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Creating an Ecosystem that Fosters Innovation and Entrepreneurial Mindset at an Undergraduate Institution through Pathways to Innovation

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ABSTRACT

This paper describes one university's journey through the Pathways to Innovation program. Efforts described herein are based on the premise that an undergraduate experience that effectively fosters innovation and entrepreneurial mindset among engineering students requires the support of an ecosystem of curricular and co-curricular programs. The paper provides critical reflection of the strategic decisions leading toward the development of co-curricular events to support students' development of curiosity, ability to make connections, and practice in creating value—the three key tenets of entrepreneurial mindset. The Pathways to Innovation Program was an NSF-funded program administered jointly by Stanford University's Epicenter and VentureWell meant to foster entrepreneurial learning into engineering undergraduate programs nationally. The approach and the examples presented in the paper are intended to help others imagine the kinds of approaches that may work at their institutions to effectively engage students and develop innovation and entrepreneurial mindset among students.

Key words: innovation, co-curricular, undergraduate

INTRODUCTION

Engineering students need to learn more than technical abilities if they are to be successful at tackling the current and future pressing global challenges. Graduates need to be able to identify emerging problems, challenge assumptions, collaborate readily, and communicate openly. They must



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be able to frame opportunities, develop and assess ideas, and create meaningful solutions, as well as be entrepreneurial changemakers ready to lead within diverse work environments.

Training engineering students to tackle today's global challenges requires learning beyond technical skills. Problem identification, interdisciplinary collaboration, open communication, and the ability to challenge commonly held assumptions are essential skills that must be developed. Successful changemakers must apply entrepreneurial practices to understand and frame opportunities, develop and assess ideas, and create valued solutions in order to be prepared to lead within diverse professional environments. An undergraduate experience that effectively supports students' development in this way requires the support of an ecosystem including, but not limited to, curricular and co-curricular programs and appropriately designed support spaces.

This paper focuses on the elements that were designed through activities corresponding directly with this Pathways to Innovation team's Pathways participation, namely the co-curricular programs. Elements of the entire ecosystem, however, namely courses, co-curricular programs, and space renovations were simultaneously designed to foster entrepreneurial mindset instead of relying on a piecemeal approach and include:

- new courses (e.g., Innovation and Realization),
- co-curricular activities (e.g., an annual student project showcase), and
- space renovations (e.g., fabrication lab, maker space, and learning spaces).

Two years following acceptance into the second cohort of the Pathways to Innovation program, this University joined the Kern Entrepreneurial Engineering Network, or more commonly, KEEN. Efforts described herein became the basis for further efforts to further enhance our ecosystem such that it may foster entrepreneurial mindset amongst our students—a primary goal of KEEN members. Herein, use of the phrase entrepreneurial mindset is based on the KEEN definition of supporting students' development of curiosity, ability to make connections, and providing practice in creating value.

This case study provides critical details on the academic program's background, the co-curricular events developed, assessment efforts, and this team's concluding thoughts on the process.

BACKGROUND

James Madison University is a public regional university located in Harrisonburg, Virginia with a total enrollment, at the time of entry into the Pathways second cohort, at approximately 21,000 students across seven colleges with 1,500 students enrolled in graduate programs. The Department of Engineering, Madison Engineering, was founded in 2005 with the first cohort of students starting in fall of 2008.



Madison Engineering is an undergraduate program that was envisioned to be an interdisciplinary progressive engineering program unrestricted by the boundaries of traditional engineering disciplines. Under the Engineering Accreditation Commission, the ABET accredited four-year Bachelor of Science program was created for 21st Century engineering needs. The curriculum of the program includes the foundational knowledge cores of math, science, engineering science, engineering management, and engineering design with project-based and experiential approaches that serve to infuse project delivery skills in design, communication, teamwork, and project management. Additionally, the program includes many opportunities to develop decision-making skills for complex realities like engineering ethics, sustainability, and innovation. Studying practitioners of engineering within the program can challenge students' abilities to not only solve problems but to find and frame opportunities. Students are pushed to focus on identifying opportunities and crafting solutions that manifest a better quality of life and create lasting value for all stakeholders. The program has a current enrollment of approximately 450 students as of August 2019 where most students complete the degree in four years.

