Engineering Education Funded Research Portfolio

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- Gatekeepers to Broadening Participation in Engineering: Investigating Variation across High Schools Comparing Who Could Go Versus Who Does Go into Engineering
- Community-Engaged Engineering Interventions with Appalachian Youth
- Engineering Pathways for Appalachian Youth: Design Principles and Long-term Impacts of School-Industry Partnerships
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- The Use of Mobile Technology & Innovative Pedagogy to Improve Undergraduate Thermal-Fluid Science Learning
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- Supporting Agency Among Early Career Engineering Education Faculty in Diverse Institutional Contexts
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Gatekeepers to Broadening Participation in Engineering: Investigating variation across high schools comparing who could go versus who does go into engineering

K-12 Context

Engineering is one of the fastest-growing sectors of the U.S. economy. However, there is a shortage of diverse engineers and scientists in this sector. This research investigation is designed to equip engineering education researchers and other important stakeholders with the knowledge and understanding of how school stakeholders can be better positioned and/or trained to support a more diverse population of students who choose to enroll in postsecondary engineering programs. By focusing on the high school level, the investigators will pinpoint how educational inequalities (as they relate to access to school resources and the role and preparedness of high school counselors and teachers in helping students choose engineering programs) will contribute to academically capable students' decisions to major or not major in engineering, especially among underrepresented student populations. This research project is both timely and potentially impactful in helping the broader engineering community identify the structural barriers that students often experience in different high schools across the state of Virginia and how these barriers may influence underrepresented students' decisions to major or not major in engineering, even when they possess the academic profile to do so. The project also has immense potential to render important findings applicable to key engineering and non-engineering stakeholders in Virginia and beyond.

Using a mixed-method research design, data collections were organized into various phases: examining quantitative data from the Virginia Longitudinal Data System (VLDS) to explore high school and college enrollment student records for every Virginia high school student; conducting in-depth qualitative interviews of key school stakeholders (e.g., teachers, school counselors, etc.) at select high schools; collecting student survey data at the same select high schools to determine alignment between what interviewees say are influences versus what students say drive them toward or away from engineering; and collecting survey data from key stakeholders to complement the qualitative interview data. By collecting both quantitative and qualitative data, the research investigation will provide important answers to major broadening participation in engineering questions. Through workshops, policy briefs, K-12 academic conferences, and connections with specific schools selected as case studies, the investigators outlined a strong plan to share findings with K-12 practitioners and policymakers.

Award Amount
$525,896

Project Dates
7/2017 – 12/2021

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Community-Engaged Engineering Interventions with Appalachian Youth

K-12 Context

This project will advance efforts of the innovative Technology Experiences for Students and Teachers (ITEST) program to better understand and promote practices that increase students' motivations and capacities to pursue careers in fields of science, technology, engineering, or mathematics (STEM) by producing empirical findings and/or research tools that contribute to knowledge about which models and interventions with K-12 students and teachers are most likely to increase capacity in the STEM and STEM-cognate intensive workforce of the future. This project is focused on a collaborative design, implementation, and study of recurrent engineering-focused interventions with middle school youth in three rural and Appalachian communities. The intervention efforts will broaden middle schoolers' participation and understanding of what engineering is, what engineers do, and help dispel the notion that it is hard and requires a love of mathematics and science. The project has the potential for recruiting future engineers who are unaware of their abilities and career possibilities because of the rural Appalachian communities in which they live. Broadening participation in engineering remains a critical national priority and this project has the potential to prevent the loss of smart capable students from engineering education and career pathways. The proposed partnership with school educators and industry experts will established an open-source engineering outreach curriculum (iFixit) and facilitate regular in-class interventions throughout the academic year.

The study design enables the examination of the participants and interventions across time and case-site contexts, where the data are collected at individual-level to look for changes over time while within-case and cross-case examination of the community-level impacts will be analyzed. The objective will be to achieve meaningful results of the two goals: Goal 1- to increase youth awareness of, interest in, and readiness for diverse engineering related careers and educational pathways which is a goal that hinges on a collaboratively designed and facilitated set of monthly interventions in a curricular setting and Goal 2- to build capacity for schools to sustainably integrate engineering skills and knowledge of diverse engineering-related careers and educational pathways aimed at both the individual-level with a focus on teachers as influential change makers as well as at the community-level focused on sustainable cross-sector collaborations. The project will offer in-school curriculum activities (interventions) six times per academic year in three similar rural communities in Virginia: 1) Bedford County Public Schools 2) Giles County Public Schools, and 3) Smyth County Public Schools. All case sites are located in rural areas or near Appalachia where there is limited industry, particularly advanced industry exposes students, parents, and educators to engineering careers. Leveraging local expertise is especially critical in this project because family pressures, cultural milieu, and preference for local, stable jobs play considerable roles in how Appalachian youth choose possible careers.

Award Amount
$1,288,622

Project Dates
6/2017 – 5/2022

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Engineering Pathways for Appalachian Youth: Design Principles and Long-term Impacts of School-Industry Partnerships

K12 Context

Engineering-related industries can be vital to rural communities, yet many youth in these communities do not commonly have educational experiences that introduce them to locally relevant engineering career pathways. In this project, engineers from local manufacturing companies will partner with educators to co-design learning innovations spanning in-school and out-of-school settings for over 2,500 high school youth from Appalachian counties. As part of these learning innovations, industry partners will introduce youth to the many applications of engineering that are present in their communities. Across a range of formal and informal spaces, such as schools and libraries, the youth will then have opportunities to use engineering practices and computer programming skills to address local issues of their choosing. Longitudinal research will determine whether and how different groups of rural youth develop and maintain interest in engineering career pathways over a sustained duration of time, from middle school through the period after high school graduation. This project will advance knowledge and practice by generating empirically-based findings that illuminate the features of innovative and responsive approaches for broadening participation in engineering careers among youth from rural communities.

This project, submitted to the Faculty Early Career Development Program (CAREER), will generate knowledge regarding how rural youth develop, maintain, or shift engineering interest pathways in the context of sustained engineering activities provided across formal and informal settings. A steering group comprised of industry representatives and formal and informal educators will plan and implement educational innovations in which rural youth have opportunities to use engineering and computer programming skills throughout their middle and high school years. In this longitudinal design-based research, cluster analyses will be conducted to determine how the youth research participants cluster relative to aspects of engineering interest over time. This research will advance knowledge by characterizing how youth with varying levels of interest in engineering may experience different engineering interest pathways. Qualitative methods, such as analyses of interviews with purposively selected youth from each of the clusters, will provide insights as to why shifts in engineering interest occurred at different points in the youths? trajectories along engineering interest pathways. In order to build capacity among the next generation of researchers in engineering education, this CAREER project will also result in the formation of new content modules for core research methods courses in engineering education doctoral programs as well as curriculum materials for a full special topics course on design-based research methods in engineering education. Content from these modules and the new course will be openly shared with other doctoral programs. This project is funded by the Innovative Technology Experiences for Students and Teachers (ITEST) program, which supports projects that build understandings of practices, program elements, contexts and processes contributing to increasing students' knowledge and interest in science, technology, engineering, and mathematics (STEM) and information and communication technology (ICT) careers.

Award Amount
$724,031

Project Dates
2/2020 - 1/2025

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Assessing the Reactionary Response of High School Engineering Teachers to COVID-19

K12 Context

The COVID-19 pandemic has disrupted education on all fronts with no warning. The response from universities to go online was relatively consistent among universities, but K-12 education?s transition has not been as straightforward. Existing issues of equity, access, and inclusion have required school districts, schools, and teachers to adopt a variety of solutions, including no instruction, online instruction, and shipping materials/supplies to students at home. The existing pilot cohort of Engineering for Us All (E4USA) teachers provides a unique opportunity to understand how teachers are transitioning, especially when implementing a new and innovative engineering curriculum. This project allows the multi-institution E4USA team (Virginia Tech, Arizona State University, University of Maryland, Loyola University Chicago, Morgan State University, Regent University, Towson University and Vanderbilt University) to collect data on what has happened during the unforeseen and unique transition to ensure better capture and understanding of the drivers behind decisions and changes within high schools.

The E4USA Team will explore the following research questions: (1) How did the pilot year E4USA teachers adapt and deliver the curriculum during the COVID-19 disruption?; (2) What effect has COVID-19 had on the initial cohort of teachers? motivation, self-efficacy, sense of expectancy/value, and imposter syndrome?; (3) Did E4USA student perceptions of the program change after the disruption?; (4) What effect has COVID-19 had on the potential effectiveness of the upcoming 2020 summer PD? A multifaceted approach will be used to collect and analyze this data. Previously collected focus group transcripts and discussion posts from the pilot teacher cohort will be revisited along with post-COVID-19 focus groups and discussion posts to explore changes due to the pandemic disruption. Focus groups will be conducted with pilot teachers, incoming teachers, and students in the E4USA class to explore how the COVID-19 disruption affected their perception of the class and of engineering. Existing survey instruments for teachers are designed to measure motivational, instructional and engagement self-efficacy. These will be modified to ask teachers to rate these items side-by-side in the context of regular classroom teaching and COVID-19 related adaptations. Existing feedback and reflection questions designed as part of the initial survey will also be modified to include adaptations related to COVID-19. Finally, we will examine course artifacts before and after the COVID disruption. This study will allow the E4USA team to develop a framework to advise and inform both internal E4USA stakeholders and external education communities. Dissemination of these findings has the potential to inform all who are developing teacher PD, those funding and researching engineering in K-12 settings, local school administrations, and other universities interested in working with K-12 schools. This unique opportunity is urgent and may be the only mechanism to truly understand how to plan for, rather than react to, future catastrophic interruptions.

