Report from the STEM 2026 Workshop on Assessment, Evaluation & Accreditation

November 1-3, 2018

Normandale Community College
Bloomington, MN
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May 31, 2019

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This material is based upon work supported by the National Science Foundation under Grant No. DUE-1843775. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.
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1. We Start with the Student

A gathering of science, technology, engineering, and math (STEM) higher education stakeholders met in November 2018 to consider the relationship between innovation in education and assessment. When we talk about assessment in higher education, it is inextricably linked to both evaluation and accreditation, so all three were considered. The first question we asked was can we build a nation of learners? This starts with considering the student, first and foremost. As educators, this is a foundation of our exploration and makes our values transparent. As educators, how do we know we are having an impact? As members and implementers of institutions, programs and professional societies, how do we know students are learning and that what they are learning has value?

The focus of this conversation was on undergraduate learning, although we acknowledge that the topic is closely tied to successful primary and secondary learning as well as graduate education. Within the realm of undergraduate education, students can experience four-year institutions and two-year institutions, with many students learning at both at different times. While four-year institutions are frequently thought of as the norm, approximately 49% of students receiving bachelor’s degrees in 2015-2016 had been enrolled at a two-year or community college at some point in the previous ten years (National Student Clearinghouse Research Center, 2017).

As open access institutions, community colleges reflect the full diversity of the nation, represented through race/ethnicity, gender, socioeconomic status, first generation, age, ability, and more. They also illustrate the myriad ways that students traverse through higher education, frequently taking more than four to six years to complete their baccalaureate degree. Because so many entering community college students do so with the ultimate goal of a baccalaureate or advanced degree, it is important that conversations about assessment in higher education address both four-year and two-year institutions. Although there are different contexts, including different relationships to four-year degree programs, community colleges also want to be sure that they are equipping students with the learning they will need to achieve their goals.

When we start with the student, we see many challenges that appear in institutional, programmatic, and course-level assessment. These are not always easily addressed at four-year institutions and can be even more difficult at two-year institutions (National Academies Press, 2016). Due to the nature of open access institutions and particularly of liberal arts transfer-oriented community colleges, challenges include lack of distinct cohorts, programs that may not be complete in and of themselves but are components of longer-term degrees, not knowing what semester will be a student’s last, and students who may be on longer pathways to their degree goals. This space, where faculty is primarily focused on student learning, is ripe for innovation. However, we also recognize that there can be significant institution-level issues, such as credit hour expectations, degree completion expectations when associate degrees might not be required for articulation to a bachelor’s degree, and caps on maximum credits in an associate’s degree that can impede innovation.

Thirty-seven participants spent two days considering cases of innovation in STEM education, learning about the best practices in assessment, and then discussing the relationship of innovation and assessment at multiple levels within the context of higher education. Six working groups looked at course-level, program-level, and institution-level assessment, as well as cross-disciplinary programs, large-scale policy issues, and the difficult-to-name “non-content/cross-content” group that looked at assessment of transferable skills and attributes like professional skills, scientific thinking, mindset, and identity, all of which are related to post-baccalaureate success. These conversations addressed issues that cut across multiple levels, disciplines, and course topics, or are otherwise seen as tangential or perpendicular to perhaps “required” assessment at institutional, programmatic, or
course levels. This report presents the context, recommendations, and “wicked” challenges from the meeting participants and their working groups. Along with the recommendations of workshop participants, these intricate challenges weave a complex web of issues that collectively need to be addressed by our community. They generated a great deal of interest and engagement from workshop participants, and act as a call to continue these conversations and seek answers that will improve STEM education through innovation and improved assessment (see Coda).

2. The Value of Assessment
We cannot take for granted that the value of assessment is broadly understood. This value is often questioned, in part because the return on the investment faculty, administrator, and/or student time does not seem to be high. We argue that, when done well, the practice of assessment can have direct and timely value, beyond simply being a checkbox for future accreditation processes that programs and institutions may be required to or choose to participate in. Assessment done well has the potential for positive impact at the national level, for institutions, programs within and across institutions (in the case of 2+2, 2+3 or 3+2 articulated programs), faculty teaching specific courses, and individual students.

For many, thinking about assessment also points toward evaluation and accreditation. While this may be the case in some instances, it is not its only purpose. There are three schools of thought currently around assessment (Jankowski, 2017):

- Measurement of current practices (example: Fulcher et al., 2014)
- Compliance with policies or accreditation guidelines (example: Kuh et al., 2015)
- Improvement of teaching and learning (example: Maki, 2010)
The lenses that we apply to how we seek information and how we view the results are dependent on the purpose of the assessment activities. It is known that what we plan to measure is where we focus our efforts. Therefore, the issue of what we measure is crucial to the ultimate success of an educational system for individual students. If we agree that student learning is the goal, then measuring items like exposure to content or basic recall outside of context is the lowest rung of the ladder. We see an opportunity for addressing access and equity in STEM education by actively measuring both access to and quality of student learning.

To delve into the benefits and challenges of accreditation, assessment, and evaluation, we must begin with a common understanding of what we mean by these terms as well as their interrelationships (see “Why Accreditation and Assessment?” for more information). According to Dr. Gianina Baker, assistant director at the National Institute of Learning Outcomes Assessment (NILOA) and the workshop keynote speaker, assessment, depending on one’s lens, can be defined as:

1) “Finding out whether my students are learning what I think I’m teaching” (from a faculty member at a long-ago workshop);
2) A systematic process for understanding and improving student learning (Angelo, 1995);
3) An integral component of learning (Alverno College); or
4) The systematic collection, review, and use of information about educational programs undertaken for the purpose of improving learning and development (Palombo & Banta, 1999).

Evaluation is “systematic investigation of the worth or merit of an object” (Joint Committee on Standards for Educational Evaluation 1999, as quoted in The 2002 User-Friendly Handbook for Project Evaluation (NSF 02-057) https://www.nsf.gov/pubs/2002/nsf02057/nsf02057_2.pdf) and, for the purposes of this report, ultimately whether a project, program, or institution is meeting its stated goals. Accreditation is the process of credentialing institutions and programs to provide the degree credentials they award, whether that is any degree or certificate at all (institutional accreditation) or a programmatic degree (like an ABET-accredited engineering degree).

As people invested in STEM learning and the transfer of knowledge, professional practice, and the values of our fields, we see ways that students can be involved in and benefit from the practice of assessment. The growing trends of reflection and active making of meaning related to discovered facts in STEM education are ways that students can benefit from assessing the learning they are doing. Reflections and artifacts from meaning making can be used as assessment tools for faculty and administrators. Assessment tools for STEM fields such as rubrics, processes, and even nifty assignments have been shared within disciplines, but these practices can be disseminated across disciplines to support not just content learning, but also the learning of systemic thinking, communication, and practice and values that cross through all of our fields.

Quality assessment is not inexpensive. However, doing it efficiently and well so that results can be fed back into the process for improvement can be cost effective in the long run. For this to happen institutions need resources and training to support long-term efforts. Institutional centers for teaching and learning can support campus cultures related to assessment, but processes need to be developed in ways that support collection and sharing of meaningful assessment data that include support for how institutions, programs, and courses can use and reflect on this information. We conclude with a call for funding not just assessment, but the study of how assessment practices can be structured to align with the values of the people called on to do the work of assessment, and to support the practices and goals of these people. This is not a simple thing, and the breadth of practices seen across STEM fields attests to this. However, when we keep our focus on the student, popping up occasionally to the bird’s eye view of how it could benefit our Earth, our nation, our
regions and our local communities to have a citizenry of STEM-capable and STEM-invested learners, we see that improving the experiences of these students could have a profound impact.

### Why Accreditation and Assessment?

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<tr>
<th>Dr. Gianina Baker, Assistant Director, National Institute of Learning Outcomes Assessment (NILOA)</th>
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<td>Dating back to the late 1800s, accreditation in the United States has always been related to protecting what we now call “consumers” (students) and ensuring that higher education serves the public interest. Part of this has included efforts designed to ensure consistency among varying institutions through established credit hours, admissions practices, standardized degree requirements, and so on.</td>
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Eventually, accreditors turned their attention to the impact and effectiveness of institutions of higher education. This meant determining not just that students were graduating, but that institutions’ claims about what students were learning could be confirmed. Since the 1980s, accrediting bodies’ expectations regarding assessment of student learning have evolved from first expecting institutions to develop plans for assessment, to showing evidence that plans for assessment were being implemented in the 2000s, to looking for proof that institutions were using results of assessment to drive improvements in the 2010s (Gaston, 2018, April).

Just as accreditors’ expectations have changed over time, so has our understanding of good assessment practice. As institutions of higher education continue to shift from assessing for accountability to that of assessing for improvement (Ewell, 2009), availability of examples of good assessment practice increases. In the midst of this shift, institutions still view the process of accreditation as the primary driver of assessment work on campus, however, chief academic officers reported on NILOA’s 2017 national survey that their institutions are increasingly using assessment results for internal improvement efforts (i.e., program review, modifying curriculum, etc.).

Assessment activities, such as curriculum mapping, assignment design, developing pathways, revising general education, scaling high-impact practices, advance embedded, authentic assessment approaches (i.e., assignments, rubrics, capstones, etc.). Such activities are a result of institutions intentionally addressing inequitable outcomes and wanting to improve their assessment practice.
NILOA’s 2017 national survey results suggest that equity concerns are becoming more of a driver prompting assessment on college and university campuses.

In 2016, NILOA, drawing from its work in the field, condensed good assessment practice into five principles “that if enacted in mission-relevant ways can spread and accelerate assessment work worthy of the promises colleges and universities make to their students, policy-makers, and the public” (p. 4):

1. Develop specific, actionable learning outcomes statements.
2. Connect learning goals with actual student assignments and work.
3. Collaborate with the relevant stakeholders, beginning with the faculty.
4. Design assignment approaches that generate actionable evidence about student learning that key stakeholders can understand and use to improve student and institutional performance.
5. Focus on improvement and compliance will take care of itself.

(NILOA, May 2016)

As institutions work to improve their assessment processes and create more equitable pathways for students, more understanding of good assessment practice, in a variety of contexts, and perhaps the addition of principles to the current list, will arise.

The next sections are based directly on the outcomes of the working groups at the workshop and are organized generally using the structure of Figure 1. Each group was composed of people from multiple STEM disciplines, illustrating another value of the community: that of connecting ideas across boundaries. While the focus of this work is on STEM education, innovation, and assessment, the relationship between STEM and a liberal arts education was discussed with this value of connecting ideas highlighting the strength of the connections between STEM and liberal education.

3. Policy and Policy Makers

Accreditation and assessment of student learning are both affected by and affect or inform policy within a STEM higher education ecosystem. The key elements of this ecosystem include:
• Federal agencies, such as the National Science Foundation and the Department of Education;
• Non-governmental bodies whose expert work impacts and drives policy, such as the National Academies and Association of American Colleges & Universities (AAC&U);
• Regional and discipline-oriented accreditation organizations;
• Disciplinary professional organizations;
• Large foundations with national or regional impact, such as the Kern Family Foundation, the Carnegie Foundation, and the Bush Foundation;
• Industry, particularly, but not solely, large firms with national and international reach; and
• State legislatures, university systems, and their associated funding models.

All parties within the ecosystem are working to improve higher education, and we need to be cognizant of their influences as well as what is influencing them. For example, by nature of the ecosystem, institutions compete for rankings and resources, which support enrollments and the ongoing financial viability of individual institutions. At the same time, this intense competition is one factor driving up the costs of higher education, which is detrimental to the ecosystem as a whole. There must be some counter-balancing force to ensure that the needs of society and the nation are considered and addressed. Assuring this balance is one of the impacts of the higher-level policy conversation.

In addition, national and state level policy help ensure we have a space that is safe for and productive of innovation. Indeed, guiding high level conversations around accreditation and related activities can support the work of faculty and higher education leaders in improving STEM education. This also ensures that efforts to improve STEM education aren’t undertaken solely by faculty and administrators at the institutional level, but by a broader range of stakeholders.

Another role of policy makers, particularly but not solely at the national level, is that of providing funding and other types of support so that under-resourced schools have access to some of the same options that effectively support student success (e.g., mentoring, first year experience programs, and undergraduate research). This is important to counter the many cases where schools with substantial resources are able to attract additional resources (information on university assets per student can be explored using IPEDS data: https://nces.ed.gov/ipeds/). The federal dollars spent on understanding and improving STEM education through programs such as NSF’s Historically Black Colleges and Universities Undergraduate Program (HBCH-UP) and Advanced Technological Education (ATE) are a small drop in the bucket of the federal government budget. However, these resources play an important role in ensuring that institutions – particularly those that serve high percentages of underrepresented students – are able to engage in this important work.