Students in the Madison Engineering program are encouraged to use the two-year capstone design sequence to focus their Bachelor of Science in Engineering degree (Pierrakos et al. 2013). Prior to capstone, students complete four semesters of engineering design work completing two curricular projects during the first two semesters of their first year followed by a two semester long, team-based design project for a local client during their sophomore year (Pierrakos et al. 2014, Nagel et al. 2012). These first two years contain the basic engineering design instruction foundational to success in capstone (Nagel et al. 2013). Two-year capstone projects in the Madison Engineering program have historically been primarily faculty proposed projects arising from faculty scholarship and connections.

Madison Engineering engages in deploying learning approaches that integrate content knowledge within a problem-based learning framework based on a philosophy of learning by doing (Pierrakos et al. 2012, Pierrakos et al. 2008, Pappas and Prins 2010, Nagel et al. 2011, Nagel, Pappas, and Pierrakos 2012). Evidence-based methodologies have been found to aid in the development and engagement of students and have been employed as part of the arsenal of Madison Engineering (Freeman et al. 2014). The evidence-based methodologies range from strategies, programs and interventions that address challenges (e.g., low levels of incoming declared STEM majors, low retention and/or graduation rates, under-represented minority student persistence and graduation gaps, low levels of student engagement in or understanding of the scientific process, low sense of community or belonging among students) that are commonly encountered on college/universities campuses (Elrod and Kezar 2016). Coupling evidence-based methodologies with various size projects that present realistic, thought-provoking problems have led to the development of high-impact educational



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experiences, where if learning is to transpire, the learner should undergo a transformation in some way that is lasting and is significant in terms of the life of the learner (David 2008, Kuh 2008, Fink 2013). This cultural background that forms the backbone of Madison Engineering founded this team's thinking through the Pathways program and guided the development process of all elements of the Madison Engineering entrepreneurial mindset ecosystem.

METHODOLOGY

In 2015, Madison Engineering joined the NSF-funded Pathways to Innovation Program administered jointly by Stanford University's Epicenter and VentureWell. The goal of Pathways is to help "faculty transform the experience of their undergraduate engineering students by fully incorporating innovation and entrepreneurship into a range of courses as well as strengthening co- and extra-curricular offerings" (2016b).

At the onset of Madison Engineering's entry into the Pathways program, the team anticipated developing a minor based around entrepreneurship, leadership, and innovation. Initially, this minor was intended to include traditionally considered elements of entrepreneurship (i.e., venture creation) coupled with traditional elements of strategic leadership. But before even engaging with Pathways, the team discovered that such a minor would require significant compromises limiting its ability to positively impact **all** Madison Engineering majors. In practice, though, the Pathways program provided flexibility to define innovation and entrepreneurship as appropriate for each constituent member; consequently, the team focused on engaging students as active agents in their own educational journey where the students were empowered as entrepreneurs creating value for themselves and their peers through opportunities afforded by Madison Engineering. And through our time in the Pathway's program, this definition evolved to parallel the KEEN definition of entrepreneurial mindset—supporting students' development of curiosity, ability to make connections, and providing practice in creating value.

Through the Pathway's prescribed Strategic Doing process, the team was urged to identify a *big easy*, or an early opportunity for success. The team identified the Madison Engineering xChange as a current departmental event ripe for reimagining, and began a three-month sprint to re-launching and re-branding the existing capstone showcase to include all Madison Engineering students. In previous years, the event, originally titled *The Engineering Capstone Symposium*, took place on a weekday afternoon and was comprised of only an academically-inspired poster fair for junior and senior capstone projects with the only invitees being junior and senior students, faculty, staff, parents, and corporate partners.

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Now, the **Madison Engineering xChange** is an annual daylong celebration, held on the weekend in late April, to showcase **all** design projects produced through affiliation with the Madison Engineering program. Senior capstone teams display final capstone project results and prototypes and junior teams present capstone project progress and early stage prototypes. First-year and sophomore design projects, honors projects, and high-school dual enrollment projects are also displayed and celebrated. Junior and senior students present entrepreneurial style pitches and display project results alongside first-year and sophomore students in a trade show display format.