Award Amount
$182,278

Project Dates
6/2020 – 5/2022

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Understanding of Engineering Core Concepts Contextualized in Domain-Specific Settings Through Active Exploration

K12 Context

The long history of experiential learning in engineering education shows the significant potential of cognitive development through direct experience and reflection on what works in practice. However, active exploration in a real-life situation may not be always feasible. Recent advances in computer science help educators develop virtual environments and game platforms that allow students to explore various scenarios and learn from their experiences. This project will explore students' learning of two engineering core concepts: design of a system and optimization contextualized in domain-specific settings. Further, it will examine students' ability to discover systematic solutions for fundamental engineering problems through active exploration in a digital game environment. An online game-based platform will be developed and used to empirically examine the effectiveness of active learning pedagogy. The game will expose users to the two engineering core concepts in the context of construction planning and scheduling through scenario-based problems. The game will be used in a graduate level construction engineering course and the final version of the game will be available for free to download and to play to anyone in the world through a dedicated website and app stores. The outcomes of the project and the game-based platform can be used in outreach programs to engage and inspire underrepresented and K-12 students in pursuing STEM education. In addition, this project will prepare and train the PI to take a leadership role in social science research on the professional formation of engineers through a mentored, collaborative research project which will expand the community of engineering education researchers.

The proposed gamified pedagogical approach will be designed based on constructivism learning theory. This research project will answer three questions: 1) Does guided active exploration in a digital game environment improve students' understanding of two engineering core-concepts (i.e., design of a system and optimization) contextualized in domain-specific settings? 2) Does guided active exploration in a digital game environment improve students' ability to discover systematic strategies to solve fundamental engineering problems? and 3) How do students perceive an interactive digital gamification platform that lets them explore scenario-based engineering problems as a formal learning tool? Addressing these questions will provide insights into how providing students with opportunities to explore the impact of manipulating various elements of an engineering problem can contribute to a better understanding of the engineering core concepts and discovery of systematic solutions for domain-specific engineering problems. To address the research questions, qualitative and quantitative analyses will be performed, including 1) pre- and post-assessments (e.g., prior knowledge surveys, benchmark exams, game-based assignments, and semi-structured interviews) and 2) game data, including log files and electronic records of students' inputs in the debriefing and articulation features. This research project will create and examine an innovative engineering education method that can be adapted to other engineering fields and education levels, including undergraduate and high school programs. Although the research uses construction engineering as a study setting, its outcomes will contribute to other engineering fields and it will add to the cutting-edge state of practice in learning at scale.

Award Amount
$38,902

Project Dates
9/2021 – 8/2023

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The Use of Mobile Technology & Innovative Pedagogy to Improve Undergraduate Thermal-Fluid Science Learning

Undergraduate Context

Student retention remains a problem in science, technology, engineering and mathematics (STEM) programs. This project will utilize mobile technologies and a technology-enhanced curriculum to improve student engagement and learning in STEM undergraduate courses. The technology-enhanced curriculum will be fully integrated in the thermal-fluids course to deliver content and to facilitate student engagement with the content, instructor, and peers. This research project will measure how mobile technology, when purposefully integrated into engineering teaching, impacts student engagement, enhancement, and extension of learning to real-life problems. Through the full integration of mobile devices, findings from this research will transform the teaching and learning of the thermal-fluid science curriculum. The study will be led by a researcher who is new to the field of engineering education research who will be mentored through research methods by an engineering education researcher. This aligns with the Research Initiation in Engineering Formation program's goal of initiating new researchers into engineering formation research to meet the needs of a diverse workforce. Undertaking such research project will supplement the lead researcher's experience in developing and implementing mobile learning in the classroom while using social science research approaches to advance both the professional formation of future engineers.

The underlying goal of this research is to measure how mobile technology, when purposefully integrated into engineering teaching, impacts student engagement, enhancement, and extension of learning. Using an undergraduate thermal-fluid science course as a model course, the primary contribution of this research is to directly improve and transform engineering students' learning in one of the most difficult and abstract content in engineering curricula. Guided by a social-constructivist theoretical framework and the Triple E framework (Engagement, Enhancement of learning outcomes, and Extension of learning goals to real-life problems), the research team will conduct a mixed-methods study, implementing mobile devices with a stylus and a technology-enhanced curriculum. To examine the impact of mobile devices on student learning, the following research questions will be addressed in the areas of engagement, learning outcomes, and extension of learning goals to real-life problems: (1) Does mobile device use facilitate engagement in thermal-fluid science course content? (2) Does mobile device use increase learning of identified difficult concepts in thermal-fluid science courses as indicated by increased achievement scores? (3) What are student perceptions of using mobile devices for solving real-life problems? The findings from this research will provide educators a blueprint for broader implementation of mobile devices in teaching and learning across STEM disciplines. Further, this project is one of the first applications of the Triple E Framework in higher education, offering potential to bridge research on educational technologies with evidence-based teaching practices.

Award Amount
$42,912

Project Dates
9/2021 – 8/2023

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RED: Radically Expanding Pathways in the Professional Formation of Engineers

Undergraduate Context

The world is embracing a new type of engineer - a design thinker who is innovative, flexible, and collaborative. This project aims to transform the offerings of a traditional engineering department with a new curriculum model that emphasizes design and innovation approaches, offering students a variety of pathways to a degree in a program with disciplinary depth and a range of learning experiences. This adaptive kind of engineering professional is in demand by creative industries that are committed to blending science, engineering, arts, and design to address the world's problems. The department's current curriculum is composed mostly of traditional engineering courses that are lecture and exam-heavy, with little opportunity for experiential learning or open-ended design. A combination of approaches will be developed that includes providing multiple paths through the curriculum for students, giving them the freedom to choose a variety of concentrations - from biomedical applications to digital arts - and providing outreach opportunities for K-12 students in underserved and underrepresented populations. These innovations will allow the department to attract a broader pool of students and prepare them for a wide variety of careers. These improvements not only broaden the diversity of students entering the program, they expand students' academic experiences and design and innovation skills. Applying this concept to an entire department curriculum will allow for the creation of a sustainable and scalable participatory curriculum that can be replicated by other programs. This project will also spur new connections with industry leaders, enhancing students' academic experiences while providing regional economic benefits.

The vision of this project is to transform Virginia Tech's Bradley Department of Electrical and Computer Engineering from a department with narrow curricular paths that attracts and produces a limited range of traditional engineers to one that draws and retains a wider pool of students and prepares them to be holistic professionals for a broader range of careers. To implement this vision the project will create and implement a reproducible process of curriculum transformation that dramatically enhances the emphasis on design and innovation. By combining threshold concepts theory and design-based learning, a department with just two highly determined paths - electrical engineering and computer engineering - becomes one overarching program. The multiple curricular pathways will be anchored in real world problems, forging new connections to K-12 education and to 21st century industries, including start-ups, design consultancies, and non-governmental organizations. This re-design process - broadening the pool of students entering the department while increasing potential career opportunities - is learner-centered, stakeholder-informed, and features assessment and evaluation efforts that can be used to continuously improve education in support of holistic professional development, ensuring it is sustainable and replicable within the time and resource constraints faced by any major engineering department.

Award Amount
$2 Million

Project Dates
7/2016 - 6/2021

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MAKER: An Ethnography of Maker and Hacker Spaces Achieving Diverse Participation

Undergraduate Context

Maker spaces have been widely touted as a potentially liberative moment for science, technology, engineering, and math (STEM) education, presenting an opportunity to bring traditionally underrepresented groups into STEM fields by engaging them in spaces that are open, creative, and supportive of people from all backgrounds. At the same time, early reports indicate that many maker and hacker spaces are already enacting certain norms that are more conducive to participation of white, male, middle-class, able-bodied hobbyists. Despite this trend, there are spaces that explicitly stand out in their inclusion of homeless makers, women, people of color, and people with different kinds of abilities. This project examines how diverse makerspaces welcome groups traditionally underrepresented in STEM, and how these practices can inform the design and operation of campus and community maker or hacker spaces that presently struggle to achieve diversity.

Ethnographic methods and Critical Discourse Analysis (CDA) are used to understand these spaces in terms of their physical and linguistic artifacts. This Participatory Action Research (PAR) includes ethnographies at 6 to 8 inclusive maker and hacker spaces, an Open Space Technology (OST) workshop focused on identifying and analyzing core attributes of transferable inclusive practices, and CDA that reflexively summarizes and propagates this information in applicable ways to academic and community sites. Research questions include: (1) What practices and artifacts do participants in diverse maker and hacker spaces employ to establish and maintain environments that are diverse and inclusive? (2) What does the discourse in diverse maker and hacker spaces reveal about how meaning and value are co-constructed around identity, creativity, and the culture of production / the production of culture in engineering? (3) What best practices emerge from diverse maker and hacker spaces, and how can these translate to design or transformation of existing maker spaces on campuses and in communities? Intellectual Merit: This work is early in its use of CDA, the Highlander strain of PAR, and OST, all novel in engineering education; and early in seeking to characterize features contributing to the liberatory nature of emergent diverse maker spaces. The work is interdisciplinary and potentially transformative in leveraging linguistic analysis and social theories to ferret out root causes of exclusionary STEM practices for the potential high payoff of building campus and community maker spaces (and other STEM spaces) that are inclusive. Broader Impacts: This project co-constructs ways to stimulate innovative design thinking in experiential curricula; increases retention and broadens participation in STEM by embedding inclusive practices; empowers citizen engineers through local and national networks of makers, students, and faculty; and enables new ways of STEM learning and design thinking that will enrich the U.S. innovation ecosystem through progressive learning environments for undergraduate engineers. Findings are propagated non-traditionally via maker virtual communities, maker fairs, and informal networks, in addition to traditional propagation through the STEM education literature and the network of 150 engineering deans and other academic leaders committed to making on campus.