Connecting and advancing all these roles are the data collection, research, and high-level reports that are supported and conducted by the ecosystem members discussed above and often used to directly create policy. A small sample of these publications include The Engineer of 2020: Visions of Engineering in the New Century (2004), Rising above the Gathering Storm (2007), and Rising above the Gathering Storm Revisited (2010), all from The National Academies Press; data from the National Student Clearinghouse Research Center on topics such as community college students’ transfer success; and NSF’s Women, Minorities, and Persons with Disabilities in Science and Engineering reports.

Given the wide array of ways that policymakers lead, guide, and support innovation and continuous improvement in higher education via accreditation, evaluation, assessment, and related policies, the working group provides the following recommendations.
Encourage a shift to more complex, systems-based thinking through a change in the metaphors used to discuss higher education. Commonly accepted terms used to discuss higher education in general and STEM education in particular, like descriptions such as education “pipelines” and “pathways,” are linear and limit our considerations of today’s more complex higher education environment and the diversity of ways that students enter and move through that environment. A shift to the language of an ecosystem opens up a model that includes many partners, niches, and subsystems. It suggests interconnections rather than pathways, which makes the assumption that every student is equally able to find a successful pathway.

Simply changing the language, however, will not suffice. Again, we return to the student to help frame our questions. When education is focused too narrowly on external demands, such as the need for an educated workforce to fuel industry innovation or to maintain the nation’s role on the world stage, students become the means to an end rather than the end itself. This opening from a recent report from the National Academy of Engineering illustrates how easily our focus can slip away from students:

> Engineering skills and knowledge are foundational to technological innovation and development that drive long-term economic growth and help solve societal challenges. Therefore, to ensure national competitiveness and quality of life it is important to understand and to continuously adapt and improve the educational and career pathways of engineers in the United States. (National Academy of Engineering, 2018)

Unless we are asking if students are learning and thriving, we will continue to struggle to maintain a healthy educational ecosystem. Additionally, agencies and individuals at all levels need to do a better job of understanding the many ways that students traverse through the ecosystem of STEM education. This understanding will impact assessment and policy to better account for the realities of today’s students and provide more nuanced opportunities for increasing diversity, equity, and inclusion in STEM.

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<tr>
<th>Institution-Focused</th>
<th>Learner-Centered</th>
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<tr>
<td>Learning assessed for a sample of students</td>
<td>Learning demonstrated for every student</td>
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<tr>
<td>Normative approach</td>
<td>Responsive approach</td>
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<tr>
<td>Summative</td>
<td>Formative</td>
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<tr>
<td>Structured (seat time)</td>
<td>Adaptive/flexible offerings</td>
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<tr>
<td>Implicit outcomes and connections</td>
<td>Explicit outcomes and connections</td>
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<tr>
<td>Individual courses</td>
<td>“Our courses”</td>
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<tr>
<td>Silos/territories</td>
<td>Integrated and collaborative</td>
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<tr>
<td>Learning occurring in the institution</td>
<td>Learning happening everywhere</td>
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*Table 1: Institution-focused vs. learner-centered assessment*

What is truly needed to address inequitable outcomes of student success is a shift of paradigms (Table 1). This shift in paradigm from one of learning to that of learning systems requires individuals to not only “think about the pedagogies that produce student learning” but also “the relationships within the organizational systems in which pedagogies are situated” (p. 43). Concentration on such relationships moves organizations from being institutionally-focused to instead student-centered. A student-centered environment “involves making learning outcomes more transparent to all stakeholders, ensuring the quality of degree across institutions, aligning and integrating general education and the major, communicating to students enhanced curricular coherence, and embedding
opportunity to apply and integrate knowledge throughout learning experiences” (Jankowski & Marshall, 2017, p. 47).

**Shift to the student as the unit of analysis in assessment:** In keeping with the recommendation above, the student should be the primary lens through which we consider assessment of learning. This unit of analysis is both smaller and larger than that of the programmatic lens: it is smaller than a whole degree program but larger in that it captures more nuances than just classroom and transcript activities. While accreditation still must focus at the program or institutional level, it can also take a more nuanced view toward student learning. Essentially, proof that students are learning and thriving confirms that we have created an ecosystem in which they can learn and thrive. This needs to be a fundamental transformation for higher education, the role of faculty, what faculty do, and how we describe and support student success in helping to “outline shared goals and identify how various groups may contribute to or advance the movement toward a student-centered approach to learning” (Jankowski & Marshall, 2017, p. 47).

By shifting to the student as our unit of analysis, we can consider individual pathways and individual credentials. In any given degree program, every student has a unique experience based on their courses, co-curricular activities, internships and co-ops, and the set of personal experiences and background that comes in with the student. This approach also expands to include the unique experiences of community college transfer students, veterans, and non-traditional students.

This level of assessment also allows us to ask “how has this particular individual built up a variety of learning experiences, capabilities, and functionings?” Capabilities are what the student is able to do and functionings are the uses to which the student puts their capabilities. From an inclusion perspective, broadening functionings beyond those currently preferred by the dominant group opens up the conversation to value the functionings and social capital of minority groups as well, as Jankowski and Marshall (2017) posit that for these groups “designing systems to help foster reflective and active learners who are successful inside and outside of higher education is vital” (p. 47).

**Assure that the fundamental citizen-building and societal improvement goals of a liberal arts education are core to STEM education experience, and that the fundamental scientific thinking of a STEM education is core to a liberal arts education experience.** STEM, the social sciences, and the humanities must integrate for the benefit of students in all fields as well as the nation as a whole. This integration adds value to STEM education and to the liberal arts, in addition to supporting a range of goals including the sustainability of the gains created for national economy and security, the need for an informed and engaged citizenry, and national prominence.

It is particularly important to recognize that the four components of STEM are not currently equally represented in a liberal arts education. While science and mathematics have long been essential parts of a liberal education, technology and engineering have not. Moreover, the traditional liberal arts curriculum is not always part of technology and engineering degrees. This disconnect has serious implications in a world of rapidly changing expectations and technology that will automate more and more types of jobs. We are living in a built world, and technology and engineering are at the heart of it. “What Percy Bysshe Shelley said about poets two centuries ago applies even more to engineers today: They are the unacknowledged legislators of the world. By designing and constructing new structures, processes, and products, they are influencing how we live as much as any laws enacted by politicians” (Mitcham, 2014). These disciplines and the traditionally-defined liberal arts (including science and mathematics) all stand to benefit from each other, as do students, business and industry,
and the world. It is by bringing these different lenses and areas of expertise together that we will be able to address the grand challenges facing us today.

**Do not allow institutions to use accreditation as an excuse not to innovate:** There is a natural tension between a process meant to provide accountability and quality assurance and the processes of innovation, since it takes time before we can confirm the quality and effectiveness of an innovation (see “Accreditation Practices, Innovation, and Perception”). Unfortunately, many view accreditation as a static process; once a program or institution receives accreditation there’s a strong desire to mitigate uncertainty related to future reaccreditation by keeping everything the same. However, this mindset disregards the fact that accreditation is also about continuous improvement.

Policy makers can address this tension by keeping pressure on institutions to not make up excuses that accreditation agencies and related activities (including ranking organizations) are the “bogeyman” that will say no to anything innovative. It may help for accreditation agencies to be very explicit that their policies are not designed to inhibit innovation and how they are designed to support innovation. This is especially important because agility is a core requirement for success as the nation, higher education, and the STEM ecosystem move forward.

**Do not allow accreditation to stifle innovation:** On the other side of the equation, accreditation processes themselves can impede innovation. Accrediting bodies and other policymakers need to re-examine specialized (versus general) program requirements for accreditation and related activities and solicit feedback from institutions and programs to better understand their impact on innovation. Accreditation and related activities should foster innovation, and while that is often one of their stated goals, the reality is often the opposite.

One example of balancing innovation with accountability at the level of institutional accreditation is the Higher Learning Commission’s (HLC) Innovation Zone, which was developed with support from the Lumina Foundation. Two initiatives that were recently announced out of the Innovation Zone are improvements to the HLC Substantive Change process and a process to allow institutions in good standing to engage in more timely innovation while maintaining accountability and quality measures. The Innovation Zone posits that “if institutions in good accreditation standing were free to innovate as alternative providers are, where the only essential measure of success is learning, was [sic] coupled with the quality assurance of accreditation, then institutions would have the ability to focus their efforts on exploring new models” (A Space to Innovate: Recommendation from HLC’s Innovation Zone, emphasis added). This approach aligns with many of the recommendations in this report and is an area ripe for further exploration.

**Recognize and articulate the benefits of accreditation:** Accreditation and accrediting bodies are often the subjects of scrutiny from multiple directions, particularly regarding issues such as the burdens of accreditation processes and the stifling effect that accreditation has on innovation. While cognizant of these issues, as can be seen in the recommendations above, we also recognize the essential role that accreditation plays in maintaining a healthy ecosystem.

The higher education ecosystem has a number of niches with different requirements, which all need representation within the whole. Accrediting bodies use a lens of diversity of institutions to ensure that the institutions in various niches are represented and that the overall ecosystem can therefore remain robust. Just as a natural ecosystem is established within a framework of physical laws, a built ecosystem is established and operates within a regulatory framework. This framework protects students, institutions, and the ecosystem as a whole by maintaining a balance between regulation and innovation, or control and lack of control. A healthy ecosystem needs resilience and difference.
Current evidence indicates that higher education is engaged in the “rich get richer” phenomena that, in the absence of oversight from accrediting bodies and other policymakers, could damage or destroy the entire ecosystem.

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<th>ACCREDITATION PRACTICES, INNOVATION, AND PERCEPTION</th>
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<td>Alan Cheville, Department Chair, Electrical &amp; Computer Engineering, Bucknell University</td>
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Accreditation in engineering has a long history that is perceived differently by historians and the faculty who are charged with the actual work of assessment or report writing. Currently in the United States and an increasing number of other countries, accreditation of engineering programs is under the aegis of the Accreditation Board for Engineering and Technology, or ABET (for more information on ABET and the accreditation process, a good starting point is the materials on the ABET website: https://www.abet.org/accreditation/what-is-accreditation/).

Most engineering faculty members’ experience of ABET is from the sexennial program visit and the assessment work and the report writing leading up to it. From this perspective ABET often seems like a monolithic organization that dictates criteria programs need to meet. However the view of historians is accreditation as a political process that balances the needs and concerns of engineering professional societies, universities, industry and government and which evolves to respond to changing societal perceptions of the needs of graduates (Akera, 2017). This process aligns with the lack of central control in educational standards in the US, unlike the more centralized processes found in many other countries, which has given rise to the rich diversity of educational institutions in the US.

In the last twenty years there have been two major, and many minor, changes in engineering accreditation processes. The first of these was a shift from clearly defined quantitative standards supported by disciplinary societies—often characterized as bean counting—to broad outcomes that emphasized professional skills that was promoted by industry. This shift, known as EC 2000, shifted from narrow checklists to assessment-driven evaluation of broad learning outcomes and introduced popular engineering ideas from the 1990’s such as continual quality improvement. This change generally met the desired outcomes (Lattuca, et al., 2006). The second, smaller change has been occurring over the last several years as ABET reduced the number of outcomes from twelve to seven and made other changes in its program criteria, in part to address the concerns of the volunteers who serve as program evaluators.

Today ABET as an organization views itself as having a role as supporting innovation of engineering degree programs. The accreditation process carefully avoids specifying how a program should assess its outcomes or setting minimum quantitative standards; these responsibilities fall to the program itself as it demonstrates continual improvement. ABET gives annual innovation awards to programs that improve students’ educational experiences (see recent awardees at https://www.abet.org/awards/abet-innovation-award/). However initial data from a multi-institutional study (Akera, et al. 2019) shows that the general consensus is that innovation in degree programs is seen to occur more through institutional change processes than through accreditation. Many faculty and administrators view ABET as maintaining standards and encouraging local discussions on curricula rather than promoting innovation; some faculty see ABET as stifling innovation.
Accreditation is also an important way to keep bad actors out of the ecosystem. Given our current understanding of brain development, particularly in late adolescence and early adulthood, institutions of higher education hold a tremendous responsibility in the development of their students that can last well beyond the college years. Accreditation is one mechanism for ensuring that the individuals coming into the ecosystem will not be harmed by institutions acting in bad faith. When considering ways that accreditation can be improved, we must remember that accreditation bodies play an important role in the overall well-being of the higher education ecosystem.