The xChange event was intentionally designed to introduce first-year and sophomore students to the program's expectations, practices, and culture while providing an opportunity for them to share their major project work with others. For junior and senior students, the xChange represents an opportunity to share their four-semester long engineering projects with peers, industry, alumni, and the public. In addition to this culture of sharing, the Pathways team desired to encourage first year and sophomore students to begin thinking about their own two-year capstone projects with the goal of encouraging students to identify their own projects with their own external partners related to their own interests; in other words, the team desired to change the culture such that students recognized the community as one where engagement was valued, curiosity was fostered, and innovation applauded. Specifically, the goal for first-year and sophomore students was for students to seek their own paths to create value; for juniors and senior students, the goal was ownership of ones' contributions. For all students, the goal was belonging through engagement.

In addition to the Madison Engineering xChange, the Madison Engineering Pathways team developed two extra-curricular events intended to enhance the existing learning culture: the Madison Engineering Launch and the Scholars' Café. These events represent our efforts to instill an entrepreneurial mindset throughout the program that empowers students to take ownership of their education in order to make positive contributions using their engineering knowledge.

The **Madison Engineering Launch** event is an active welcome for all incoming first-year students. It is a re-imagining of two hours within the university required first-year orientation session that is traditionally reserved for academic departments to discuss degree progression requirements. At the event, incoming students interact with the Madison Engineering Leaders (a cohort of upper level students in an optional engineering leadership program), faculty, and staff. The Launch provides students with an initial exposure to the Madison Engineering culture through the use of games and discussions designed to illustrate the concepts of community, contribution, and culture. The Launch event ends with a challenge: *Identify a pain in the community as you orient to Harrisonburg, and bring a photograph of that pain to your first day of Engineering 101: Engineering Opportunities.* Through the coupling of the Launch with Engineering 101, the goal is to create a venue for students to practice curiosity and connection making while beginning to recognize their potential to identify



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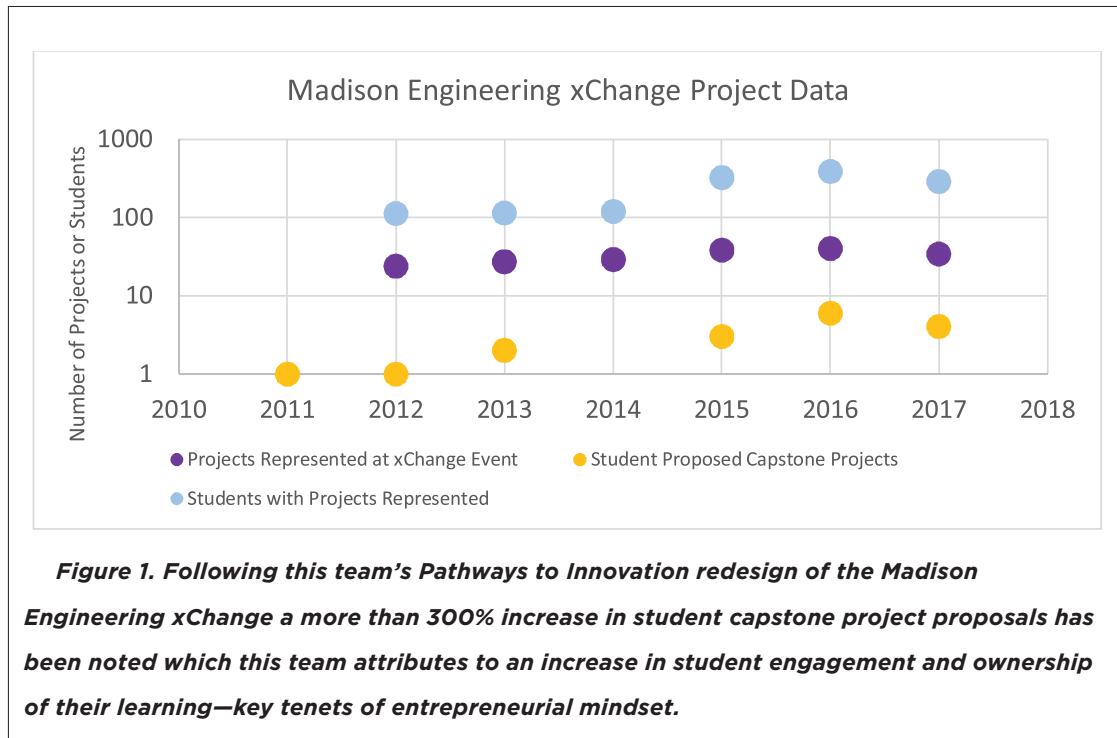
opportunities and make change; a key facet of being entrepreneurially minded. In class discussion facilitated by student leaders and course instructors during Engineering 101 helps students to recognize the links between engineering, entrepreneurship, opportunity identification, and change making.