Award Amount
$344,033

Project Dates
8/2016 – 7/2022

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The Virginia Tech Network for Engineering Transfer Students (VT-NETS)

Undergraduate Context

The Virginia Tech Network for Engineering Transfer Students (VT-NETS) is a collaborative effort between Virginia Tech, Virginia Western Community College, and Northern Virginia Community College. This S-STEM project will establish stronger networks between Virginia Tech and the Virginia Community College System to increase the success of engineering transfer students following the community college-to-bachelor's degree pathway. The total number of scholarships awarded across all three institutions is 336 over five years. Community colleges are cost-effective gateways to four-year universities for academically talented, low-income students. The creation of a strong partnership, including early and frequent interaction between the student and the four-year institution, will enhance the potential for successful student transfer and timely completion of a baccalaureate degree. VT-NETS creates this partnership and serves as a research-based model for future collaboration between community colleges and four-year institutions.

The goal of this project is to design, implement, and empirically test curricular and co-curricular activities that support the transfer of students following the community college-to-bachelor's degree pathway to an engineering degree. Aligned with the mission of the NSF S-STEM program, the research team will use an embedded case study approach organized around the transfer student capital framework to advance understanding of how various factors affect the success, retention, transfer, and graduation in engineering for low-income students. The results of this project will help educators develop new interventions and fine-tune current efforts (e.g., making them more sustainable, efficient, and effective) to add value to existing strategies. Such integration with current student support practices will more broadly increase the success of transfer students in engineering nationwide. VT-NETS will illuminate and prioritize the human, financial, and physical resources dedicated towards these efforts and will enhance the infrastructure at the partner institutions for supporting all transfer students in engineering.

Award Amount
$5.4 Million

Project Dates
6/2017 - 5/2022

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Investing in Instructors: Creating Intelligent Feedback Loops in Large Foundational Courses for Undergraduate Engineering

Undergraduate Context

A diverse and highly skilled engineering workforce plays a critical role in maintaining economic competitiveness and protecting national security. To achieve these aims, engineering programs in higher education must guarantee that curricula are both rigorous and equitable. As demand for engineering majors increases, so too do section sizes for foundational engineering courses. There is growing evidence that such courses represent significant barriers to student success and that the penalties associated with large classes can disproportionately affect women and underrepresented groups. Further, these educational environments make it challenging to implement evidence-based teaching practices known to be better for student learning. This project will build a learning organization ecosystem -- a grassroots effort involving engagement between faculty and departmental and institutional support structures to collaboratively identify problems and continuously, systematically improve the quality and equitability of the engineering curricula. During this project, sixteen instructors responsible for teaching approximately 4800 undergraduate engineering students in large foundational courses will be impacted. Beyond the instructors and the students directly impacted, research findings and project outcomes will be shared broadly so that other faculty and administrators might similarly improve their educational enterprise.

This project responds to national calls for undergraduate engineering to become more data-driven by exploring how existing, diverse data sources can be leveraged to enhance educational environments. Early efforts will focus on creating intelligent feedback loops, robust streams of existing institutional data (e.g., historical transcript data, student evaluations), existing instructor-level data (e.g., past exams), and newly collected data (e.g., surveys about how students spend time pre/post high-stakes tests). Such data sources will be triangulated and analyzed in a way that can be used by the instructors and the research team. Summer workshops will also be conducted to engage faculty and administrators in a participatory design process: (1) to build individual instructor action plans and (2) to construct an institutional change action plan collectively. Research efforts center at the intersection of learning analytics and faculty change to inform how others might productively leverage institutional data to improve the STEM undergraduate education system. The research team consists of educational researchers, engineering faculty, and administrative leaders from the college of engineering, institutional effectiveness, and learning sciences. Thus, the team is well-poised to not only lead this effort programmatically and from a research perspective, but also institutionalize project-developed strategies and outcomes.

Award Amount
$298,599

Project Dates
7/2017 - 12/2021

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Institutional Transformation: Cultivating an ethical STEM culture through an integrated undergraduate general education

Undergraduate Context

This project will study the implementation and effectiveness of a university wide ethical reasoning curriculum. The project will identify and assess the culture of ethics education that emerges from "Pathways to General Education" at Virginia Tech. The project will do a systematic analysis of institutional transformation. It will focus on the culture of STEM ethics by tracing the implementation of ethical reasoning into a new general education curriculum. The research will evaluate the transferability of this approach to other institutions. The project will contribute to broadening students' expertise beyond their field of study and to provide competencies that will transfer to the workplace. Summer institutes, webinars, on-line training modules and workshops will be developed for faculty to promote ethical considerations in teaching and doing STEM. The findings of this project will be of interest to faculty members, students, university administrators and businesses.

The project will include multi-pronged evaluations of the efficacy of a new curriculum program at Virginia Tech. It will understand the dynamics of the individual, collective, and institutional processes evident in their implementation; and test the overall utility of the ABCD theory of change as employed in this transformation effort. There are four categories of anticipated impacts from this project: 1) evaluation for direct improvement in faculty ethics teaching competency, 2) evaluation of students' ethics learning competency, 3) estimation of changes to ethical climate in an R1 STEM focused university, and 4) dissemination of findings and best practices from this project's research to other institutions. The project will collect qualitative and quantitative data through interviews, surveys and participant observation.

Award Amount
$599,282

Project Dates
8/2017 - 7/2022

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vObjects - Understanding their Utility to Enhance Learning of Abstract and Complex Engineering Concepts

Undergraduate Context

Thermodynamics is a subject that often features engineering problems that are not well-defined and abstract concepts that are often hard for students to understand. In addition, the scale at which thermodynamic phenomena occur makes it difficult, if not impossible, for students to interact with authentic physical objects that exhibit such phenomena. To address these challenges, this project will use virtual objects (vObjects) to enhance learning by closely mapping the learner experience to real-life engineering scenarios. This study will be one of the first to systematically evaluate characteristics and features of a virtual learning environment designed to support the "messiness" of real world problem solving.

This project will employ technological advancements for manipulation of vObjects to help students apply foundational knowledge to the solution of ill-defined problems and to address the improvement of virtual learning for future engineering curricula. A comprehensive understanding of the utility of vObjects in engineering will contribute to the development of online learning environments, including augmented reality environments. Virtual learning of engineering skills can also be used as a tool for broadening participation in STEM by providing the opportunity for greater access by diverse students. In broad terms, this research will contribute to improving and transforming undergraduate engineering education by enhancing student learning of theoretical and abstract engineering concepts.

Award Amount
$229,562

Project Dates
8/2017 - 12/2021

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Cultivating Apprenticeship Learning for Architecture, Engineering, and Construction Using Mixed Reality

Undergraduate Context

For students pursuing careers in the architecture, engineering, and construction industry, learning multi-faceted skills are critical for career success. To enable this range of skill development, many schools and universities participate in student-based design and build competitions, where teams of students build actual structures to learn some of these tactile skills. While these competitions can be beneficial for learning, they can also be cost and resource intensive, which limits access to this type of learning experience. This research aims to explore the use of mixed reality as a cyberlearning technology to assess how this type of increasingly affordable technology may be able to provide a similar type of learning experience for physical construction activities. Such insights will advance the understanding of how people learn about Architecture, Engineering, and Construction topics, specifically, and with cyberlearning environments, in general. In the near term, this work will support authentic learning and skill development by leveraging emerging technologies. This approach will offer an educational experience that requires fewer resources than required for a physical design/build experience. In the long term, this study will provide a genre of cyberlearning to prepare students for careers better and faster than traditional approaches. This is especially critical because this hugely impactful industry has struggled in recent years with productivity issues; this will be further challenged as it approaches a major labor shortage. This work offers a new, and potentially more accessible, approach for preparing the next generation of Architecture, Engineering, and Construction professionals capable of improving the field.

The objective of this research is to: develop markerless mixed reality technology (using a Microsoft HoloLens®) aimed at sufficiently replicating physical design and construction learning environments to enable access to students at institutions without sufficient resources; and assess the impact of a mixed reality facilitated cyberlearning environment on promoting cognitive-, affective-, and skill-based learning that occurs during traditional (in-person) design and construction activities. Carnegie's Three Apprenticeships --of the head, heart, and hand-- serves as the theoretical underpinning for this study. The following research questions guide this study: 1) Can mixed reality sufficiently replicate the physical environment and simulate the experience of project design and construction in the building industry? 2) In what ways can a mixed reality cyberlearning environment enable access to learning experiences that are otherwise inaccessible? 3) To what extent does the mixed reality-facilitated cyberlearning environment promote the cognitive-, affective-, and skill-based learning that occurs during traditional design and construction activities? Through a collaborative partnership, the two institutions involved in this work will test this cyberlearning environment with students at two remote locations. One location includes a physical building structure for students to explore, and the other will only include the mixed reality environment. This approach will enable the research team to identify the unique value provided by mixed reality where physical presence is unavailable. Through this structured research, it will also help qualitatively and quantitatively evaluate the impacts on explicit and tacit knowledge generation through mixed reality for apprenticeship learning in the Architecture, Engineering, and Construction industry.