As an industry, we have a foundation of knowledge on how students learn and the practices that are most likely to support learning, and this foundation continues to grow and evolve. The national policy conversation needs to discuss and provide resources to motivate faculty and institutions to adapt and adopt this knowledge at scale in their own systems. Motivation includes the systems of evaluation and rewards and understanding the value of the research to the institutions, faculty, and student experience. National investments are necessary in research and enabling technologies to bring the most effective practices to scale at a sustainable cost. Assessment of students and programs is key to this process, as is the implementation of the other recommendations. Funders of curricular and pedagogical projects should assure that proposers understand the needs and context of the target educational ecosystem and assist projects with developing effective means of adoption of their work.

4. Institutional Issues and Ideas

Institutional accreditation is foundational to STEM education in the sense that it provides institutions with the ability to award students financial aid, confer degrees, and ultimately remain viable. Institutional accreditation is typically dependent on geographic location and performed by six regional accreditation bodies, with additional national specialized accreditors (faith-related and career-related). See “Accrediting Bodies” for details.

In addition to institutional accreditation, most institutions pursue additional programmatic accreditations. This creates challenges for campus leaders needing to balance multiple complex accreditation processes while maintaining quality at all levels and meeting overarching institutional accreditation requirements. How these various processes work together (or don’t) must be addressed in order to connect this work to benefit students.

Accreditation and assessment have been linked in the United States higher education environment for decades. Over time, accreditors’ expectations regarding institutional assessment of student learning outcomes has evolved from expecting institutions to plan for assessment to now expecting assessment results to be used to inform institutional planning and budgeting (Gaston, 2018). In order to do so, institutions need to understand program level accreditation and assessment expectations and structure institutional or common learning outcomes while taking program learning outcomes into account. One challenge is in effectively pulling data from course learning outcomes and mapping to program and institutional outcomes.

How can institutions leverage program level assessment and accreditation to support institutional level assessment and accreditation? How can we bring assessment to the level of the student? One critical element that can support accreditation and assessment at the institutional and program levels is institutional research and data. For some, particularly under-resourced and two-year institutions, access to clear and accurate data from an established institutional research office may be a challenge. Even among larger, wealthier institutions, we do not see regular disaggregation of data by student demographics (e.g., race/ethnicity, socioeconomic status, disability status, gender) that can inform improvements at the course, program, or institutional level. Although 70% of institutions report that
they track achievement of learning outcomes, only 17% are regularly disaggregating data on student attainment of those outcomes (Rhodes, 2019). Ensuring equal access to resources that support collection and analysis of data around achievement of student learning outcomes will allow more institutions to make improvements based on data that will ultimately have a positive impact on students.

**ACCREDITING BODIES**

Regional accrediting bodies are responsible for accrediting institutions (as opposed to programs or colleges within institutions).

The Council for Higher Education Accreditation (CHEA) is a voice for accrediting bodies, accredited institutions, and ultimately for students and their families. CHEA’s website ([https://www.chea.org/](https://www.chea.org/)) provides information on accrediting organizations recognized by CHEA and the US Department of Education (regional, faith, and career-oriented national accreditors, and programmatic accreditors), a searchable database of accredited institutions, accreditation and public policy, and public education materials on the importance of accreditation.
CURRICULUM TRANSFORMATION AT THE UNIVERSITY OF BATH, UK
Dr. Dawn N. Albertson, SFHEA, Curriculum Development Manager, Transformation Lead

Institutional Context
Bath has a lot to offer. Located in a World Heritage City, the University of Bath is a top 10 UK Institution and current Sports University of the Year, with 12 of our subjects coming in as Top 10 in their discipline. Eighty-seven percent of our research activity was judged as “world-leading” and “internationally excellent” in the Research Excellence Framework. We recently earned Gold in the Teaching Excellence Framework, which notes teaching of the highest quality in the UK, U consistently delivering outstanding learning and outcomes for students. We were also a finalist institution in the first Higher Education Academy (HEA) Global Teaching Excellence Award (2017), given to the University as a whole in recognition of institution-wide approaches to teaching excellence.

Perhaps surprising is our youth. At just over 50, it could be argued that we have achieved beyond our years, but the trajectory was set at the beginning. Our Royal Charter states, “The objects of the University shall be to advance learning and knowledge by teaching and research, particularly in science and technology, and in close association with industry and commerce.” Unusual for the time, that industrial and business emphasis has manifested in a quality and quantity of sandwich placement options, central to our teaching identity that few universities can match. All our undergraduate level disciplines provide opportunities for year-long placements, and a full 2/3 of our students complete a placement or study abroad as part of their degree program. This mix of real-world application alongside teaching and research excellence is at the heart of a University of Bath education and has placed us 4th for student experience and 5th for graduate prospects as a whole on the league tables.

The Curriculum Transformation Initiative
The landscape of higher education is changing in the UK and the world beyond. It has never been more critical for an institution to ensure that their portfolio reflects their strength, values, and strategy. Our Curriculum Transformation initiative is an opportunity to build upon our strong points as an institution and advance our priorities in order to maintain, and surpass, our current level of success.

All undergraduate and postgraduate taught courses, of which there are over 200, will be reviewed in an exercise of co-creation between staff and students. The project is being led by the Centre for Learning and Teaching to ensure that quality education is the ultimate output. A Curriculum Development Team has been assembled with diverse expertise in teaching and learning across the HE, secondary, and furthering education sectors that collectively support and deliver the University Education Strategy through development, implementation, and day to day management of the Curriculum Transformation initiative. They work collaboratively with colleagues campus-wide, research, prepare and disseminate a variety of resources, and offer specialist advice aligned with best practice in pedagogy and the guiding themes and principles of the institution.

The process has a strong scaffolding of direction, but allows for flexibility at the local level to ensure each program offering is enhanced in a way that works for their goals and vision. There are guiding themes, principles, and parameters that each course must take into consideration and by the end demonstrate, if they don’t already. While there are many guides in the project as a whole, several are rather specific to our institution like citizenship, sustainability, and building on meaningful partnerships. Some are more broad like being inspirational, a focus on graduate attributes and competencies, as well as building on existing success. Finally, several are directly focused around teaching and learning; these include:
• A course-wide approach
  o Focusing on the student experience across the program as a whole, rather than as a set of modules/units. Demonstrating how the course provides a coherent set of intended learning outcomes and viable, engaging, and inspiring methods that enable students to achieve them. This will ensure that the key knowledge and skills relevant to a particular subject field are embedded into the course without redundancy, opens up opportunities for creativity, and allows for more agility when making changes in the future.

• A critical look at assessment
  o Embracing assessment for learning and reduced, more thoughtful, assessment whilst maintaining rigor to increase the wellbeing of our faculty and students

• Supporting the needs of all learners
  o Cultivate curricula so that all students develop a sense of belonging, purpose, and identity. Recognize the differing needs of students at all levels, particularly those who represent marginalized communities, and support integration through interventions that promote understanding, tolerance, and empathy.

• Engage with research
  o Create opportunities for students to actively engage with, and contribute to, research communities at the University. Build cultures of research and inquiry within the curriculum from day one, so that students move from being passive consumers to becoming genuine partners in the production of knowledge.

The process is phased, with key stakeholder engagement around the existing provision being central to the start. Information is gathered from current students, alumni, staff, placement providers, employers, accrediting bodies, and others on the program in general, and around the principles specifically. Relevant performance and satisfaction data, as well as competitor and market information, is pulled together so the program team is able to collate a clearly informed image of the current offering. From there, in a process of thoughtful reflection and co-creation with students, the faculty identify the ways in which they would like to fully embrace the vision of the transformation within their specific discipline and course. A revised, visionary prospectus is the final output of the first phase.

The next phase finds our course teams beginning to craft a vision for their program as a whole, embracing a course-wide perspective. Reflecting upon who their graduates are and what they can do, the teams use this as a starting point to ensure a purposeful alignment of this desired outcome and the program plan. One of the most exciting and facilitating aspects of this project is a formal decoupling of assessment and study units. Separating these two historically intertwined aspects of an education frees up a multitude of possibilities in the ways in which assessment can be creatively, and most effectively, leveraged to benefit students in their learning. Looking by year, the teams create a plan of delivery which ends in the details commonly seen in any new program or major change application.

To date, suites of programs in Biosciences, Chemical Engineering, and Health Sciences have gone forward as pioneers. These vanguard courses are just finishing up with final approvals with plans to admit students for this fall. Upon reflection from the lessons learned with them, alterations have been made to operational aspects of the process, and the rest of campus will begin submissions January 2019.
While accreditation and accrediting bodies are frequently criticized and called to improve their own processes, their role in influencing the higher education ecosystem is unlikely to be significantly diminished in the near future. As discussed previously, institutional accreditation plays an important part in assuring the quality of higher education offerings. Moreover, accrediting bodies have been tremendously influential in pushing for the growth and evolution of assessment of student learning. How, then, do we balance the needs of quality assurance and innovation, of institutions and programs and their students? See “Curriculum Transformation at the University of Bath, UK” for an example of a bold initiative to improve programs and student outcomes.

Throughout the ecosystem, individuals and organizations want to improve higher education with the best intentions of their disciplines in mind, but this does not result in a coherent system for assessment. We must again use a student-focused lens, particularly today when the needs and interests of students encompass everything from a post-secondary certificate to an advanced degree. Are students learning a discipline only, or getting an education? Tensions between institutions, programs, and accrediting bodies do not necessarily benefit students, even when they all share the same goal of improving student learning. We need to better understand the impact that accreditation, evaluation, and regulation have on the educational ecosystem and on students.

5. Program Accreditation and Assessment

Specialized program accreditation can serve a number of purposes and provide value to multiple stakeholders. Students and their families often view specialized accreditation as evidence of value and the quality or rigor of a program. Employers look for graduates of accredited programs, and economic regions look to accreditation to ensure adequate supplies of workers in key industries. However, accreditation expectations vary from program to program and are not equally applied to all types of institutions.

Program accreditation can be an equity issue, as many schools that serve diverse students (e.g., community colleges and minority-serving institutions) may not have the funds and faculty capacity to make a long-term commitment to specialized accreditation. This same issue can be seen at the K-12 level, where schools that cannot afford the right equipment cannot participate in programs such as Project Lead the Way, even if they have faculty trained in the curriculum. While many view accreditation as a necessary cost of business, we must also question if this cost may act as a gatekeeper that limits full participation from the range of higher education institutions and the students they serve. If, as we have asserted earlier, accreditation plays an important role in the higher education ecosystem, how can we ensure that all programs that wish to participate in program accreditation are able to do so?

In particular, the differences between liberal arts, transfer-focused community colleges, technical colleges, and four-year institutions highlight the challenges of ensuring that the various parties understand and communicate clearly around issues of assessment and accreditation. Unlike career-focused technical programs that use specialized accreditation as a measure of quality to meet business and industry requirements, transfer-focused community colleges typically do not have the same market pressures driving them to pursue programmatic accreditation. Depending on the school (and, in some cases, state system), STEM programs may not have a specific degree option at the two-year level. In many cases, articulation agreements or innovative arrangements such as Minnesota State’s Transfer Pathway degrees act as a proxy for accreditation (see “Minnesota State Transfer Pathways: Chemistry” for an example of the process).
### Minnesota State Transfer Pathways: Chemistry

Betsy Longley, Ph.D. Instructor and Chair of Chemistry, Normandale Community College

In AY16, the Minnesota State Colleges and Universities (MN State) system began developing a series of Transfer Pathways to provide students with a consistent path from a two-year college offering an associate degree to any four-year state university offering a degree in the same major. Students who complete a Transfer Pathway degree program at a MN State college and are admitted to any of the 7 MN State universities will be guaranteed junior status, and given assurance that all 60 college credits will count toward the related bachelor’s degree.

Each transfer pathway describes all of the lower-division major content and competency requirements needed to prepare students to enroll in the major at the university. A total of 27 Transfer Pathways have been developed, including 5 in the STEM fields (Biology, Chemistry, Computer Science, Mathematics, and Mechanical Engineering). The example of Chemistry will be used to discuss how the Transfer Pathway addresses evaluation and assessment.