The Madison Engineering **Scholars' Café**, held in mid-Fall, is a venue for Madison Engineering students to share and learn about the “scholarly” endeavors undertaken by their peers. Here scholarship may include scholarly, publishable research, but also, scholarship may include engagement in research for venture creation, community service, self-directed learning, design, et cetera. The Scholars' Café uses the World Café model (2017b) allowing all of the students attending to hear from their peers about their research experiences and to learn more about the projects being presented. Similar to the Launch and the xChange, students are challenged to identify an area of interest, dig deeper, gain an understanding, and work toward finding opportunities. Through the Scholars' Café students are exposed to stories of their peers taking ownership of their learning and utilizing the resources of James Madison University to create value for themselves and for a community. Existing opportunities are presented for the students to explore, but also, students are encouraged to use these stories from their peers as motivation for their own exploration.

Through these events, our objective is to foster: an **Identity of Innovation** whereby students, faculty, and staff demonstrate curiosity in the world around them by identifying issues and meaningful ideas; **Ownership of Contribution** whereby students, faculty, and staff feel empowered to develop useful solutions and disseminate them to create meaningful value; and **Belonging through Engagement** where students, faculty, and staff develop connections, share, and collaborate to further develop and refine relationships and solutions to important engineering opportunities.

ASSESSMENT

Assessment focused on data that would improve the student experiences. In focusing on the experiences, there are differences between: (a) assessment, (b) focusing on desired outcomes of the assessee (where the standards for quality are developed by the assessee in collaboration with the assessor), and evaluation, and (c) focusing on the desired outcomes of the evaluator where the standards for quality have been developed by the evaluator (Jensen 2007). There also existed a desire to create forms of assessment where students were prompted to perform tasks that allowed them to engage with problems and questions that could potentially lead to the individual growth of the students and lead the evaluators to a better understanding of the value of the experience. These initial assessments described below were a rudimentary beginning and allowed the team to gain quick event feedback that could be used for iteration of future events.



For the xChange, the initial evaluation efforts focused on measures of student interest and student engagement. The team collected the total number of projects represented at the xChange and by association, the approximate number of students as well as the number of student-proposed projects following participation in the xChange (Fig. 1). The number of student proposed projects served as a proxy for student engagement as attendance at the xChange is not a graded element of any courses in the Madison Engineering curriculum. We noted an approximately three-fold increase in student proposed projects over the time period. Enrollment remained relatively stable during the time period.

With respect to the Scholars' Café, student participation nearly doubled in the second year rising from 27 students during the 2015-16 academic year to 44 during the 2016-17 academic year. This interest prompted the development of a companion Graduate Café in the Spring 2017 semester, which also had strong interest with 29 students attending. Unfortunately, student follow through on engagement in scholarly activities post attendance in the Scholars' Café has proven much more difficult to track than student proposed and run capstone projects.

For the Madison Engineering First-year Launch, we "hacked" the system inviting students through email and social media to an "extra" orientation activity on the Saturday morning before the start of the 2015-16 academic year. We did not have students RSVP nor did we collect attendance records of the students, but we did document the event heavily through the departmental social media feeds.