Award Amount
$410,635

Project Dates
9/2017 – 8/2022

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Professional Identity Development in Civil Engineering Students with Disabilities

Undergraduate Context

Currently available statistics suggest that between 11 and 15% of U.S. college students identify as individuals with disabilities, yet little work addresses identity development within this population broadly, and even less explores their experiences within engineering. Calls from both disabilities studies and national organizations such as the American Institute for Research consistently ask educators to broaden participation in Science, Technology, Engineering and Math fields to include individuals with disabilities. Therefore, this work targets an urgent need in engineering education research. The study lays a foundation for broadening participation in engineering by enabling us to better understand the supports and barriers students with disabilities experience. Educators will be able to use the findings to develop inclusive educational experiences that promote identity formation, diversity, and universal design. At the same time, because the students will are followed into the workplace, the findings can benefit engineering employers as they hire engineers with disabilities, again focusing on systems and structures that support inclusion and accessibility. Moreover, the project will build bridges between the engineering education and disabilities studies community by establishing partnerships and bolstering ongoing conversations within engineering that help to move disability from the margins to the center. The project addresses the call for studies on the "development of identity as an engineer and its intersection with other identities" by conducting a longitudinal study of students with disabilities in civil engineering. The project will use constructivist grounded theory to study two cohorts over three years. The first cohort follows 20 students from the fall of their first year through the spring of their junior year, with interviews twice a year (early fall and late spring). The second cohort, run concurrently, follows 20 students from spring of their junior year through their first year in the workplace, again with interviews twice a year. This approach spans the full undergraduate experience as well as the transition to work, and provides a rich data set from which to develop a theory of identity formation for this population.

Consistent with grounded theory, the project does not impose an existing theory on the data; however, the understanding of identity broadly draws on social identity theory (SIT), which treats identities in terms of group membership developed through comparisons of values and behaviors members make with one another and with individuals belonging to other groups. This approach is consistent with existing studies of individuals with disabilities in college as well as with studies of professional identities, and allows the project team to situate the work within the broader landscape of identity research in engineering. The project addresses a significant gap in research on the professional formation of engineers by extending an emergent theoretical model of identity development in civil engineering to students with disabilities as they advance through their degree program and into the workforce. It provides significant contributions to research on identity development in engineering broadly, research on diversity and inclusion in engineering, and research on disability studies in higher education - issues that, to date, have seen little integration.

Award Amount
$400,388

Project Dates
9/2017 – 5/2022

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Examining the impact of mechanical objects in students learning of thermodynamics-related engineering problems

Undergraduate Context

As technology quickly advances in modern society, it is important that the engineers of tomorrow fully learn the basic concepts of engineering so that they can apply these concepts throughout their careers to a range of new applications. Many engineering courses in college involve teaching abstract concepts that are often difficult for students to understand. For example, "Thermodynamics" is an important course that involves learning about relationships between heat, energy, and mechanical work. Thermodynamics is known to be a difficult course for many students since some of the concepts in the class, such as heat and energy, are abstract. One method for teaching difficult engineering subjects is to use physical or mechanical objects that a student can touch and manipulate in order to demonstrate important concepts. This project examines new approaches for the use and evaluation of mechanical objects as teaching tools in a thermodynamics course with the idea that results from this work can then be applied to additional engineering courses.

This project examines person-object interactions, a significant and critical aspect of engineering, to examine how these interactions affect comprehension of challenging concepts. The primary question to be addressed in the project is fundamental to engineering education and practice: What is the value of mechanical objects in learning engineering related concepts? This study uses quasi-experiments in a mixed methods design where different mechanical objects are used in several problem-solving activities in Thermodynamics classes. Physically demonstrating key thermodynamics concepts, involved in traditional problems, such as the conversion of heat to work, ideal gas behavior, or liquid-vapor phase change processes can be augmented with the use of mechanical objects. For example, a typical "piston-cylinder" arrangement in an automobile engine can be modeled with a simple mechanical object that consists of a plunger in a syringe with an integrated temperature sensor to physically illustrate relationships between compression, expansion, work, heat, temperature, and pressure. The study results will be analyzed in order to provide a clear picture of how the use of mechanical objects supports engineering activities and how individual differences affect the learning process. At the end of the project, the researchers will develop typologies of object use and mental models describing the cognitive processes involved in solving engineering related problems. Finally, the results from this work will provide guidance as to how mechanical objects can be used as educational tools.

Award Amount
$338,798

Project Dates
5/2018 – 4/2022

EngE Collaborators
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Cognitive Barriers to Understanding Complexity in Human-Technical Systems: Evidence from Engineering Students and Practitioners

Undergraduate Context

According to the National Academy of Engineering, poor understanding of complex human-technical systems, i.e., systems that have many interacting parts, has been a major cause of "man made disasters" that include, for example, the Fukushima Daiichi nuclear accident and the Deepwater Horizon oil spill in the Gulf of Mexico. Various studies show that even well-schooled engineers have difficulty understanding basic concepts of complex human-technical systems. This research will provide insights of the important cognitive (e.g. reasoning, thinking) skills for the understanding of complex systems for both engineering students and working professionals. Examples of cognitive barriers are for example, the experts' tendency to look at details at the expense of looking at the big picture, and the human tendency to focus on short-term as opposed to the long-term outcomes, among others. This research will address the needs of industry and government to educate and develop complex problem solvers for the US workforce so that the US maintains its economic competitiveness, national security, and position as a global leader in innovation. Given that engineers design, build and manage human-technical systems throughout their careers, it is important to study the effect of the cognitive barriers during and after their formal education. From an educational point of view, the research will integrate the results into engineering courses, case studies, team assignments and simulation platforms. From an outreach point of view, the research will use the results for the design and offering of company, government agency, and University workshops.

This is a multi-disciplinary project, which lies at the intersection of complex systems and engineering education and will study undergraduate students with different educational experiences as well as professionals with different work experiences. Central conceptualizations of systems thinking is the focus on understanding the workings of complex interconnected socio-technical systems. In our project, our specific definition aligns with the system dynamics school of thought, which provides established methods for analyzing system behavior whose final behavior over time might be counter-intuitive. The research assumes that engineers can recognize and manage system complexity and that classroom education and field experiences can be essential for learning how to understand complex systems. The central research hypothesis is that education in engineering programs and real world experiences influence (positively or negatively) engineers' understanding of complex systems. In order to investigate the main hypothesis, four specific research questions (RQ1-RQ4) are studied. Three vignettes with different levels of structuredness and complexity representing engineering tasks will be used. The research questions are as follows: RQ1: What is the relationship between engineering students'/professionals' level of education/expertise and their performance on three vignettes that vary with respect to problem structuredness and complexity? RQ2: What is the relationship between engineering students'/professionals' perceptions of their own systems thinking competencies and their performance on three vignettes that vary with respect to problem structuredness and complexity? RQ3: How do engineering students and professionals differ in their approaches to solving problems that vary with respect to problem stucturedness and complexity? and RQ4: How do engineering students and professionals describe how and where they developed their cognitive skills of understanding complex systems?

Award Amount
$403,178

Project Dates
9/2018 – 8/2022

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Accelerated Learning and Assessment in Engineering Mechanics

Undergraduate Context

Repeated deliberate practice in problem-solving can increase students' understanding of difficult engineering concepts. In addition, students who receive frequent formative feedback are better able to identify and correct problems with their reasoning. Unfortunately, few undergraduate engineering courses provide students with such opportunities for repeated practice, targeted feedback, and focused tutoring. This project aims to enable these opportunities by developing an automated educational intervention tool for learning engineering mechanics. This open-access, problem-solving interface will provide engineering students with feedback and tutoring, based on their performance on practice exercises. Since all developed materials will be open-source and open-access, the project can also inform and support the work of students and teachers beyond the local institution. By focusing on developing strong analytical problem-solving skills, this project directly responds to industry and the federal government priorities for developing an engineering workforce that is capable of innovative problem solving. Thus, this project has the potential to contribute to the ability of the U.S. to maintain its economic competitiveness and position as a global leader in innovation.

The project will: 1) develop an innovative problem delivery and assessment system and evaluate its effectiveness in meeting specific learning and assessment goals in engineering mechanics; 2) systematically study how this technology-rich problem-solving interface can enhance the learning, teaching, and assessment of complex knowledge through an education research study; and 3) critically evaluate opportunities and barriers to scaling and transferring the innovation across educational contexts. This study should contribute to understanding how technological solutions, such as automated tutoring systems, can enhance learning and assessment of complex knowledge and skills. As a result, this project is likely to have relevance for teaching and learning of other engineering topics, as well as topics in other STEM fields.