The Chemistry Transfer Pathway development team, like all other Transfer Pathway teams, was comprised of faculty from both two-year colleges and four-year universities, along with college staff (including advising) and administrators, totaling 19 team members. We began our work by evaluating the curriculum in the first two years of a chemistry major at the four-year universities, with an eye toward specific course content and learning outcomes. We did the same for the corresponding courses at the two-year colleges, and then began the work of identifying which content and outcomes were integral to the Transfer Pathway and which were not.

We approached this work first and foremost through the lens of student learning, both in terms of how the content of one course serves as the foundation for a subsequent course, as well as whether assessment of the competency requirements would present an adequate gauge of student proficiency in the course content.

Partway through the development process, all MN State students, faculty, and administrators were invited to a Stakeholders Meeting to provide input on the proposed pathway, including course requirements and learning competencies.

**Challenges:**

- Determining which Math, Physics courses to include: some two-year colleges required only algebra-based Physics while some two-year universities required calculus-based Physics, for example.
- Determining whether Analytical Chemistry (taught at some two-year colleges, also taught at four-year universities) would be accepted for transfer by four-year universities.
- Limiting the Transfer Pathway curriculum to 60 credits (the General Chemistry course is a four-credit course at some two-year colleges and a six-credit course at others, for example).

In working to address these challenges—particularly when there was disagreement among us—we leaned on the Chemistry Program Guidelines published by the American Chemical Society and always came back to our common ground, the students.

While the pathways degrees are too new for any meaningful assessment of their impact, we do know a number of things simply through participating in the process. Most notable, perhaps, is that...
the process highlighted how very rare it is for two- and four-year institutions to have such opportunities to communicate and collaborate on program design and program learning outcomes. This process gave a very small group of faculty the chance to close the feedback loop and provide and receive direct feedback on how community college students are doing post-transfer. It gave community colleges a voice to share information on the experiences and challenges that community college students face pre-transfer as well. A key takeaway question is: how can we create more and more ongoing processes that bring two- and four-year institutions together for work in their programs that is firmly centered on the student lens?

One of the challenges community colleges face with program assessment is related to meeting the needs of the student body and the ways they move through the institution. Again, except for career-oriented programs, which can be found at traditional technical colleges and community colleges, students at two-year institutions are more likely to be part-time and more likely to have to stop out for work or family obligations on their way to transfer and/or a degree. As a result, community colleges’ programs are not cohorted, nor are they able to offer capstones or other options that can act as an additional level of program assessment. Instead, curriculum mapping is the primary process for identifying and connecting course level outcomes and assessment to the key learning outcomes for the first two years of a four-year STEM degree.

Within these challenges, there are great opportunities for community colleges to innovate and improve programs as well as student learning. Because of the community college focus on teaching and learning, these institutions need to become more actively involved in driving conversations around assessment of student learning, particularly at the program level. In order to do so, institutions and faculty must be willing to take on the risks associated with innovation and to maintain communication with four-year receiving institutions. Additionally, community colleges need to consider the typical teaching load of faculty and ways to incentivize and reward individuals who are working to improve assessment at the individual and program levels. By increasing their visibility and contributions to assessment and evaluation conversations, community colleges also elevate issues important to their diverse student bodies.

Other issues and recommendations apply to four-year institutions specifically as well as all institutions of higher education in general. 

**Identify and address institutional barriers that stifle programmatic innovation.** Existing institutional policies and processes such as those related to courses, credentials, and student records can have a dampening effect on programmatic innovation. Some of these may be related to accreditation requirements, while others may simply be long-standing processes (“we’ve always done it this way”). Processes and standards around evaluation and reward structures (e.g., tenure and promotion) and faculty workloads can inhibit participation in innovative initiatives that are often labor-intensive and may not be recognized as valuable contributions to the campus (particularly when compared to more tangible results like publications). Even infrastructure such as technology systems and physical spaces themselves can limit or stifle innovation. Institutional and even departmental cultural norms can dampen innovation or restrain those who may participate in such efforts. All of these factors can be even more challenging for innovations involving inter-, trans-, and multi-disciplinary approaches. See “University of Tennessee Biology Curriculum Overhaul – Vision and Change” for to see how one department made significant changes to the curriculum.
This NSF-sponsored effort revised a biology majors’ two-course introductory sequence as outlined by the Vision and Change in Undergraduate Biology Education final report. Select faculty members across three biology departments served by the introductory courses formed a task force in 2010 to consider ways to improve the courses. After the publication of the Vision and Change final report (AAAS, 2011), the faculty decided to adopt the concepts and competencies from the report as the new unified learning objectives for the two courses. The curricular changes were phased in over three years of reform to ease the transition to the new course structure. A decision was also made to remove the labs appended to each course and instead add a weekly 50-minute small-group discussion led by teaching assistants focused on primary literature and biological literacy in an AL context. This resulted in a proposal to switch from a traditional two-course, eight-credit introductory sequence to a three-course, eight-credit sequence with two lecture/discussion courses (three credits each) and an independent two-credit lab/discussion starting in Fall 2014.

Throughout the curricular reform process, faculty met as a group to discuss the reform, participate in professional development sessions, and share resources. Instructors worked together and jointly developed the implementation guidelines for the revised lecture courses. On average, these meetings occurred once a month and lasted at least one hour each. These meetings included faculty review of primary literature on topics such as backward design and student-centered learning. There were no course or sequence requirements for how AL or the new curricula were to be implemented, beyond what was decided upon by the group. Course learning objectives, major topics, total course points, and textbook materials were the same; however, topic sequence, specific activities and assignments, and book readings, for example, were allowed to vary by instructor.

At the end of each semester of observations using the Classroom Observation Protocol for Undergraduate STEM [COPUS; Smith et al., 2013], the instructors were provided access to their own data and the compiled data for the program. All data were shared anonymously. Some of the instructors also participated in communities of faculty, postdoctoral associates, graduate students, and undergraduates who worked together to design the discussion curricula; however, the meetings with instructors about changes to the lecture courses were separate from the meetings about the new discussion curricula. These classroom observations revealed that instructors increased their average use of active learning by 12% of total class time. Interviews revealed that instructors shifted their definitions of active learning and talked more about how to assess student learning. Collaboration, feedback, and time may have been important factors in the reform, suggesting that small shifts over time can accumulate into real change in the classroom.


Developing approaches to overcome these barriers requires conversation, better understanding, and collaboration that must involve diverse parties on campus including registrars, deans, department and program chairs, and institutional research. It involves understanding both institutional and specialized accreditation requirements as well as processes that are dictated by other external mandates such as state legislatures. For issues that are the result of long-standing institutional practices, all parties need to ask questions and learn about the assumptions often inherent in those processes in order to identify ways to remove or mitigate these barriers. These collaborations have the potential to open the door for greater STEM programmatic innovation.

**Recognize people’s resistance to change and the role that can play in stifling innovation.** Addressing the various institutional barriers to programmatic innovation will not, in the long run, be effective if we do not also consider the various ways individuals will react to change or suggested change. For example, if tenure and promotion structures are changed to encourage multi-disciplinary program innovations, those who have been working under the old structure are very likely to feel threatened or insecure about their future under the new model. Even those who pursue tenure with the goal of then using their position to push for change may find that the process of obtaining tenure creates habits that can ultimately lead to complacency and a reluctance to rethink the system.

For innovation to stick, institutions and individuals need to be aware of and employ best practices in change leadership. This is a place where having an outside facilitator or otherwise neutral party can help, as can awareness of and sensitivity to organizational culture. By its very nature, higher education is committed to preservation and protection of values and ideas. It takes courageous individuals at every level of an institution to try to balance this unspoken mission with the need to innovate and change in order to remain relevant and viable in the 21st century.

Returning once more to the student lens can help to inspire change. Focusing on institutional missions around student success can guide our work in assessment and innovation. So too can a deeper understanding of higher education as an ecosystem, and as one that is facing pressures to evolve or accept changes imposed from the outside. Systemic thinking, and institution-wide understanding of the ecosystem we operate in, can drive ecological evolution by those within higher education instead of top-down change imposed by external forces.

**Promote efforts for greater transparency in the documentation and communication of student learning.** Course syllabi frequently do not make explicit the connections between content and student learning outcomes. Similarly, course and program descriptions in catalogs can be opaque. This can impede curriculum mapping from general education to programs and can confound articulations of transfer credits. Unclear or sparse documentation of student learning outcomes on transcripts can even impact how potential employers may recognize the value of a degree. Faculty often express reservations regarding innovative approaches to courses, professional skills, and programs due to concerns about how titles, labels, and identities will be interpreted by outside entities.

**Promote the value of institution-level assessment requirements as a lever for positive change.** Ensuring that all departments are conducting meaningful assessment and evaluation can provide the motivation and urgency necessary to stimulate innovation. Valuing the service, and scholarly work, conducted by faculty managing programmatic assessment as part of reward structures could increase the impact of assessment as a tool for innovation. It is highly recommended that institutions work to align their internal assessment processes and protocols with those used by external disciplinary accrediting bodies so that faculty are not duplicating efforts. As accrediting bodies vary in their assessment processes, such as central student learning outcomes or continuous improvement cycles,
institutional requirements need to remain flexible. Institutional student learning outcomes, for example, may help a program to frame the outcomes for external accreditation.

In both institution- and program-level accreditation, the key is to ensure that programs are conducting meaningful assessment and evaluation. This means encouraging an institutional (and individual) mindset that considers assessment to be inherent to effective teaching and learning rather than assessment to satisfy the requirements of institutional and/or program accreditation. This limited view of assessment results in incremental changes, if any are made at all, rather than transformative innovation.

**Promote the value of disciplinary accrediting bodies as a lever for positive change.** In particular, guidelines and recommendations that extend beyond a list of content that students should know and venture into what students should be able to do can serve to stimulate programmatic change. These criteria can serve as levers for innovation not only by necessitating currency in the discipline but also, more profoundly, by encouraging a more holistic student-centered approach which integrates accreditation expectations with the needs of 21st century learners and institutional expectations. For example, ABET accreditation places an emphasis on the assessment and evaluation of student outcomes that describe the knowledge, skills, and behaviors students have by the time of graduation. The outcomes defined for each of the four ABET accreditation commissions are informed by input from industry, professional societies, and academia and include both technical and professional skills. While the vast majority of ABET-accredited programs chose to adopt the ABET outcomes as is, some programs include additional student outcomes that address knowledge or skills that may be specific to their program and important to their constituencies. Assessment and evaluation of student outcomes focuses the process on what the students know and can do as opposed to what has been taught. Assessment results inform continuous improvement of the program and serve as a driver for innovation.

Since the initial implementation of outcomes-based assessment by ABET in the late 1990s, engineering programs have gone through significant changes in both the content of the curriculum and the various pedagogies used in the classroom. Most of these changes have been brought about by the recognition that professional skills are essential for practicing engineers in the 21st century, something that has been reiterated by the National Academy of Engineering publication on the Engineer of 2020. Consequently, many engineering curricula now include courses that educate students on the professional and ethical responsibilities of engineers and courses focused on technical communication or formally embed these topics in engineering courses. Pedagogies have evolved so more faculty are incorporating experiential/hands-on learning and problem-based learning so students have an opportunity to develop their intra- and inter-personal skills, such as teamwork and communication.

Ultimately, disciplinary accrediting bodies, such as ABET, should be viewed as a means to an end, not an end in themselves. The goal for any degree program and the affiliated faculty should be to implement continuous positive change to enhance the students’ educational experience and learning. The goal should not merely be to satisfy the requirements of the accrediting body.

**Encourage innovation and mitigate risk-averse behavior from programs.** Seeking initial accreditation can inadvertently lead to reactive behavior, with the perceptions of “what accreditors want to see” driving both curriculum and assessment. Programs can also be reluctant to change after obtaining accreditation because individuals feel they “passed” their last accreditation review and do not want to do anything to jeopardize a successful review in the next cycle. This attitude is unfortunately contradictory to the very intent of program assessment, which is supposed to promote continuous improvement based on data rather than encouraging the status quo.
Concerns about variability in program evaluation can equally serve to stifle innovation. Fear of being too innovative or too different, as well as potential consequences due to divergence from traditional thinking, can hinder programs from pursuing new ideas.