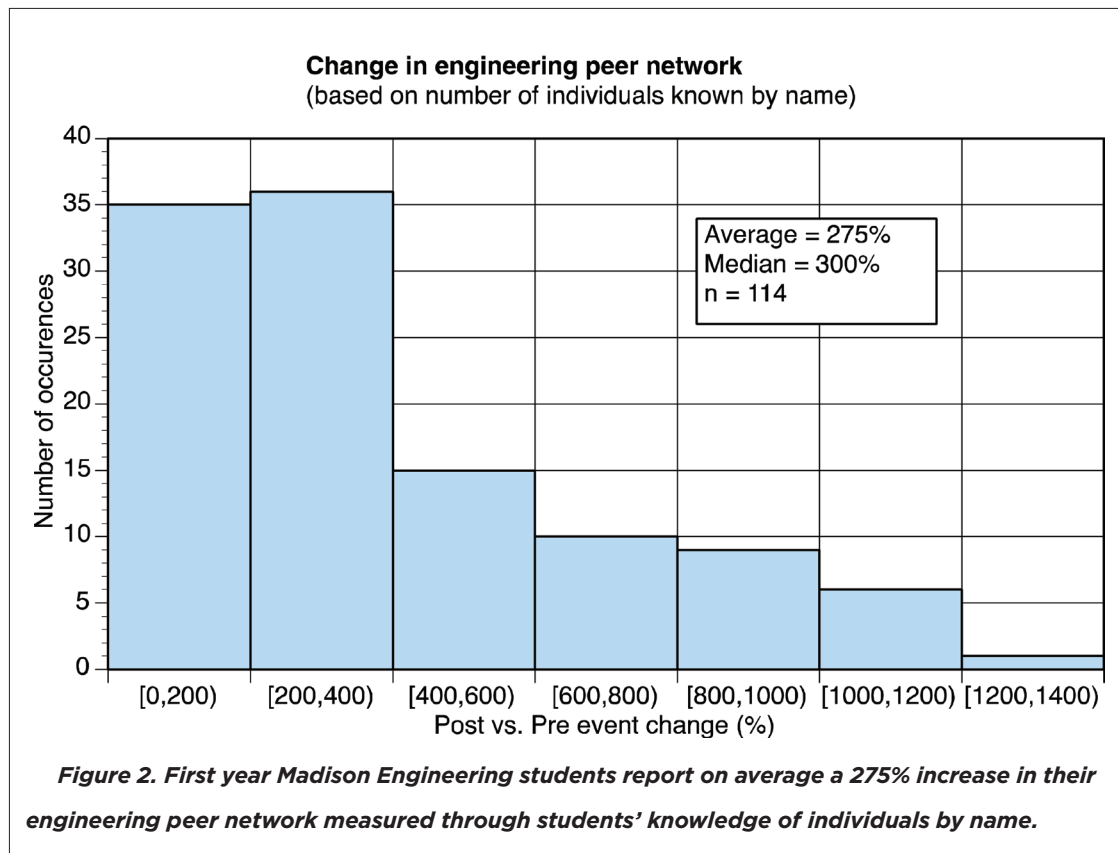


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Based on people counts in the pictures, attendance is estimated at 160 first year students in the 2015-16 academic year and 120 first year students in the 2016-17 academic year. This high-level of turnout indicates a real “itch” for these students to be a member of the engineering community, and our efforts were further recognized by the university president in follow-up conversations related to the engagement of JMU students.

In addition to attendance data from the Launch, we had interest in knowing how deep of a community was being developed among our students. To understand this, we asked students to record the number of students that they knew by name at the start of the launch, at the conclusion of the launch, and after the first week of classes creating an understanding in the change in each engineering students peer network through engagement in Madison Engineering first year activities (Fig. 2). Figure 2 presents this data as a histogram grouping together the occurrences of participants self-reported percent changes in 200% increments.

Future evaluation and assessment efforts are planned to focus on student mindset and a sense of belonging. Some measures exist (Fry and Pistrui 2011, Kleine and Yoder 2011, Dweck 2007) that





explore the mindsets of students along a fixed and growth mindset spectrum as well as an entrepreneurial mindset. The sense of belonging will be evaluated by assessing the attitudes of the students as it relates to the Madison Engineering Department as a community with an interest in the relationships among people in the Madison Engineering community. Further instruments are planned to be constructed that allow the students to apply their knowledge in a real or analogous situations to express capabilities through doing.

DISCUSSION & CONCLUSION

Considering options for a “big easy” in the Strategic Doing process led this team toward making changes to the xChange event held yearly, and start the process of creating a suite of co-curricular programs. The design and implementation of these kinds of programs will vary from institution to institution because of their unique context. For Madison Engineering, the co-curricular programs now are an essential element in our entrepreneurial mindset ecosystem. Perhaps through serendipity, but designed and purposefully executed nonetheless, the program simultaneously began to consider the design of new engineering spaces in a consolidated footprint of an inherited building on the James Madison University campus. This new space and the co-curricular elements discussed herein of our ecosystem will support an existing, but relatively new and nimble, engineering program with an emphasis on sustainability, problem seeking, and problem solving. These have also joined by a suite of engineering technical electives for students interested in diving deeper into topics such as innovation, design thinking, prototype development and deployment, venture creation, and social entrepreneurship.