Award Amount
$298,535

Project Dates
3/2019 - 2/2022

EngE Collaborators
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Impact of Interactive Holographic Scenes in Developing Engineering Students' Competencies in Sensing Technologies

Undergraduate Context

With support from the NSF Improving Undergraduate STEM Education Program: Education and Human Resources (IUSE: EHR), this project aims to serve the national interest by preparing construction engineering and management students to use modern sensor technologies at construction sites. Over recent years, the construction industry has adopted widespread use of sensing technologies at construction sites, with resulting operational and safety benefits. The use of these sensing technologies has triggered a demand for construction engineering graduates who can enhance industry operations, innovation, and safety through successful deployment of sensor systems. However, it is difficult to prepare a future workforce that is technologically competent in the use of sensing technologies because safety, schedule, and weather-related constraints limit student access to construction sites. This proposal aims to overcome these limitations, in part, by using a mixed reality pedagogical framework combined with holographic telepresence technology. This educational approach is intended to equip construction engineering and management students with competencies in sensor technologies. The project promotes academia-industry partnerships by involving industry practitioners in determining the relevant construction engineering competencies and in developing an appropriate pedagogical approach. The learning activities developed for undergraduate students will also be adapted for use in K-12 programs.

In this project, holographic telepresence is being employed to bring digital participants and remote locations into the engineering classroom in 3D, thereby permitting hard-to-reach construction site personnel and experiences to be imported into the engineering classroom in real time. The goal is to create and assess a pedagogical framework for equipping construction engineering and management students with the competencies required on construction project sites. Specifically, the proposed framework involves projecting interactive holographic scenes of construction sites into the classroom environment, so that students can explore strategies for finding data sensing solutions to industry problems. A mixed method research study will be conducted to answer research questions that address the nature of the expected core competencies of graduating construction engineers and the value of the interactive holographic scenes in training construction engineers. The findings will serve as a guide for developing: (1) an innovative construction engineering and management education curriculum; and (2) a training program tailored towards improving existing construction workforce technical competencies. The plans include investigation of demographic influences on learning and spatial reasoning in the 3D holographic environment, which is likely to yield interesting insights regarding broadening participation in engineering. An important benefit of the project to society lies in the potential to demonstrate that affordable holographic telepresence technology can be harnessed by our educational institutions to provide higher levels of engagement in the STEM teaching and learning process. The NSF IUSE: EHR Program supports research and development projects to improve the effectiveness of STEM education for all students. Through the Engaged Student Learning track, the program supports the creation, exploration, and implementation of promising practices and tools.

Award Amount
$299,976

Project Dates
7/2019 - 6/2022

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Market-driven design concept formation in undergraduate engineers

Undergraduate Context

Designing successful products requires a balance of many competencies, including technical expertise and business acumen. While undergraduate engineering programs emphasize technical design and analysis, they generally do not adequately teach or discuss marketability, and evidence suggests that engineering students are graduating without a sufficient grasp of the bigger picture of design. At the same time, research in engineering design has resulted in new market-driven design techniques, which provide guidance for design practitioners regarding how to develop products that are both technically sound and marketable. This research project studies the application of market-driven design methods to engineering education, by examining how undergraduate engineering students learn design. It specifically seeks to understand how students' mental models of design develop throughout a third-year design curriculum, which introduces market-driven design concepts through course material and novel interactive tools. By learning more about students' initial mental models of design, as well as how this course influences their conceptions, this project will provide a foundational understanding and recommendations regarding holistic design education for engineers.

To bridge the gap between market-driven design and engineering education research, this proposal explores how students currently understand design as a process before and after exposing them to market-driven design approaches and tools in the context of an engineering design course. The fundamental research questions are: (1) To what extent do undergraduate engineering students' initial conceptions of design account for the market context, such as competition and consumer considerations? (2) In what ways do these design conceptions change after introducing market-driven design techniques and tools in a design course? Data from concept maps (pre- and post-instruction), student reflections on their conceptions of design, and a survey of student perceptions of the course and their understanding of design will be collected and analyzed. This will contribute to a stronger understanding of how students conceptually balance the technical and non-technical elements of design, as well as evidence regarding the value of a constructivism-based educational approach to advancing student understanding of market-driven design. In addition, these research questions will help design researchers to understand the needs of market-driven design methods, as it provides a baseline for how engineers are currently approaching design and how receptive they are to the processes and tools from the research community.

Award Amount
$51,918

Project Dates
8/2019 – 7/2022

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Writing Education Initiating Identity Transformation in Engineering Students-The Wri2tes Project

Undergraduate Context

This project seeks to better prepare engineers for professional work by understanding how experiences of learning to write in school help develop students' capacities for engineering judgement and their identities as responsible professionals. The engineering disciplines are rigorous in their application of scientific principles, and these principles are directly addressed in undergraduate engineering classrooms. However, engineers are also called to make decisions that implicitly account for complex criteria, including the welfare of those who use or are impacted by the systems they design and the economic needs of their employers. As a result, in many ways engineering is an art that requires practitioners to routinely navigate difficult tradeoffs that require professional judgments. These judgments include often-conflicting economic, ethical, social, and value-based dimensions, requiring engineers to make well-reasoned decisions for the benefit of society. In order to best serve the public, engineers need to communicate their judgments to engineers, non-specialists, clients, and a variety of others. One key goal in all such interactions will be to convey themselves as competent professionals; either as insiders to other engineers, or as authoritative experts to those seeking their advice. The art of engineering, in short, is tightly bound to the negotiation of engineering identity: engineers must be able to practice engineering as art and develop sound judgments that balance complex, competing objectives or constraints, and they must simultaneously convey these judgments in ways that will help them identify-and be recognized as-engineers. Despite this tight connection, however, little work to date has investigated the relationship between the writing engineering students do and the development of engineering identities, particularly in terms of engineering judgment.

This project addresses this gap by exploring how students' experiences with writing shape their identification with the engineering profession and the way they convey engineering judgments to better ensure that tomorrow's engineering workforce will best serve the needs of public. To investigate the ways students produce engineer identities in written artifacts through which they expect to be recognized as engineers, the project employs a two-phase qualitative case study; Phase 1 uses semi-structured interviews and analyses of student work to explore engineering identity production in writing, and Phase 2 uses those results to design and study assignments intended to more effectively foster engineering identity production in writing. The study is grounded in Gee's use of identity as an analytic lens, Tonso's identity production theory, and Lea and Street's academic literacy approach. In Phase 1, the case studies will focus on the ways students produce engineer identities through their written projects. Course documents (including assignments and related material) as well as instructors' autoethnographic field notes on implementation will provide contextual data for the case. In Phase 2, the insights from the initial cases will be used to design appropriate teaching tools and approaches. Few studies in engineering identity have investigated the role that navigating difficult tradeoffs in writing plays in students' engineering identity construction. In addition, few investigators have examined the ways in which the artifacts students produce reflect the choices students must negotiate during their professional identity development and production. This study contributes to our knowledge of how a critical professional practice-writing-contributes to the development of students' holistic engineering identities in ways that best prepare them to develop products and systems that meet societies needs.

Award Amount
$18,257

Project Dates
8/2019 – 7/2022

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Diversifying Paths through Engineering with Extra-/Co-Curricular Participation

Undergraduate Context

While most current research in teaching and learning is performed in the classroom, evidence suggests that the quality of a student's learning is also affected by experiences outside of the classroom (i.e. extra-/co-curricular experiences). Engineering students in particular have available to them a rich variety of learning opportunities outside of the classroom - such as competition teams, undergraduate research experiences, and service learning organizations - which reinforce and strengthen the knowledge they gain through engineering coursework. The goal of this project is to determine the impact of engineering students' participation in extra-/co-curricular activities on their development into professional engineers. Understanding the specific benefits that engineering-focused extra-/co-curricular programs offer to students will allow those in career and academic advising positions to provide targeted advice to students on how to personalize their pathways through college engineering program, focusing on topics that are interesting to them and finding avenues for strengthening existing skills or learning new ones. The extra-/co-curricular setting also gives students a relaxed, enjoyable opportunity to practice engineering skills in an authentic environment, leading to improved confidence - a feature that is particularly important for students from underrepresented groups in engineering - and a more technically competent engineering workforce. Further, although certain features of the engineering-focused extra-/co-curricular experience may be challenging to reproduce in a classroom setting, other features may provide inspiration for alterative teaching practices which can enhance learning within the classroom.

This project answers two fundamental research questions: (1) What specific features of students' academic and professional development are affected by engineering-focused extra-/co-curricular participation, and (2) What specific features of extra-/co-curricular activities most influence students' academic and professional development' The research has a two-phased design where the first phase implements the Statics Concept Inventory, the Engineering Professional Skills Assessment, and a self-efficacy survey to measure achievement of learning outcomes including mastery of fundamental engineering concepts, development of professional skills, and self-efficacy. In the second phase, participants from Phase 1 are recruited for interviews in order to uncover possible explanations for the research findings in Phase 1. The approach used in this work will lay the groundwork for other scholars in non-engineering disciplines to perform assessments of their own discipline-specific extra-/co-curricular activities to determine if similar patterns exist. The framework used in this research will also allow other scholars to explore factors related to engineering-focused extra-/co-curricular participation which are not covered in this research, for example, determining how the extra-/co-curricular experience uniquely affects engineering students from underrepresented groups.