**Value assessment and evaluation through greater support for STEM faculty.** Accredoiting bodies provide training for individuals seeking accreditation for their departments. However, the lack of accrediting bodies for many STEM disciplines results in a significant void in opportunities for training and validating of importance, particularly in times of volatile funding for higher education. Administrators, faculty, and even graduate students would benefit from professional development offered at the disciplinary or institutional level. The wealth of resources available through organizations such as NILOA as well as many institutional and specialized accrediting bodies needs to be widely disseminated among faculty and departments to encourage this type of professional development. Disciplinary associations are another sources for information and professional development on assessment and developing learning outcomes.

The culture of teaching and learning, embodied by teaching and learning centers, can be separate from that of assessment, which is often the purview of institutional research. Institutions may benefit by expanding their capacity to provide support for assessment as an integral, formative component of the teaching and learning effort and provide more support for faculty seeking to use assessment for continuous improvement of their teaching, their courses, and their programs.

**Encourage greater emphasis on the program level and on faculty collaboration.** On a day-to-day basis it can be easy for faculty members to focus on their own classes and to view themselves as individual, autonomous units. The top barrier to effective, sustainable assessment at the program level is convincing faculty to have a holistic view of the program instead of only seeing the courses they teach. Faculty members need to adopt a mindset that seeks ways to improve their program as well as their individual courses.

Similarly, faculty members need to be aware of the impacts that changes in their programs may have on other departments. Curricular changes in one department may have a ripple effect on other disciplines, even in cases where there is little or no multi-disciplinary collaboration. Regular communication and sharing across disciplines and departments on issues regarding curricular design and assessment practices can help to create an environment where faculty members can broaden their lens beyond their individual courses.

Program-level accreditation, evaluation, and assessment offer rich opportunities to consider how an academic program can be greater than the sum of its parts. It requires collaboration and contributions from all faculty in a program as well as an understanding of how program and institutional accreditation and assessment of student learning are interconnected and can support each other (see “Considering Accreditation of a Technology Program” for some of the issues that must be addressed by community colleges seeking external accreditation). How can institutional leaders, including academic chairs, create a mindset that encourages faculty to look beyond their own courses? While offering many opportunities for innovation and improved student learning, community colleges in particular face challenges to successful program-level assessment. This too creates opportunities for innovation and collaboration, particularly between two- and four-year institutions, to create practices of meaningful program assessment within the community college as well as those that can bridge lower division and upper division courses. How can two-year colleges assess program learning when a two-year degree isn’t needed prior to transfer? How can two- and four-year institutions create feedback loops that provide two-year faculty with information on how...
their students perform after transfer? How can two-year colleges capture information on program-level learning in non-cohorted programs? Exploring answers to these questions will have a significant impact on all students.

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<th>Considering Accreditation of a Technology Program</th>
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<td>Conversation between Dr. Cary Komoto, Dean of STEM and Education and Nancy Louwagie, Chair of Engineering Technology and PI, NSF DUE 1700624</td>
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Normandale Community College offers the only vacuum technology program in the nation, which was established in response to regional semiconductor industry needs. Vacuum technology technicians are needed in a wide range of industries that are reliant on vacuum and thin film technologies including semiconductors, medical manufacturing, research, food preservation, and glass coating. Normandale offers certificate and degree options in vacuum and thin film technology.

Q: I understand that you have been considering accreditation for the vacuum technology program. Can you talk a little about that process and what has been going through your minds?

**Cary Komoto:** One of the challenges with the vacuum [technology] program is finding the right accrediting body, because a lot of those focus on a particular industry and we couldn’t really find one that fit neatly with the vacuum program. From our standpoint, that would really be a big disadvantage or maybe advantage, for those who can find the right kind of accrediting body. I think those can be really good if they are industry recognized and provide a third party evaluation – you know, the whole reason for accreditation is to have an outside body look at what you’re doing and decide yes, this is quality and meeting goals, and in technical programs, obviously, goals of industry and meeting the needs of industry. That’s where the huge advantage of these things are, especially if they’re a recognized industry accrediting body. I think that provides value because it says something about what a graduate of the program knows how to do. Also really valuable for the person as well, when they apply for jobs.

Q: How does that fit with innovation? You pointed out that if the accrediting body exists, it’s a benefit. But if it’s a program that’s innovative or more niche-focused, does that stifle innovation, do you think?

**CK:** I think it could go both ways; if the industry or the accrediting body doesn’t keep up with the times, it could be stifling because you’re being evaluated on things that are outdated. But if it really is an accrediting body that is keeping up on innovations it can reward organizations for being innovative and creative. In the case of vacuum, because we really haven’t had that outside accrediting body, it’s a neutral thing. We’ve become innovative because of trying to figure out where we fit in the world of vacuum.

**Nancy Louwagie:** I think that’s a good point, is that’s been freeing. We’ve had a lot of liberty to do different things and define what these standards are. All these things are always pros and cons, when you have that flexibility you can really feel the freedom to try some different things but on the other hand if you don’t have criteria or something that’s agreed upon as standards, everything is up for grabs. Defining what you want to be is limitless and can become a cycle of “what are we supposed to be” and “are we the right thing?”

Q: Do you then, in the absence of accreditation or an accrediting body that gives you those standards,
CK: Yes.

NL: Because our program has been more aligned, or let’s say used, by industry. We have primarily a student body who are working [with] or working around the equipment we get a first-hand view. We hear “this is what I do with it [the technology]” and “this is how I experience it.” You have a vicarious sense about the day-to-day things they do with it. Now, being able to back that up into some kind of educational outcome can be tricky.

Q: And to do it so it isn’t tied to any specific employer?

NL: Exactly. That’s really critical too, because employers use the technology in different ways, some much more advanced than others. Yet that’s still the core to a lot of them getting done what they need do in manufacturing production or research.

CK: Again, backing what the students have been saying, having the industry advisory board too, where we have other people like supervisors who are also part of it, they can also say what they’re looking for. You add that onto what the students are actually day-to-day doing I think you get a pretty complete picture. But again, the trick is because this technology is used in a variety of ways that scope is pretty broad and so trying to figure out what is the core that we need to provide students so they can be successful. And then there obviously needs to be some on the job training and so on.

NL: And to the right level. That’s always the trick with technology and the two-year experience. The technology is still the same as it is to the scientist and the engineer, but the way the technician has to engage with it has a different feel to it. So to what extent do they need to know some of the underlying scientific and mathematical principles in order to be effective in their jobs?

Q: So both what you identify as the learning outcomes and potentially the pedagogy you use is going to look different.

NL: Right.

Q: So is there an accrediting body you’ve been looking at that could potentially accredit the vacuum technology program?

NL: There’s a subpart of ABET [Engineering Technology Accreditation Commission – ETAC] for technical program accreditation. In having conversations with Erie Community College – the state of New York actually requires all of their technical programs to hold an accreditation. They mentioned another accrediting body in addition to ABET. It’s the Association of Technology, Management, and Applied Engineering [ATMAE]. Minnesota State University Moorhead’s Operations Management program is accredited through it [ATMAE].

You need to be smart about which one you choose because of factors such as cost and time intensity of obtaining and maintain accreditation] So you need to think about what you’re getting out of it. But at the end of the day, that third party stamp of approval is important to a program. I know for myself, and this isn’t an accrediting body, but for the past couple of years what we’ve looked to is the relationships with the professional societies. So what does it mean to have their stamp of approval?
Q: So an accrediting body can be that external, third party, quality assurance. Are there any downsides to having that external confirmation?

CK: Potential costs and the amount of time to obtain that approval. Like with AQIP [institutional accreditation through the Higher Learning Commission], there’s X number of hours sunk into putting together the portfolio, to show yes, we’re doing all the things we need to do. There’s a partial downside if it’s excessive and taking you away from actually doing the program. On the other hand, you need to reflect on what you’re doing to make sure that you’re doing it right. You don’t just go ahead and do it and not figure out is this really what we should be doing. We’ve kind of been doing this on our own, with the industry advisory board that Nancy’s put together. We’ve been checking in with industry who’ve been hiring our grads and finding out are these [graduates] doing what the businesses want them to. If they were to say no, we’ve been trying to figure out how to make things happen so that we are meeting their needs.

Q: At the workshop, we talked about how the process of obtaining and maintaining accreditation can cause people to be afraid to innovate – we did it this way last time, we need to keep doing it this way to maintain accreditation. As an outsider considering accreditation, is that something that you concerns you? Do you think there are ways you can work around that?

CK: I would hope that accrediting bodies would recognize that in technology programs, things are always changing. If you’re not innovating, if that’s not part of the evaluation, then what are you doing? In certain fields, the technology is changing overnight. If that’s not part of what you’re trying to measure as part of a program –

NL: That brings up an interesting question about the process. Do accreditation bodies allow for some type of evaluation of what you’ve done to recognize changes in technology? I mean, 3D printers weren’t here and now they are, and how does an accrediting body itself deal with what new technology is coming on board?

CK: Like additive manufacturing, what is the accrediting body for that?

NL: Technicians supporting additive manufacturing technology. Who knows what that is? It’s just now in facilities, we have people using the technology, but there isn’t a standard.

CK: Maybe the 3D printer is analogous to vacuum, because 3D printing can be used in so many different applications, from very high tech to very low tech ones.

Q: You raise some interesting questions, and perhaps that’s the best place to leave our conversation. Thank you for taking time to share with us.

6. Crossing Multiple STEM Disciplines
The nature of work is changing dramatically. Jobs exist today that did not exist a decade or two ago, such as web developer, mobile app developer, data scientist, bioinformatician, and robotics engineer. At the same time, jobs that can be automated are disappearing. The nation will need an adaptable workforce that is capable of solving emerging problems and seizing emerging opportunities that are
Future Education for the Future of Work
To take advantage of new opportunities requires a workforce that embraces a diversity of knowledge and skills, perspectives (including cultural), and modes of thought and dispositions. Traditional, individual disciplines remain relevant and also gain new applicability as they enable transformative connections with other disciplines and advance their own disciplinary content, practices, and discourse based on discoveries in other disciplines. Emerging disciplines bring fresh perspectives to existing problems and scientifically sound approaches to new problems.

The future of research increasingly calls for collaboration and integration across disciplines as well. Convergence research, defined as “a means of solving vexing research problems, in particular, complex problems focusing on societal needs,” was identified as one of the 10 Big Ideas for Future NSF Investing in 2016 (National Science Foundation).

The benefits of crossing traditional disciplinary boundaries include:

- Breaking out of silos
- Forging new connections with disciplines
- Understanding deep similarities in seemingly disparate fields
- Maintaining and enhancing the relevance of traditional fields when combined with other fields and applied to new problems

Many of the future types of jobs, including the ones listed above, will require such cross-disciplinary mindsets. This is likely to be increasingly true of the jobs that will exist in the future that we cannot even name now.

Approaches that involve multiple disciplines vary along a continuum with various degrees of blurring disciplinary boundaries, channeling interactions across disciplines, and creating integrations that transcend boundaries. There are several approaches and models for building curricula and programs that provide students an integrated learning experience. Multi-, inter-, and transdisciplinary approaches all provide opportunities to incorporate knowledge and frameworks from two or more disciplines but differ in the degree to which they are integrated.

On the cross-disciplinary continuum, three common approaches are:

- Multi-disciplinary approaches encompass discipline-specific approaches that draw knowledge from different disciplines without crossing their boundaries
- Inter-disciplinary approaches integrate approaches from different disciplines that can affect the research output of individual disciplines
- Trans-disciplinary approaches transcend disciplinary boundaries to form a new holistic approach

All can serve as models for synthesizing, integrating, and connecting concepts.

Based on the definition of the National Research Council (2014), multidisciplinary generally consists of loose cooperative interaction among scholars of different disciplines working on the same problem, whereas inter-disciplinary refers to problem solving in which there is cross-disciplinary learning and intensive blending of ideas from the different disciplines. In transdisciplinary collaborations, mutual learning and knowledge integration transcend specific disciplines and result in a more comprehensive and novel framework. The implementation of these approaches at the level of a course or a program requires varying degrees of planning, coordination, and cooperation.
The ongoing dynamics of disciplines interacting with and benefiting from each other in R&D labs or other industry settings suggests that institutions of higher education should also allow for cross-disciplinary learning through more programmatic venues. Academic units in higher education are typically structured along traditional disciplines, yet generating new knowledge and solving complex problems often requires the flow of ideas and the incorporation of knowledge and tools from different disciplines. The confluence of various STEM/STEM disciplines has generated new fields such as robotics and bioinformatics. Moreover, the integration of STEM with humanities and social sciences, which is viewed as an essential component of a well-rounded liberal arts education, continues to inform new areas such as Data Science and Ethics.

