Jim Woodell,** VP for Economic Development & Community Engagement, APLU

ADDITIONAL RESOURCES

Work-and-Learn Models

The Ohio State University- Partnership Principles

https://engage.osu.edu/about/principles.html

National Network: *Work-and-Learn in Action*

http://www.nationalnetwork.org/wp-content/uploads/2016/10/WALGuidebook_10.25.2016.pdf

National Network: Learning While Working: Building 21st Century Competency-Based Apprenticeships

http://nationalnetwork.org/wp-content/uploads/2015/01/The-21st-Century-Competency-Based-Apprenticeship-Model1.pdf

Employability Skills

National Network of Business and Industry: Common Employability Skills Framework

http://nationalnetwork.org/resources/common-employability-skills-3/

Manufacturing Education

Author Bill Bonvillian: *Advanced Manufacturing – The New American Innovation Policies*

https://www.bonvillian.org/advanced-manufacturing

Association of Public & Land-Grant Universities: *Ready for Jobs, Careers, and a Lifetime Report*

http://www.aplu.org/library/ready-for-jobs-careers-and-a-lifetime/file

Association of Public & Land Grant Universities: *Aligning Technology & Talent Development Report*

Report 1: http://www.aplu.org/library/aligning-technology-and-talent-development/File

Report 2: http://www.aplu.org/library/report-2-aligning-technology-and-talent-development/File

Report 3: http://www.aplu.org/library/report-3-aligning-technology-and-talent-development/file

MForesight: *Reports*

http://mforesight.org/download-reports/

Future of Work- McKinsey & Company

https://www.mckinsey.com/featured-insights/future-of-organizations-and-work

Endnotes

[i] National Academy of Engineering. (2004). The Engineer of 2020: Visions of Engineering in the New Century. Washington, DC: The National Academies Press. https://doi.org/10.17226/10999.

[ii] Bureau of Labor Statistics. (2016). Occupational Outlook Handbook, 2016. Retrieved from http://data.bls.gov.

[iii] National Center for Education Statistics. (2016). Integrated Postsecondary Education Data System. Retrieved from https://nces.ed.gov/ipeds/datacenter/SelectVariables.aspx?stepId=1.

[iv] Lumina Foundation. (2014). What America Needs to Know about Higher Education Redesign. https://www.luminafoundation.org/files/resources/2013-gallup-lumina-foundation-report.pdf.

[v] Strada and Gallup. (2017). College Student Survey: A Nationally Representative Survey of Currently Enrolled Students. Retrieved from https://news.gallup.com/reports/225161/2017-strada-gallup-college-student-survey.aspx.

[vi] Berdanier, C. G. P., Branch, S. E., London, J. S., Ahn, B., & Cox, M. F. 2014. Survey analysis of engineering graduate students' perceptions of the skills necessary for career success in industry and academia. In *ASEE Annual Conference and Exposition, Conference Proceedings* American Society for Engineering Education.

[vii] Strada and Gallup (2017)

[viii] National Academy of Engineering (2004)

[ix] Berdanier, Branch, London, Ahn, & Cox (2014)

[x] National Academy of Engineering (2004)

[xi] Milligan, M. (2017) Fostering Innovation Through Accreditation. *Medium*. Retrieved from https://medium.com/@ABETaccredit/fostering-innovation-through-accreditation-9b57de5fcc0f.

[xii] ABET. 2017. Engineering Change: Lessons from Leaders on Modernizing Higher Education Engineering Curriculum. Retrieved from http://www.abet.org/wp-content/uploads/2018/02/ABET_Engineering_Issue-Brief_final_web.pdf.

[xiii] U.S. Census Bureau. (2015). Statistics of U.S. Business Annual Datasets by Establishment Industry. Retrieved from https://www.census.gov/programs-surveys/susb.html.


lift


ASSOCIATION OF
PUBLIC &
LAND-GRANT
UNIVERSITIES


National Center for
Manufacturing Sciences