Award Amount
$59,898

Project Dates
9/2019 – 8/2022

EngE Collaborators
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An Interdisciplinary Approach to Prepare Undergraduates for Data Science Using Real-World Data from High Frequency Monitoring Systems

Undergraduate Context

With support from the NSF Improving Undergraduate STEM Education Program: Education and Human Resources (IUSE: EHR), this project aims to serve the national interest by improving undergraduate understanding of data science. It will accomplish this goal by incorporating data science concepts and skill development in undergraduate courses in biology, computer science, engineering, and environmental science. Through a collaboration between Virginia Tech, Vanderbilt University, and North Carolina Agricultural and Technical State University, the project will develop interdisciplinary learning modules based on high frequency, real-time data from water and traffic monitoring systems. The project intends to develop a common approach for introducing data science concepts in STEM disciplinary courses. By embedding data science into a variety of undergraduate STEM courses and creating a partnership that includes a Historically Black College/University, this project has the potential to broaden participation in data science, including participation of students from populations that are underrepresented in data science and/or STEM fields.

This project will develop data science learning modules to implement in eight existing STEM courses at the collaborating institutions. The learning modules will be motivated by real-world problems and high-frequency datasets, including a water monitoring dataset from Virginia Tech, and transportation and building monitoring datasets from Vanderbilt. The learning module topics will include: Interdisciplinary Learning, Data Analytics, and Industry Partnerships. These topics will facilitate incorporation of real-world data sets to enhance the student learning experience and they are broad enough that they can incorporate other data sets in the future. The project aims to develop and implement an interdisciplinary collaborative approach to support undergraduate students in developing data science expertise through their disciplinary course work. Such expertise will better prepare students to enter the STEM workforce, especially those STEM professions that focus on smart and connected computing. The project will investigate how and in what ways the modules support student learning of data science. The project will also investigate how implementation of the modules varies across the collaborating institutions. It is expected that the project will define key considerations for integrating data science concepts into STEM courses and will host workshops to introduce faculty to these considerations and strategies so they can incorporate the learning modules into the STEM courses that they teach. The project collaborators will provide the framework for generalizing and transferring the learning modules to other STEM education communities, thus broadening the scope and the impact of this project beyond the three collaborating institutions. The NSF IUSE: EHR Program supports research and development projects to improve the effectiveness of STEM education for all students. Through the Engaged Student Learning track, the program supports the creation, exploration, and implementation of promising practices and tools.

Award Amount
$900,195

Project Dates
10/2019 - 9/2023

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Responsive Support Structures for Marginalized Students: A Critical Interrogation of Navigational Strategies

Undergraduate Context

Fostering educational environments that empower every student to access available and necessary resources in their pursuit of undergraduate engineering degrees is a national imperative. To support this goal, colleges and universities provide numerous forms of student support intended to increase the retention and graduation rates of its undergraduate engineering students (e.g., peer mentoring programs). Because of the current lack of diversity in engineering, support often focuses on marginalized groups, such as Black and Latinx students. However, student outcomes and previous research reveals the need for more responsive student support tailored to individual students? needs. Accordingly, the aim of this CAREER project is to advance the extent to which the engineering education community understands how marginalized students 1) navigate undergraduate engineering programs, and 2) make decisions with respect to seeking help. The study will provide information directly to student support services. By understanding the experiences and decision-making of Black and Latinx students, colleges and universities can support educational environments that are more responsive to the potential diversity of the student populations. The impact of this work will be the more intentional use of university investments and resources focused on broadening participation in engineering.

This CAREER award is a multi-case study which seeks to: (1) compare the support systems and navigational strategies across four universities of undergraduate engineering students? responses to challenging situations (e.g., receiving poor grades, needing a recommendation letter), and (2) critically interrogate the effectiveness and appropriateness of different navigational strategies as defined by the students themselves. Primary data sources include institutional documents (e.g., program descriptions) from academic units and interviews with marginalized students. Data analysis is informed by person-environment fit theory. This project will introduce person-environment fit theory to scholars and practitioners who focus on marginalized students in engineering, and significantly advance fundamental knowledge of the strengths and deficiencies within university support structures and processes. The results of the study will inform the development of Situational Judgement Inventories for undergraduate engineering students, which will be openly shared, and seminars and workshops for educators and administrators.

Award Amount
$570,901

Project Dates
5/2020 - 4/2025

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Leveraging Design Thinking to Deal with Ambiguity Embedded in Data-Driven Engineering Problems

Undergraduate Context

We introduce a pedagogical approach to promote engineering design thinking in conceptual courses to better prepare engineering students to join a contemporary STEM workforce. Using a case study approach, our specific aim is to advance our understanding of how engineering design can be leveraged to solve ambiguous, data-driven engineering problems presented in an undergraduate probability and statistics course while influencing students' approach to conceptualizing, solving, and communicating solutions to introductory probability and statistics problems. There are two research questions guiding this study. First, "In what ways might the content, assessment, and pedagogy of an introductory probability and statistics course be modified to facilitate design thinking and tolerance for ambiguity among undergraduate engineering students?" Second, "To what extent can the development of design thinking influence engineering students' tolerance for ambiguity when dealing with data-driven engineering problems?" The proposed case study includes three phases. During the redesign phase, the research team will critically examine an existing probability and statistics course design and adapt the content, assessment, and pedagogy to reimagine how the course concepts are introduced and evaluated in a way that also includes an emphasis on design thinking. Then, the course will be redesigned around a semester-long project that will require student teams to: select among options for an open-ended project, leverage design thinking and course concepts learned to address the problem, and communicate their results to stakeholders. During the implementation phase, the research team will implement the pedagogical innovation, and collect qualitative and quantitative data to address the research questions. Qualitative data will include pre-post scores on the Tolerance for Ambiguity Scale. During this final phase, the data will be analyzed and the results will be disseminated to colleagues on the University of South Florida campus and to the broader engineering education community via conference proceedings and a journal publication. We expect our findings to not only impact how engineering courses are taught at the focal institution, but also lead to insights that can be leveraged by other engineering education scholars. In addition to producing insights situated in the engineering education literature, the mentor-mentee relationship inherent in this RIEF project is designed to extend the community of engineering education scholars.

Award Amount
$74,814

Project Dates
7/2021 – 6/2023

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Faculty Assessment Mental Models in Engineering Education

Undergraduate Context

The process of forming engineers is an iterative one that requires feedback to indicate developmental progress and identify areas for improvement. A primary source of feedback comes from assessment, which can play many roles in engineering education: a signal to students of what they do and do not understand about a concept; feedback to instructors about students' conceptual understanding as well as what may or may not be working regarding their own teaching approaches; and information to administrators and prospective employers evaluating students' abilities. Although assessments function as a linchpin in the formation of engineers, it is unclear how faculty members - i.e., the individuals typically designing and implementing these assessments - think about this pertinent signaling mechanism. Because faculty members often have autonomy in making course decisions, understanding how they think about assessments is essential to establish the foundation on future efforts in promoting diverse and improved assessment approaches in engineering education. To better understand how faculty think about and make decisions on assessment, we have designed a three-phase study that uses interviews, surveys, and natural language processing techniques to gather extensive data from a diverse sample of faculty who will undoubtedly have diverse views on students and assessment. The outcomes of this study will include characterizing faculty mental models of assessment and how those models inform instructional decisions. In developing these outcomes, we will also identify potential biases, misconceptions, and problematic, systemic patterns in assessment implementation. The knowledge generated through this project will inform better faculty training and policies to advance this vital area in the formation of engineers.

To characterize faculty mental models and how they inform decision-making regarding assessment, we will engage in a three-phased, multi-method study. Drawing on exploratory interviews, Phase 1 will map the landscape of mental models that faculty members might have related to assessment. Phase 2 will draw on the initial interviews and add experience sampling methods to expand this mapping to connect those mental models with decisions made by faculty related to assessment over the course of a semester. Phase 3 will use a survey to expand the study sample in order to support inferential statements about the population of engineering faculty members in US engineering education ecosystems more broadly with regard to mental models and decisions related to assessment. This study will make several important contributions regarding intellectual merit. First, our study will identify a range of mental models that faculty engage in assessment-related decision-making, providing a view of the current state in engineering education. Second, building on these findings, we will illuminate the connections between these central instructional decisions and deeper perspectives that faculty members wield. Third, from a methodological perspective, we will implement ground-breaking methods that combine experience sampling methods (ESM) and natural language processing (NLP) and provide a model for other researchers in engineering education to do the same.

Award Amount
$570,901

Project Dates
9/2021 - 8/2024

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NRT: Disaster Resilience and Risk Management (DRRM) - Creating quantitative decision making frameworks for multi-dimensional and multi-scale analysis of hazard impact

Graduate Studies Context

Every human being can be impacted by a disaster, especially in coastal areas. At present, six out of ten people live near the coast and are susceptible to hurricanes, tsunamis, and other hazards. Coastal and other hazards also threaten economic and geopolitical stability, and national security. Hurricanes Sandy (2012) and Katrina (2005) and the Tohoku tsunami (2011) and Typhoon Haiyan (2013) are reminders of the immense long-term impacts such hazards pose. Despite the accelerating risk of such events, resource allocations and coping strategies are often complicated and by varying stakeholder interests. This National Science Foundation Research Traineeship (NRT) award to Virginia Tech will synthesize expertise in science, engineering, planning, and business to address the critical issue of growing disaster losses attributed to both natural and man made hazards. The program will train a new community of multi-disciplinary researchers, practitioners, and leaders at the master's and doctoral levels. Over five years, the project will support 26 trainees on NSF stipends, and an estimated 150 additional students will participate in at least one element of the program. Each trainee will pursue a degree through existing academic entities at Virginia Tech or through the university's new Individualized Interdisciplinary PhD program.