There are several examples of existing and emerging areas of work where concepts and tools from two or more disciplines are required. In some cases, such as bio(medical)engineering and robotics, these opportunities primarily require competence across different STEM curricula. In other cases, like artificial intelligence, a substantial grounding in ethics and computer science is required. Another example is the interactive media and game design field, which requires knowledge of programming and art. Data science, a new emerging STEM discipline, connects traditional disciplines of mathematics, statistics, and computer sciences with a variety of application domains that draw from many other disciplines such as engineering, business, finance, or health sciences. Connecting STEM with disciplines outside STEM is suggestive of new educational programs, such as liberal science or a liberal engineering.

A widespread model is the use of courses that foster the intellectual engagement and critical thinking of first year students as they transition to college. Often designated as First Year Colloquia or Freshman Seminars and bearing only one credit hour, they are centered on complex issues that require students to examine a problem from multiple disciplinary perspectives. As such, they provide context and meaning for a deeper dive into the various disciplines. This model could be strengthened through deliberate opportunities for students to continue to integrate knowledge through their experience, with a culminating capstone experience to demonstrate students’ competencies in this area.

Most models for integrating the perspectives from multiple disciplines involve the creation of new programs. The creation of a Robotics major at Worcester Polytechnic Institute (WPI) is one such example (see “The WPI Robotics Engineering Program: Case Study in Educational Innovation”). The program has associated faculty from various home departments, and a portfolio of courses that are either multidisciplinary or interdisciplinary and often team taught. The program builds on the strength of WPI in the areas of engineering and computer science and addresses the need for such training in the workforce.

Yet another model for providing an integrated learning experience to students without creating new programs consists of leveraging existing courses and departmental structures. For example, Spelman College introduced transdisciplinary modules that connected biology and physics. Students were introduced to a problem in biology (e.g., electrophysiology) and a basic concept of physics (e.g., electricity) in order to solve the problem. In their introductory physics course they revisit the problem and reexamine it after a deeper grounding in the discipline. Finally, in an upper level biology course they revisit the problem from the perspective of the subdiscipline (e.g., neuroscience).

Finally, another albeit less widespread model is the year-long ‘Integrated Science’ course that is implemented at Princeton for students considering a career in science. It covers fundamental
principles from freshman science courses across STEM disciplines in ways that help students make connections and understand unifying principles.

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<th>THE WPI ROBOTICS ENGINEERING PROGRAM: CASE STUDY IN EDUCATIONAL INNOVATION</th>
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<td>Prof. Michael A. Gennert, Founding Director, WPI Robotics Engineering Program</td>
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Worcester Polytechnic Institute (WPI) is the 3rd oldest technology-centered university in the U.S. WPI offers degrees in Engineering, Science, and Business from B.S. (and a few B.A. programs) through Ph.D. in 30 undergraduate and 50 graduate degree programs. With approximately 250 T/TT and 180 NTT faculty, and 4,700 undergraduate and 2,200 graduate students, the university comprises a close-knit community. The university was recently rated first in the nation for “The Top Faculties; Schools that do the Best in Combining Scholarly Research with Classroom Instruction” by The Wall Street Journal. WPI is especially well known for the wide adoption of Project-Based Learning, exemplified by the Global Projects Program, under which almost all undergraduates complete an off-campus project at one of 40+ project centers across six continents. In recognition of its project-based engineering curriculum, WPI was awarded the 2015 Bernard M. Gordon Prize for Innovation in Engineering & Technology Education by the National Academy of Engineering.

In 2007 WPI launched an undergraduate degree program in robotics. At that time, there were only a handful of universities worldwide offering undergraduate Robotics programs, and none in the United States, although many universities included Robotics within a discipline such as Computer Science, Electrical Engineering, or Mechanical Engineering. WPI took a decidedly different approach, introducing Robotics as a multi-disciplinary engineering discipline to meet the needs of 21st century engineering. The curriculum was designed top-down, starting from vision – an exemplary multidisciplinary initiative combining education, research, and innovation – to objectives – understand the fundamentals, apply them to design and construct robots and systems, have imagination and entrepreneurial spirit, and exhibit ethical behavior and standards – to outcomes that are specific and measurable – to curriculum and resources. Curriculum development was guided by a set of principles. The program would have to be: clearly articulated, broadly-based, flexible, achievable in 4 years, consistent with the WPI educational philosophy, and accreditable by ABET.

Although accreditability was a guiding principle, it was far from the driving concern. Rather, it served as a reality check on curriculum design: any proposal that suffered accreditation shortcomings would likely have other defects as well. The approach worked; the program was accredited in 2011, reaccredited in 2015, and won the ABET Innovation Award in 2016. The resulting curriculum, designed top-down, incorporates a number of best practices, including spiral curriculum, unified set of core courses, multiple pathways, inclusion of social issues and entrepreneurship, emphasis on project-based and active learning, and capstone design projects. The program has been highly successful in meeting its desired outcomes, including quantity and quality of enrolled students, results from competitions, interaction with industry, graduate placement in jobs and graduate school, overall student learning, external recognition, and ABET EAC accreditation. The program has been assessed using several quantitative measures: enrollment, cohort survival within the program, course and project evaluations, and student placement success.

By any measure, it has far exceeded expectations.

Challenges
There are many challenges to cross-disciplinary education, ranging from epistemological to pragmatic challenges.

Epistemological challenges raise questions about:
- What disciplines should be brought together
- Why connections among selected disciplines are of interest
- What accomplishments are achieved through cross-disciplinary connections that cannot be accomplished separately
- How to motivate and support disciplinary mastery of content in cross-disciplinary endeavors without diluting learning in individual disciplines.

The answers should be clearly articulated to create a sound rationale for new educational structures that support cross-disciplinarity. They should also be revisited when addressing the more pragmatic challenges related to culture, organizational structures, and resources. These challenges should be addressed early and transparently to turn obstacles into strengths.

Explicitly discuss and develop the culture of the new program. Any new cross-disciplinary program must decide what culture to adopt (or create) among faculty, students, and staff. The importance of this work cannot be overlooked; addressing the challenges of organizational structures and resources alone is not enough to develop a functioning culture for the new program.

The cross-disciplinary program faculty must take time to formulate expectations for learning and develop processes for communicating expectations within the new unit. It is important to create dialogue across participating and related units throughout this process. Various disciplines participating in the new unit may have differing opinions about its importance, which must be recognized and addressed. All of these discussions prepare the program for appropriate assessment processes that are meaningful to program stakeholders.

Faculty in a new cross-disciplinary program also need to work together to determine the types of learning that are most appropriate for the cross-disciplinary intent and strategize plans to implement cross-disciplinary learning. Ultimately, the goal of a cross-disciplinary program is an equitable, integrated, and coherent learning experience. As the program develops, faculty may want to deliberately build in time for reflecting on student learning and proficiencies and review or revise learning expectations as needed, incorporating regular assessment into their program implementation.

In the process of building a new program culture, it is common to feel “productively lost” or “positive restlessness.” This is a good thing and should be viewed as a natural part of the process of building something new. In a similar vein, faculty, students, and staff may struggle with some elements of an identity crisis as they develop the language and understanding to describe the new program and craft narratives that can translate that identity outside of a particular institution and into broader academia and the workplace. Again, this is an opportunity for discussion and collaboration among all parties, including students, who may need assistance in communicating the value of their multi-disciplinary educational experience to potential employers.

Be aware of and address potential barriers to developing new structures and reallocating resources. Creating cross-disciplinary programs means developing new organizational structures and reallocating resources such as funding, people, and space away from established departments. Resistance to such changes may be attributed to not knowing or not having a say in how the “power”
shifts and to the risk of participating departments getting “weaker” individually. An opposite view of embracing a new organizational structure is that of a “rising tide lifts all boats,” where sharing resources creates advantages for all participating units. Preventing contention and fostering collaboration can be challenging and will likely require participation and support from a range of stakeholders within the institution.

Other structural challenges include determination of faculty workloads and issues related to the tenure and promotion structure. Inter-departmental teaching, research, and service need to be recognized, as well as the integration of co- or extra-curricular learning that are beneficial to cross-disciplinary endeavors.

7. Course-level Assessment

Individual courses not only form one of the key elements of an academic program, they are, through general education requirements, frequently the primary way that STEM disciplines can engage non-STEM majors and develop a more STEM-literate populace. Further, course level assessment can provide valuable insights for faculty members collecting data on their students’ learning. Likewise, it is where students have the most direct experience of useful assessment.

Most course-level assessment takes place at the student level and consists of course tests administered by instructors. Being experts on the subject matter, course instructors are good judges of what it means to display competence in the subject. However, recent advances in the science of learning and in evaluation strategies means that we can perform more informed course-level assessments than in years past. Studies of human learning over the past several decades have resulted in considerable knowledge about how people learn (Bransford, Brown & Cocking, 1999), and this knowledge in turn has been used to develop strategies based on evidence for helping students learn more effectively—so-called evidence-based instructional strategies (Dancy & Henderson, 2010; Dancy, Henderson & Turpen, 2016; Henderson, Mestre & Slakey, 2015; Paschler et al., 2007; Dunlosky et al, 2013).

This section of the report provides a brief overview of the types of assessments that can be performed at the course level that not only go beyond traditional course-level instructor-constructed exams, but that also can provide insights into whether or not reforms instituted in STEM courses are more effective than traditional instructional approaches.

Beginning at the student level, course-level assessment can occur in (at least) three areas:

- Factual and procedural knowledge used in the discipline
- Conceptual knowledge and so-called “tacit” knowledge possessed by experts in the discipline but often not made explicit in teaching
- Professional skills such as group work skills, writing, and presentation skills

Most course-level testing focuses on the factual or procedural aspects of the discipline, and course instructors are quite adept at designing assessments to get at this type of knowledge.

Assessment of conceptual and tacit knowledge is more difficult to accomplish for two reasons: misconceptions possessed by students, and the “expert blind spot.” Instructors may not be aware of misconceptions possessed by students in the discipline, which are erroneous concepts formed by students that interfere with the teaching of scientific concepts. Much has been written about misconceptions in STEM disciplines (e.g., Brown et al., 2018; Docktor & Mestre, 2014; Herman, Zilles & Loui, 2012; Montfort et al., 2015; Streveler et al., 2013, 2014), and “conceptual inventories,” designed to identify student misconceptions, are now common in many STEM fields (Hestenes, Wells
& Swackhammer, 1992; Herman, Zilles & Loui, 2014; Jorion et al., 2015). The inventories are intended to guide instruction by helping instructors identify learning difficulties so that they can help students overcome them. If an instructor is knowledgeable about students’ learning difficulties, not only can they design instruction to help students learn the conceptual subtleties of the discipline, but also design assessment strategies to ascertain the degree of conceptual understanding possessed by students.

An example from physics can serve to clarify these points. The problem shown in Figure 3 is typical for an introductory mechanics course for scientists and engineers. The problem is moderately difficult for students and requires the application of Newton’s Second Law of motion to the hanging mass and to the pulley. These applications result in two equations in three variables, namely the angular acceleration of the pulley, the linear acceleration of the hanging mass, and the tension in the string. The third equation needed to solve for any of these variables is one relating the linear and angular acceleration. Despite the procedural difficulties in setting up and solving the problem in Figure 3, many students are able to accomplish it. However, in the follow-up conceptual question shown in Figure 4, students falter. Instead of relying on the procedural analysis they did in solving the problem, now they tend to rely on a knee-jerk, intuitive response and answer that the acceleration is the same if a hanging mass is attached to the string or if the string is pulled with a tension equal to the weight of the hanging mass. To physicists it is obvious that in the hanging mass case, the tension in the string must be less than the weight of the hanging mass since the mass drops and accelerates downward; if the tension in the string were the same as the weight of the hanging mass, the forces on the hanging block would balance out and the block would not move. Yet, that is the favorite answer provided by novice students since they believe both situations are the same. Thus combining conceptual with procedural problems enables instructors to probe a wider spectrum of understanding.