The Pathways to Innovation model applies an entrepreneurial model à la Lean Startup (Blank 2013, Ries 2011) toward higher education prompting universities to seek problems, prototype often and quickly, gain frequent feedback, iterate, and deliver. A drawback, however, is difficulty in establishing a strong well-validated assessment program, and instead, the on-the-fly changes were documented, numbers of participants were maintained, and written and verbal feedback was continuously solicited—both formally and informally. For us, this was an unavoidable weakness in the overall Pathway’s approach, as time was a limiting factor; the team was adding the development, deployment, and management of these co-curricular programs to the team members’ existing schedules. And the pace was frenetic; all three events were conceived and operationalized over seven months. The process and timing required that decisions be made on limited information and feedback to the best of team’s abilities at the time, and formal assessment, while encouraged, nearly always was discounted to more pressing managerial challenges. This approach worked well for the James



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Madison University engineering department and team as it fit well in our already nimble start-up mentality of trying to develop and accredit a new engineering program.

Over the course of two years, however, this team has begun to understand where more data is required and what data is required, and this team has begun to tap into the strong assessment culture at James Madison University toward the development of a new assessment measure that can be used to assess students' entrepreneurial mindset. Assessment is now focusing on entrepreneurial mindset of students across the curriculum, and while some measures exist, a new measure that focuses on the KEEN definition of entrepreneurial mindset (2016a) is being developed through partnership with JMU's Center for Assessment & Research Studies. Initial use is planned for early September 2017; however, this assessment is occurring outside of the team's Pathways involvement and is consequently, beyond the scope of this case study.

Toward transferability of our efforts, the solutions provided herein are intended to help inspire readers on the kind of programs that might work at different universities and institutions. Four key elements have allowed this team to develop this program centered around entrepreneurial mindset at James Madison University from the seeds available. First, is the establishment of a high-functioning team (e.g., Four Sight (2017a) can help with team formation or understanding team thinking preferences) where team members play on each other strengths and coax one's top performance from each member. Embrace a growth mindset with each other, with one self, and with the team. Apply a strategic process; for this team, the Strategic Doing process was particularly effective; for others, though, a different process may work better. Either way, a documented strategic process keeps the team focused on an end goal, working toward delivery. Finally, mind your business. In other words, what does the organization value? At James Madison University, the culture values entrepreneurial thinking, engagement, and undergraduate learning. Because of these cultural values, the Pathways to Innovation program was a great fit for this team at James Madison University.

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Keith Holland is an Associate Professor in the Department of Engineering and currently serves as the interim Vice Provost for Research and Scholarship at James Madison University (JMU). As an educator, he strives to involve students and faculty in interdisciplinary project collaborations to develop innovative solutions for the classroom, industry, and the world. He has been involved with the development and support of ecosystems which foster entrepreneurial mindset and action, industry partnerships, and international engagement. His areas of scholarly inquiry and application include educational innovations, solar energy materials, wind energy systems, and electronic device design.



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Justin Henriques is an Associate Professor in the Department of Engineering at James Madison University. He holds a Ph.D. and M.S. in systems engineering, a Masters in urban and environmental planning, a B.S. in applied science, and a B.A. in philosophy. His areas of research focus include infrastructure systems, humanitarian technology, and climate change vulnerability assessments. He teaches courses that incorporate social entrepreneurship and design for social impact. He is currently an Entrepreneurship Faculty Fellow at James Madison University.



Kurt Paterson crafts learning experiences, spaces, and communities to help students of all kinds imagine, design, and build solutions that matter. An award-winning teacher, scholar, mentor, and servant leader, Kurt currently serves as Head of Engineering at James Madison University. This program, one of the nation's newest, reinvents engineering education through a design-focused, project-based curriculum that engages students through collaborations with industry and society across all eight semesters. His scholarly interests include the creation of effective learning ecosystems, relationship-driven learning, and engineering leadership. He has served as chair of ASEE's International Division, founding chair of ASEE's Community Engagement Division, and committee member for creating ASEE's Chairs Conclave. A first-generation college student, Kurt earned his Ph.D. in Civil and Environmental Engineering from the University of Iowa.