The project will develop new transdisciplinary approaches critical for advancing knowledge and understanding of disaster-resilience and risk management across different STEM and non-STEM disciplines. The involved faculty are not only experts in their own disciplines, but also have a shared history of transdisciplinary disaster-resilience and risk management research and education. Trainees will work with faculty and each other to develop innovative, comprehensive, inclusive, and sustainable methods and practices that seek to mitigate disasters emanating from natural and manmade hazards. Trainees will also learn about and lead stakeholder engagement exercises that explore how people and institutions respond to disasters and risk. Integration of student research with stakeholder interaction and engagement provides a novel and potentially transformative educational component that could be replicated in other transdisciplinary graduate programs. Intentional training in the societal context in which disasters unfold has the potential to deepen communications among disaster-resilience and risk management professionals and researchers and the communities they serve. Educational innovations include, i) integrating research and education through a unique approach to stakeholder engagement, ii) emphasizing intentional development of transdisciplinary thinking, and iii) integrating faculty and graduate students into a community of practice that fosters diversity and inclusion. The result will be diverse, globally competitive scholars who understand the fundamental aspects of disaster resilience and its broader implications outside traditional STEM fields.

Award Amount
$3 million

Project Dates
9/2017 - 8/2022

EngE Collaborators
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Learning from the PROSE: Exploring professional organizations' role in supporting Black engineering student success

Despite millions of federal investments to broaden participation, Black students continue to be underrepresented at all levels of engineering. Existing research not only provides evidence of the barriers to undergraduate engineering degree completion, it also reveals factors that positively influence the academic outcomes of high-achieving Black students. Factors like being more socially integrated on campus and being conscious of one's racial identity are among them; and involvement in certain types of professional organizations on campus provide a context for both of these factors to occur. As part of Learning from the PROSE (Professional Organizations Supporting Excellence), the aim of this study is to understand how students' engagement with identity-related organizations - like the National Society of Black Engineers (NSBE) and those that makeup the National Pan-Hellenic Council (NPHC)- contributes to the successful completion of engineering programs. This project is focusing on the experiences of those who have already successfully completed their undergraduate education, namely Black graduate engineering students. The findings from this study will advance our understanding of the unique role identity-related organizations play in promoting the success of one of the least represented groups in engineering. The explicit focus on Black engineering graduate students who have graduated from a range of institutions allows us to deeply explore similar dynamics in different contexts. By extension, this will allows us to develop a robust set of strategies for supporting minority students at all levels of education, reinforce the efforts of professional organizations that align with various dimensions of their identity, and shed light on pathways to the professoriate.

Although Black people represent approximately 13% of the U.S. population and are one of the fastest growing demographics in the nation, they made up less than 4.4% of engineering degree recipients at the undergraduate, Master's and doctoral levels during the 2015-2016 academic year. This work will learn from Black engineering graduate students that have successfully navigated engineering environments and self-selected to continue study in a graduate engineering program. Using the Model of Co-Curricular Support and Community Cultural Wealth as theoretical underpinnings, this qualitative and video-based research project will investigate how engagement in identify-related organizations as undergraduate students contributed to the successful navigation of their engineering programs. More specifically, this project aims to investigate the mechanisms by which professional organizations provide the critical professional and psychosocial support that contribute to the development and success of Black engineering students using a three-phase approach: performing a systematic literature review, conducting phenomenological interviews, and exploring novel means of dissemination. Although existing research typically investigates such experiences while being enrolled in undergraduate engineering programs, using a phenomenological approach, this study takes a comprehensive and reflective view that can only be obtained after the experience is over. Moreover, relying on a mixture of qualitative and video-based methods provides the basis for disseminating the research findings in traditional and novel ways. This study will uncover critical aspects of access to networks and support systems from the perspective of Black engineering students that have demonstrated persistence while highlighting partnership opportunities among existing on-campus programs that could promote a shift away from the siloed approaches to supporting student success.

Graduate Studies Context

Award Amount
$675,000

Project Dates
9/2018 – 8/2022

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Rising Doctoral Institute

Graduate Studies Context

Research has shown that underrepresented historically underrepresented racial and ethnic groups (African American, Hispanic American, Native American, and Pacific Island) are finishing the doctorate in engineering in lesser rates than their majority peers. For every seven doctorates in engineering granted to majority students, only one minority will obtain one. To address this problem, we developed the Rising Doctoral Institute (RDI) which aims to provide a timely and preparatory experience for rising doctoral students in engineering to address issues related to transitioning into the PhD encountered by underrepresented students. However, we understand that a single intervention will not change the landscape for underrepresented PhD students. For this reason, our proposed project aims to develop a research-based intervention model of this preparatory experience and develop a community of practice among institutional partners to develop and adapt this model for local contexts. Integral to the project is an investigation of the dynamics of academic systems and how implementing programs like the RDI can influence systemic change within the institution. Thus, the goals of the proposed project are to (1) research the effect of early interventions for doctoral students on the transition into the engineering doctorate, and (2) develop sustainable models for institutions to implement on their campus to help underrepresented students? transition into the doctorate.

The intellectual merit of this project lies in the integrated research-to-practice design. Using quantitative and qualitative research methods, we will uncover the factors that lead to a successful transition into the doctorate among underrepresented students as well as strategies for designing context-appropriate local RDIs. To meet these goals, we designed a five-year project. In year 1, we will host an RDI modeled after a pilot program hosted in 2019 and invite representatives from five collaborating institutions to observe and coach them as they develop an RDI-type intervention for their institution. In year 2, the collaborating institutions will each host an RDI-type intervention at their institution, and the RDI PIs will serve as on-site consultants helping the collaboration institutions address the needs of incoming underrepresented graduate students. In year 3, we will host a showcase with the initial collaborating institutions to overview different models of the RDI and scale the project to up to 20 new institutions to develop their versions of the RDI. We will also develop the network of institutions hosting RDI interventions through mentor group sessions. In years 4 and 5, we will nurture this community of practice led by the five initial collaborating institution leaders and develop products based on the research findings such as evaluation tools for measuring the impact of RDI, guides to hosting support programs such as the RDI, and guides for mentoring doctoral students entering the PhD. Over five years, this project has the potential to positively impact the doctoral degree completion rates of approximately 1,500 underrepresented doctoral students who will participate in an RDI implementation and 50 leaders from collaborating institutions across 25 institutions. The research outcomes include: 1) research-based variations on an intervention model for rising underrepresented doctoral students in engineering, 2) data on the impact of such early interventions in the transition of underrepresented doctoral students into the doctorate, and 3) a research-based model to assist institutional leaders with developing sustainable support structures and systems for incoming PhDs at their institutions.

Award Amount
$370,948

Project Dates
1/2021 - 12/2025

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Non-Academic Career Paths of Master's & PhD Engineers

Graduate Studies Context

Most engineering Master's and PhD graduates will enter careers in sectors such as industry and government, yet research and resources focused on graduate education have historically focused on preparation of future faculty members in academia. This project will meet the call for enhancing the professional preparation of engineers by focusing on non-academic career pathways of both Master's and PhD students in engineering. Advanced engineering degrees are becoming increasingly important in these non-academic sectors for both individual career trajectories as well as for continued competitiveness within the global innovation landscape. The project will identify how graduate programs can better support students for these careers so that they may successfully and quickly make contributions in their new positions. Additionally, both industry and government have emphasized the need to broaden participation in engineering, and this project will pay particular attention to the experiences of how minoritized graduate students may be best supported on their career paths. The project aligns closely with the goals of the Professional Formation of Engineers funding program "to create and support an innovative and inclusive engineering profession for the 21st century." At its core, the project aims to understand and identify ways to enhance the professional formation of engineers at the graduate level so that they are best prepared to transition successfully into the non-academic workforce.

This project will seek to understand: 1) how recent alumni of engineering graduate programs describe being exposed to, preparing for, and making decisions about non-academic careers, and 2) how engineering faculty, staff, and administrators support students to prepare for such careers. The project will use an ecological theoretical framework to organize data collection and analyses, which will allow the investigators to consider individual decisions within broader systems and environmental factors that influence engineering graduates' pursuit of non-academic careers. The project will triangulate multiple data sources to understand the issue from different perspectives. First, the investigators will conduct national-scale quantitative analyses of non-academic career pathways in engineering using the Survey of Earned Doctorates (SED) and Survey of Doctoral Recipients (SDR) and provide benchmarking data to all institutions with engineering graduate students. Second, the investigators have purposively sampled four institutions that are active members of multiple engineering research centers (ERCs) and/or Industry-University Cooperative Research Centers (IUCRCs) and, as such, are well positioned to support career pathways for engineering graduate students beyond the academy. This project will investigate experiences of alumni, center directors, and faculty to understand how these institutions and programs prepare engineering graduates for non-academic careers and to gain insight on how graduates make career decisions. The sampling strategy to focus on Centers is a unique strategy that purposefully collects new data from NSF-supported collaborations that theoretically put students in research spaces that transcend the boundaries of academia. Minority-serving institutions are intentionally included in the sample to understand how minoritized graduate students in particular can be best supported. Prior work on PhD students has shown that despite many calls from industry and the government that broadening participation is needed, women and students from underrepresented minority groups still are more likely than their white, male peers to have no job offers at the time of graduation. Third, based on findings from that initial sample, the project will generate and administer questionnaires to graduates, directors, and faculty at 44 additional institutions leveraging the ERC/IUCRC network as a sampling mechanism. This step will increase the representativeness of the sample and enable exploration of differences across institutions, disciplines, and ERC/IUCRCs.