A massless string is wound around the outside of a solid disk with a radius of 0.2 m and moment of inertia 1 kg m². A mass, m = 2 kg, is attached the end of the string and released. What is the acceleration, a, of the hanging mass while the string unwinds?

a) 7.3 m/s²
b) 3.9 m/s²
c) 0.78 m/s²
d) 0.38 m/s²
e) 2.5 m/s²

Figure 3: Sample Physics Problem 1

Now we remove the hanging mass, m, and instead grab the string and pull it with a force equal to the weight of the hanging mass, mg. How does the new angular acceleration of the disk compare to before?

a. The new angular acceleration would be larger than before
b. The new angular acceleration would be smaller than before
c. The new angular acceleration would be the same as before

Figure 4: Sample Physics Problem 2
The expert blind spot refers to an expert in a domain “forgetting” how difficult it is for a novice to learn the domain initially, since they possess a deep understanding of the domain. The manifestation of this is that in teaching, they apply concepts and procedures efficiently and often neglect to make tacit knowledge visible for novice students, and think that their students will learn and adopt this knowledge readily. In fact, research on expertise indicates that it takes considerable time and effort to develop expertise. Our expert knowledge as domain experts has deep meaning for us, but novices find it difficult to attribute similar meaning, since they lack deep knowledge and perspective in the domain. Thus, it is important for instructors to become aware of the expert blind spot and to teach in ways that unpack expert knowledge for students in digestible bite-size units. Making tacit knowledge visible for students while teaching also helps novices gain insights. Pointing out and illustrating why by cuing on problems’ surface attributes (namely a problem’s objects and storyline) is not an effective way to approach problem solving in a discipline, since it is the underlying concepts and procedures that are useful in solving problems. One can also expand course-level assessment to include tacit knowledge, such as problem categorization tasks that measure whether students are cuing on problems’ surface attributes or the underlying concepts needed for solution as a means of adding measures of nuanced understanding.

Similarly, professional skills are often not tested in course assessments, but if the community deems those important then some assessments specifically designed to probe those skills would be warranted.

One can also evaluate courses in terms of the degree to which they use instructional strategies based on evidence of effectiveness. Recent reports and articles provide research evidence for particular strategies that are effective for helping students learn more effectively than with the traditional teach-by-telling lecture method. For example, frequent testing (see references by Roediger and collaborators) helps to build links in memory to knowledge so that it can be more easily accessed. Therefore, incorporating frequent quizzes or short tests in STEM courses is a good strategy for promoting long-term learning. Helping students become actively engaged in their learning also promotes better conceptual understanding (Hake, 1998, Freeman et al., 2014, Bransford et al., 1999). Low-cost classroom polling technologies (a.k.a. “clickers”) can be used both to frequently test students in a low-stakes manner while serving two other purposes: 1) engaging them collaboratively with their neighbors to discuss conceptual problems, and 2) providing instructors with information on those aspects of the course that students find difficult, thereby helping instructors become coaches of learning rather than dispensers of information.

### EVIDENCE-BASED INSTRUCTIONAL STRATEGIES

Jose P. Mestre, Prof. of Physics and Educational Psychology, University of Illinois

| A neglected issue in course assessment/evaluation is the impact of evidence-based instructional strategies (EBIPs) on learning in subsequent courses. Although EBIPs indicate more conceptual learning on the part of students in single courses, whether this transfers to subsequent courses, or whether a sustained multi-course EBIP approach would have a multiplier learning effect, remain to be explored. To study this would prove difficult since longitudinal studies are hard to plan and execute. What research has shown is that transfer of learning is difficult to achieve. Therefore a safe conjecture is that one-time EBIP-taught courses would impact deeper understanding in that course but have little influence on deeper understanding on subsequent courses if those are taught with non-EBIP pedagogies. Another way of framing this question is: **How much exposure to EBIP pedagogies is required before students assimilate the approaches and use them to learn on their own?** |

Report from the 2018 STEM 2026 Workshop on Assessment, Evaluation & Accreditation
Another instructional practice with substantial evidence of effectiveness is to provide “interleafed” practice rather than “massed” practice (Dunlosky, et al., 2013; Paschler, et al., 2007). In a STEM context, providing interleafed practice might mean giving weekly homework sets that always contain some exercises/problems from all the content that has been previously covered in the course. Traditionally, homework sets embody only massed practice in that they only contain problems/exercises from the previous week’s coverage of course material. Similarly, every exam in a STEM course (or program) could be cumulative and interleave problems from all previously covered material, thereby forcing students to study and synthesize all course material previously covered. Combining student-generated solutions with worked examples is yet another technique that has been shown to be an effective learning strategy (Sweller & Cooper, 1985; Ward & Sweller, 1990).

Thus, in addition to direct student-based assessments, courses can be evaluated in terms of the extent to which they employ evidence-based instructional practices of the type discussed above. Although reforming a course so that it employs one or more evidence based practices does not necessarily guarantee improved learning on the part of students, research evidence consistently signals that they do result in more learning on average than traditional methods (Mestre, et al., 2019), although there are still some important unanswered questions (see sidebar). There are two approaches to conducting this type of course-level evaluation:

- Through surveys, asking instructors to answer questions identifying the types of evidence-based instructional practices they employ, if any. Note that this approach also would not credit instructional approaches based on hunches. As an extreme example, a STEM instructor could swear by a method whereby they lecture slowly and loudly while students drink potent coffee, but short of reproducible research evidence of better learning on the part of students, this would not qualify as superior instruction.

- Through use of a classroom observation protocol, such as the Classroom Observation Protocol for Undergraduate STEM (COPUS) (Smith et al., 2013). Observation protocols such as COPUS tally what is happening in the class at regularly spaced time intervals and provide data such as the percentage of time that students are working collaboratively, listening to the instructor lecture, answering instructor questions, answering clicker questions, and moving through the classroom coaching students. COPUS and similar classroom observation protocols allow some baseline measure of the extent that student-active approaches are employed in teaching.

Course-level assessment and evaluation is closest both to the individual student and to the faculty member. As such, it provides important information both on how and how well students are learning, as well as insight to help faculty members understand how to improve their teaching practices. As an important element of accreditation (both institutional and programmatic), course-level assessment and evaluation practices need to be consistently and effectively applied by all faculty members. Many faculty members are very interested in improving their assessment methods as well as their ability to apply evidence-based practices, but need resources and support to do so. While a great deal of information is available through entities such as NILOA, NSF, and others, there are no centralized repositories to provide guidance for faculty. At the institutional level, administration and faculty leaders can provide resources and support, including funds for workshops and conferences. Centers for Teaching and Learning are another resource to help faculty build and refine their assessment knowledge. How else can we encourage all faculty members – not just those who are new to academia – to stay abreast of knowledge in this field and continually improve their assessment practices?
8. Cross-content Assessment

The idea of identifying, defining, and assessing knowledge and skills that are shared across STEM disciplines was a topic of keen interest at the workshop. Perhaps not surprisingly, this area attracted the most workshop participants and also turned out to be the most difficult to talk about. This began with participants’ struggles to find a term to describe this body of knowledge, with terms including non-content, cross-content, and transdisciplinary content used interchangeably throughout the workshop.

Workshop participants also had lively discussions about what specifically comprises this body of knowledge. Some competencies are foundational to STEM disciplines (“epistemological commonalities”) such as experimentation, classification, and analysis. Others are professional skills such as effective communication, teamwork, and ethical practices or tie into institutional common learning outcomes (e.g., valuing diversity or creative and critical thinking). Specific concepts often connect and can be integrated across multiple disciplines as well.

This conversation can be seen as part of a broader one happening throughout higher education. It is at least partially related to heightened scrutiny of accreditation and higher education, particularly vis-à-vis concerns about the cost of a degree relative to its value and complaints that graduates do not have the skills employers require. Examples abound, from the Association of American Colleges and Universities (AAC&U) VALUE Rubrics for 16 identified learning outcomes (https://www.aacu.org/value-rubrics), 21st Century Skills from New World of Work (developed under the Doing What Matters for Jobs and the Economy framework of the California Community Colleges system), and Learning for Life and Work from The National Academies Press. A science-focused example, while designed more broadly for all liberal arts students to achieve, is the Scientific Thinking and Integrative Reasoning Skills (STIRS) framework (https://www.aacu.org/stirs/framework) from the AAC&U.

At the STEM level, workshop participants agreed that employers demand cross-cutting skills, that these skills are necessary to successfully navigate the 21st century work world, and that they are the very skills that can contribute to innovation. However, there is no clear consensus of what these skills include, nor do we know to what extent each discipline recognizes or emphasizes these skills. However, these skills are currently listed on rubrics by accreditors, which suggests one route forward to develop an understanding of cross-cutting skills that should be included in STEM programs.

HLC provides an interesting example at the level of institutional accreditation with the release of the beta revision to the criteria for accreditation. Currently Criterion 1.C addresses diversity and the role of the higher education institution in a multicultural society. The beta revisions provide much more specific language such as “provides opportunities for civic engagement in a diverse, multicultural society and globally-connected world” instead of “understands the relationship between its mission and the diversity of society.” Overall, the beta revision of this criterion is much more specific, includes co-curricular activities as well as learning activities that prepare students “for informed citizenship and workplace success,” and addresses equity and inclusion as well as fostering a climate of respect for all members of the campus community.

At the level of specialized accreditation, ABET’s Criterion Four (Student Outcomes) addresses the student outcomes needed for graduates to “enter the professional practice of engineering.” Among these skills are learning, communication, ethical responsibility, and functioning on a team. “Iron Range Engineering & Twin Cities Engineering” describes the way this criterion is incorporated into a project-based-learning format.
Iron Range Engineering & Twin Cities Engineering
Rebecca Bates, Professor & Chair, and Ron Ulseth, Director of Academics, Iron Range Engineering,
Minnesota State University, Mankato

Iron Range Engineering (IRE) and its younger sibling Twin Cities Engineering (TCE) are upper-division, project-based learning programs designed to develop students who meet all of the graduation outcomes defined in ABET’s Criterion 3, but have a novel and proven learning experience. The institutional context is Minnesota State University, Mankato, a Midwestern, public, comprehensive university with about 15,000 students with roots as a Normal (teacher training) school that is currently celebrating its 150th anniversary. On campus, there are four traditional engineering programs that award a total of about 100 engineering degrees per year. IRE and TCE are located 280 and 70 miles from campus respectively. Both draw students from regional two-year colleges. IRE’s first graduates earned the Bachelor of Science in Engineering degree in December of 2012 and TCE’s were in December of 2014 and there have been over 150 graduates of the two programs.

IRE was conceived as a no-lecture learn-as-you-go project-based-learning (PBL) curriculum for the last two years of a four-year engineering degree. The programs are based on semester-long industry-sponsored projects using a PBL approach, with supplemental technical learning supported by “learning conversations” rather than lectures. The ideal is when technical learning is directly tied to projects. Self-directed learning by the students is a foundational characteristic of the program and student self-reflection on their metacognition is central to their growth. As such, students define their own learning goals and outcomes related to each project with guidance from faculty mentors, and propose how they will demonstrate their learning to faculty mentors. At the end of the semester, students submit their design report and provide a final oral design review to their clients and mentors. Exams on their technical learning are usually conducted orally throughout the semester and cumulative exams are in front of a panel of mentors from both industry and the faculty. Professional skill development is a focus of the program as well, with a dress code, a professional code of conduct relating to student and staff communication, and a learning environment that closely mimics a professional practice environment.

The IRE model was developed to address the need for change in engineering education by considering the entire education system and building around: 1) trans-disciplinary thinking, 2) industry-sponsored project-based-learning, 3) experiential learning in context, 4) competency-based assessments, and 5) significant exposure to professionalism, design, creativity, and innovation.

The IRE model addresses the “how” of student learning in engineering while allowing for deeper integration of the what, the technical content merged with professionalism and design skills needed for successful careers. Students combine learning of technical information with the execution of engineering design projects. Students divide their time every week between learning by doing the design and learning through methods that include self-learning, peer-learning, and learning from faculty and other external experts. Much of the learning is experiential and done in the context of the design. Students learn, practice, and receive feedback on professionalism, design, creativity, and innovation throughout the four-semester curriculum. TCE shows that the model is transferable to a different industry context and different funding model. Growing pains for both programs were addressed by creating a culture that represents the espoused values of the programs such as autonomy, self-directed learning, respect, student ownership, reflection, and community. The programs received the 2017 ABET Innovation Award.

www.ire.minnstate.edu and cset.mnsu.edu/ie
Not surprisingly, the lack of a common understanding or set of definitions around these types of cross- or trans-disciplinary knowledge and competencies resulted in recommendations that include more questions than clear cut directions:

**Develop a national cross-disciplinary conversation.** Individuals and organizations throughout the STEM education ecosystem have an opportunity to create a dialogue among and between disciplines to discuss the knowledge and competencies that are common among STEM graduates. Additionally, this is an opportunity to infuse the STEM perspective more explicitly within the broader conversations about educating students for the 21st century world of work. Many disciplinary professional societies have been engaging in this work at the level of their discipline and bringing these perspectives together to look for common ground as well as areas of divergence; this offers an excellent starting point for a larger conversation. What does it mean to think like a scientist? How is this different from or similar to thinking like a mathematician? Are there commonalities regarding identity development and belief systems across STEM? In addition to professional skills such as communication and teamwork, are there skills or mindsets that are unique to STEM or at least more critical to success than in non-STEM disciplines? How can these skills be woven into the curriculum and assessed?

**Explore opportunities for institutional collaboration.** These cross-cutting skills and knowledge are not only common across STEM disciplines but also potentially overlap with institutional-level learning outcomes. This opens up opportunities for robust conversations not only among and between specific STEM disciplines but also with institutional leadership and with non-STEM departments. How can this process embrace both top down and bottom up movement for adoption? How can it include all stakeholders in the process? Where are the connections with institutional common learning outcomes, and how do STEM disciplines identify and build the STEM-specific context separate from institutional and program outcomes?

Not only do faculty in individual STEM departments need to come together to identify and define the content and proficiencies that are desirable for their programs, they should also communicate with others within the institution to identify commonalities with non-STEM disciplines and institutional learning outcomes. Communication and collaboration among these parties could result in innovative, meaningful experiences for students such as grand challenges that address issues of concern in the local community.

**Support faculty development.** In spite of recognition among many faculty members that this type of content is critical to prepare students for further academic and career success, there are not clear roadmaps for how to actually integrate trans-disciplinary content into traditional courses for a more holistic approach. This is particularly true for faculty currently teaching, who are more likely to have completed their education without explicitly addressing cross-cutting content. For faculty with no recent experience outside of academia, how do we provide information and opportunities to explore cross-cutting skills in today's STEM workplace? What kind of professional development is needed for faculty? How do we help faculty effectively weave content together within a program to promote development of these skills? Also, we know that if skills are not used and reflected upon they will not solidify. How can we effectively incorporate opportunities for practice and reflection in labs, research experiences, internships, and other elements of the educational experience, including co- and extra-curricular experiences? How do we develop content that reflects and engages diverse students at the course level?
**Return to the student.** When we bring the student lens to the topic of cross-cutting content, we must consider how students benefit from learning and mastering these skills beyond the obvious advantage of facilitating their transition from education to work. Does attainment of these skills improve graduates’ ability to advance in their careers? Do they better prepare graduates to adapt to rapid changes in not only the workplace but in other areas of life? How do we determine where students are in relation to these skills when they enter a program and how do we provide students with flexibility in scaffolding further development of these skills? What assessments will help us understand gains in student learning? How do we transcript these gains (e.g., portfolios, badges, competency-based certificates)? How do we assist students in discussing these skills with future employers?

**Cross-content skills and knowledge: a starting point.** In the hopes of starting a broader conversation, we propose the following as part of the cross-cutting STEM knowledge, skills and dispositions:

1. Critical thinking, which, while not unique to science, may look different in STEM fields
2. “Scientific” thinking (and what that means)
3. Inclusive actions within STEM
4. Experimental design
5. Universal design and design thinking
6. Accessing information
7. Evaluating reliability of data
8. Communication, particularly of results and methods that generated the results
9. Analysis of the impact of STEM results on society
10. Teamwork within, across and beyond STEM fields

What other skills are important for STEM learners – both those who will pursue a degree and career in STEM and those whose only exposure to STEM in an academic setting may be through their general education requirements? Are any of these competencies important for a STEM-literate populace? How can we continue this conversation and ultimately begin to teach and assess cross-cutting STEM knowledge, skills and dispositions?

**9. STEM Education of the Future**

Assessment is how we know that STEM education is working; it provides the evidence to support hypotheses about how students learn and the high impact practices that improve student learning outcomes. As scientists, we shouldn’t use any other sort of process. This workshop highlighted several areas where applying the scientific method to assessment of student learning can help move STEM education forward and contribute to the body of knowledge regarding STEM teaching and learning: improving program assessment at community colleges, building/strengthening feedback loops between two- and four-year institutions, using assessment practices to improve equity and inclusion, and expanding workforce development to meet needs of a technology-based economy.

Accreditation ensures the quality and consistency of higher education while also encouraging continuous improvement. Within the tension created between the two, the STEM education ecosystem needs to find ways to innovate that will benefit students first and foremost, and through those thriving students will come benefits to STEM disciplines, their bodies of knowledge, the workforce, and the nation.

As we seek to build and assess the STEM education of the future, we must remember that, much as we discovered at this workshop, there are myriad ways that we can learn from each other. These include...
across disciplines, institutional types, and among faculty, administrators and the students themselves. We must also remember to remain connected to, and to learn from, other disciplines in the liberal arts.

This report has identified some of the barriers to innovation that individuals and institutions often face. Often these have to do with institutional culture and policies, and also with higher education policy. Bedrock tenets such as the tenure system and academic freedom can create barriers when individuals who are leery of change use them as the reason for not trying something new. Junior faculty may feel they can’t meet job expectations for tenure and be innovative. Senior faculty may feel burned out. Beware the phrase “we’ve always done it this way” and seek out those who are equally interested in framing educational innovation on students and their success.

For any of this report’s recommendations to work, there will need to be resources dedicated to the efforts. This includes people, time, and money but also support to evaluate and disseminate activities that are currently underway. In particular, we need funding that can allow longitudinal studies that allow us to understand things like the benefit of multiple classes that use evidence-based educational practices, how assessment impact equity and inclusion, or the long-term post-graduate experiences of students who participate in innovative educational processes.

10. Coda: Wicked Challenges

This workshop highlighted a number of complex, intriguing topics that generated significant interest and excitement among participants. We have identified these as “wicked” challenges – not quite on the level of grand challenges, they are more every day in the sense that they are integral to our day-to-day work in higher education. These challenges also share some characteristics with wicked problems, which can’t be classified as right or wrong, are understood only in retrospect, have no defined end point, and are unique. They are challenges that cannot be solved individually, nor even within a single institution or group of institutions. Wicked challenges require the entire STEM education ecosystem to be involved in considering solutions. At the same time, they are “wicked” in the colloquial sense of the word – amazing or excellent – in that they encourage us all to engage fully in innovative, collaborative work with the potential of significant impact on students. Both the challenges and the potential results are rewarding and bring out the best in us.

Wicked challenges also represent entangled tensions that both push and pull at our understanding of, need for, and ability to implement assessment that truly benefits the student. At all levels of the ecosystem, and in both assessment and accreditation arenas, we call for a greater focus on grounding discussions on the lens of the student first. Without creating an environment that supports students and helps them thrive, we will not realize the benefits of a well-educated workforce or an informed citizenry.

This report is a summary of one workshop held in the upper Midwest in late 2018. It sets the scene by describing where the conversation is currently focused, but we have designed it to act as a beginning as well. We have raised questions that need to be explored further, and by a much broader audience. We call for readers in all niches of the ecosystem to consider the wicked challenges, to explore answers to questions, and to take the conversation further. Where can we bring wicked challenges next? What existing work is already addressing these issues in whole or in part? How can and should we connect to other working models in education included in curriculum, instructional, and learning theories? How can policy makers and funders act as conveners and catalysts to this work?
As an example, the next step for this working group is another convening of interested participants to perhaps look at some of the cross-content issues that were the focus of a great deal of energy and discussion at the workshop. In particular, the group could spend some time thinking about what "scientific thinking" is and what might set apart critical thinking from a STEM perspective to move towards assessments in those areas. Readers are encouraged to find the most interesting question, perhaps one raised here, and explore that in both your local context and the broader STEM ecosystem.
11. References


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## Appendix B: Workshop Agenda

**Thursday, November 1, 2018**  
**Hilton Minneapolis/Bloomington**  
**3900 American Blvd West, Bloomington, MN 55437, Jefferson Room**

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>4:30 - 5:30</td>
<td>Registration Available</td>
</tr>
<tr>
<td>5:00 - 5:30</td>
<td>Networking &amp; Appetizers</td>
</tr>
<tr>
<td>5:30</td>
<td>Dinner Seated, tables mostly by discipline groups</td>
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<tr>
<td></td>
<td>Introduction to the workshop by Becky Bates</td>
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<tr>
<td></td>
<td>Please introduce yourselves to the members of your table!</td>
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<tr>
<td></td>
<td><strong>Initial questions:</strong></td>
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<tr>
<td></td>
<td><em>What does assessment mean in your discipline?</em></td>
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<tr>
<td></td>
<td><em>What are the challenges?</em></td>
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<td></td>
<td><em>What are people thinking in that area?</em></td>
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<tr>
<td></td>
<td><em>What does innovation mean in your field?</em></td>
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<tr>
<td>After entree &amp; coffee</td>
<td>Keynote Address by Dr. Gianina Baker</td>
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<tr>
<td>After keynote</td>
<td>Discuss ground rules of conversation for the workshop.</td>
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<tr>
<td></td>
<td>Split into discipline groups (5 groups) for discussion. Begin applying ground rules.</td>
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<tr>
<td></td>
<td><em>Continue with the initial questions.</em></td>
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<td></td>
<td><em>What artifacts did you bring?</em></td>
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<tr>
<td></td>
<td><em>How do these illustrate your values?</em></td>
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<tr>
<td>7:30pm</td>
<td>Adjourn for the evening.</td>
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</table>

**Friday, November 2, 2018**  
**Normandale Community College, Partnership Center, Room P0808**

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
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<tbody>
<tr>
<td>7:30 - 7:45 am</td>
<td>Depart from hotel via carpool or hotel shuttle</td>
</tr>
<tr>
<td>8:00 - 8:30</td>
<td>Continental breakfast, juice &amp; coffee available</td>
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<tr>
<td></td>
<td>Sit with disciplinary groups</td>
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<tr>
<td>8:30 - 10:00</td>
<td>Presentation &amp; discussion of case studies</td>
</tr>
<tr>
<td></td>
<td>University of Bath</td>
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<td></td>
<td>WPI Robotics Engineering</td>
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<tr>
<td>10:15 - 11:45</td>
<td>Presentation &amp; discussion of case studies</td>
</tr>
<tr>
<td></td>
<td>Iron Range Engineering &amp; Twin Cities Engineering</td>
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<tr>
<td></td>
<td>Introductory Biology Course Overhaul</td>
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<tr>
<td>11:45 - 12:00</td>
<td>Find affinity groups: types or levels of assessment/evaluation/accreditation</td>
</tr>
<tr>
<td>12:00 - 1:00</td>
<td>Working lunch in affinity groups. Prep for Rule of Mobility</td>
</tr>
</tbody>
</table>
1:00 - 1:30  | Brain break: Check out the Japanese Garden or the library or a comfy chair facing a window.

1:30 - 3:15  | In affinity groups: Generate recommendations, name concerns, call for action, etc. One recorder per group or select a new recorder

3:30 - 4:30  | Report out recommendations and large group discussion

4:30 - 5:00  | Return to disciplinary groups and reflect on missing issues or augmentation of recommendations.

Post 5pm  | Dinner on your own.
Reflection work:
Generally reflect on the work of the day. What is good? What could be framed differently? What will be effective in your field? Also reflect on whether we are missing any groups, stakeholders, types of programs, or perspectives that should be named in the morning.

| Saturday, November 3, 2018  
Normandale Community College, Partnership Center, Room P0808 |

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
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<tbody>
<tr>
<td>7:30 - 7:45 am</td>
<td>Depart from hotel via carpool or hotel shuttle</td>
</tr>
</tbody>
</table>
| 8:00 - 8:30  | Continental breakfast, juice & coffee available  
Sit with affinity groups |
| 8:30 - 10:15 | Writing work in small groups (start with affinity groups, move as needed) |
| 10:30 - 11:45 | Finish writing and report out. Synthesis of ideas should be finalized here. |
| 12:00 - 12:30 | Boxed lunches provided to take away or eat on site. Finalize any group messages. Any final logistics announced.  
*Workshop fully adjourns at 12:30.*  
*Thank you!* |