Award Amount
$191,434

Project Dates
9/2021 – 8/2024

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Supporting Agency Among Early Career Engineering Education Faculty in Diverse Institutional Contexts

Broader Contexts

Faculty are at the center of many potential solutions to national and global calls for transformative improvements in STEM education. The last 20 years have seen significant advancement in understanding of how to create effective learning environments for STEM education. While many individual faculty have adopted new approaches to teaching, change has not been deep or widespread enough to make a major impact across all of STEM education. Better understanding is needed of how faculty can become change agents in order to effect this change. This study focuses on exploring the experiences of early career engineering education faculty as they attempt to impact the engineering education experiences of students locally and more broadly. Engineering education faculty are unique in that they have formal training in the types of change desired, and are often embedded in disciplinary engineering departments where they can apply their knowledge to create change. Understanding their experiences and the academic cultures in which they are working will provide information on how they can and cannot influence education practices in their departments. Doing so will enhance our efforts to train and develop faculty prepared to drive change in engineering education.

In the first phase of a two-phase study, collaborative inquiry and collaborative autoethnography methods will be used to systematically examine the PIs' own experiences as six early career faculty members in diverse settings: this will include scrutinizing acceptance of ambiguity, responses to disappointments and challenges, willingness to adapt, and ability to collaborate. Subsequently, in the second phase, the experiences of 12-15 additional early career faculty members will be examined to refine and expand on the phase one results, increasing their applicability to multiple settings. The results of this project will (1) advance the engineering education community's understanding of existing structures for facilitating change (or the lack thereof) in engineering education (2) identify barriers and supports for making change as early career engineering education faculty; and (3) develop a co-constructed understanding of how to better prepare and support faculty to exercise agency as it relates to impacting engineering education during their first few years in academic positions. These advancements are critical because the calls for change in engineering education will continue as technological advances are made and the role of engineers in society continues to evolve. By identifying the barriers and supports that affect early career faculty's abilities to take strategic and intentional actions towards achieving impact, the results of this study will enable engineering education graduate programs and national engineering education organizations to make programmatic changes to benefit future faculty. In addition, the evidence-based insights resulting from this study have the potential to expedite the on-boarding process of new engineering education faculty, promote improvements in STEM education nationally by faculty at all stages of their careers, and support the development of the field of engineering education research.

Award Amount
$64,170

Project Dates
6/2017 – 5/2022

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Leading for Impact: Enhancing Entrepreneurial Mindset for Women in Engineering Education Leadership

Broader Context

As noted on their website, KEEN has been successful in attracting University partners that are passionate about promoting an entrepreneurial mindset (EM) among engineering graduates (https://engineeringunleashed.com/). However, a critical question remains with regard to how to make KEEN's work a living body that extends after the foundation funding. The answer, at least in part, comes from having a strong mentoring community that can sustainably bring in new members and help them find value-added development opportunities. In the "Faculty Development Plan" YouTube video, Doug Melton lays out a blueprint for the Kern Family Foundation with regard to faculty development (bit.ly/keenblueprint). According to the video, the Kern Family Foundation is behind the research question, "What faculty development would impact our mission?" with the mission being promoting an entrepreneurial mindset. Our proposed project supports answering this question by specifically examining the mentoring of women in leadership positions within the discipline of Engineering Education. We argue that the discipline of Engineering Education can serve as a model of EM in leadership; Engineering Education as a discipline has been and continues to be built predominantly by women who are demonstrating an EM even though it is not labelled as such. We further argue that there is power in using an EM label and intentionally fostering an EM environment and community. Understanding how women have intentionally and unintentionally leveraged elements of EM can create a foundation for promoting EM more broadly among leaders in engineering disciplines.

The "Faculty Development Plan" video lays out a blueprint with a specific approach to faculty development through formal mentoring that includes a short workshop (roughly 3 days) and a commitment to a cohort for the next year to "develop, deploy and assess" changes related to promoting EM. The blueprint further suggests that three groups should be involved in creating this experience: 1) curriculum committee who establishes broad EM-related outcomes, 2) a facilitation group that leads the workshop sessions, and 3) a coaching group that provides feedback throughout the year to the participants. Importantly, the blueprint calls for a discovery process that needs to happen to develop the right kind of workshops where EM can really apply.

Our proposed project directly targets this discovery process as a first step in building an EM in leadership faculty development program for women leaders within engineering. We will bring together a group of women leaders in the Engineering Education discipline who: 1) currently hold administrative leadership positions such as the Full Professors who serve as Department Head/Chair of Engineering Education Departments, 2) those who were leaders in creating Departments (even if not with a formal title) such as Full and Associate Professors in emergent Departments, and 3) those who are doing the work now to create or expand Engineering Education Departments and programs (often Associate or Assistant Professors). We will host a 2-day workshop with the intentional and explicit goals of establishing 1) an agenda for a formal workshop on EM leadership for women in engineering, and 2) publishable research and scholarship on EM among women in leadership in Engineering Education.

Funding Source: Arizona State University as a subcontract from the Kern Family Foundation

Award Amount
$66,786

Project Dates
8/2019 – 10/2021

EngE Collaborators
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You Can Too: Stories of STEM Faculty Who Achieved Tenure While Pursuing Their Passion

Broader Contexts

The promotion and tenure process can be grueling and demotivating for new faculty (O'Meara, 2010). Faculty requirements and expectations may be unclear, making it difficult to choose how to navigate the process. New faculty commonly feel stress and frustration in determining an efficacious path to tenure (Sorcinelli, 1992). Eddy & Gaston Gayliss note:

> The literature on new faculty concerns identifies a number of major stresses facing new faculty: not having enough time for research, teaching, and service; inadequate feedback or lack of recognition; unrealistic expectations about what can be accomplished in the time given; lack of collegiality; and difficulty in balancing work and life outside of work" (Eddy & Gaston Gayliss, 2008, p.90).

For many faculty, the exigencies of tenure overshadow personal needs, including intellectual interests, personal health, and family. In fact, new faculty's perception of tenure demands can pit these factors against one another.

You Can Too (working title) is a book project that will create a collection of 10-15 stories from faculty who employed entrepreneurial mindset in order to achieve tenure and life-balance while pursuing their intellectual passions. Each story will be approximately 5,000-6,000 words. Each author will describe their pathway into the professoriate, as well as their motivations and challenges along the way. Each story will focus on the challenges faced pursuing tenure, and how they met these challenges by creating value in areas about which they were passionate. Narratives will be organized by themes to avoid redundancies, although themes may not emerge until we begin recruiting authors. Project deliverables include recruiting a diverse collection of contributors, creating a protocol and interviewing contributors, converting interviews into narratives, member-checking narratives, writing an introductory chapter and concluding chapter that summarizes themes, and marketing the collection to publishers. While the book is a primary tangible product of this effort, the process of creating the book and the book itself will yield a variety of other means to disseminate what is learned through this project including journal publications and outreach to graduate students who are future academics faculty.

Award Amount
$99,904

Project Dates
8/2019 – 12/2021

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Funding Source: Arizona State University as a subcontract from the Kern Family Foundation

Defining 21st Century Lifelong Learning Skills for Engineering Practice

Broader Contexts

Lifelong learning is critical for the engineering field because of technological advancements, changing regulations, interpretation and synthesis of massive data, and a host of other factors. Furthermore, the Accreditation Board for Engineering and Technology, professional licensure boards, and engineering education research have identified that lifelong learning needs to be promoted to better meet industry needs. Currently, educators do not have a clear, and data proven, picture of what skills require additional study post-graduation, how practitioners engage in lifelong learning, or how student perceptions of lifelong learning may differ from practitioner's reality. The goal of this research is to investigate practitioner experiences and perceptions of lifelong learning to determine the skills developed and methods of learning utilized. The research will also investigate how those skills and methods change throughout career progression and how closely they match student perceptions of lifelong learning. A better fundamental understanding of what and how practitioners study and develop skills as they progress through their career will inform the engineering education community about what learning abilities are required to be prepared for lifelong learning as professional engineers.

This study seeks to understand three research questions: 1) What skills are most developed by practitioners at different career positions, 2) How do practitioners find and consume information on the skills they want to develop, and 3) What perceptions do undergraduate students have about the skills they will need to develop throughout their career and how do they think they will develop those skills? A research plan has been developed to investigate and answer these questions first by conducting qualitative analysis of semi-structured interviews of practicing engineers in the Pacific Northwest. Interview recordings and transcripts will be analyzed using interpretative phenomenological analysis to obtain a rich understanding of practitioner perspectives of lifelong learning. Then, the project will conduct quantitative analysis of lifelong learning survey results of practicing engineers and undergraduate students. Lastly, researchers will compare the practitioner and student survey results to identify differences in perceptions about lifelong learning. The outcomes of the mixed-methods study will quantify lifelong learning skills developed during engineering practice and their relationship to career position, which will increase our fundamental understanding about what skills practitioners study as they progress through their career. Identifying gaps in knowledge and perceptions between student beliefs about lifelong learning and the realities of practice will provide insight to the engineering education field about what skills may be lacking or less developed and how future work could further improve engineer formation and preparation.

Award Amount
$33,331

Project Dates
9/2019 – 8/2022

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Immersive Virtual Reality with Haptic Feedback to Improve Safety Hazard Recognition, Assessment, and Decision-Making Among Construction Professionals

Broader Contexts

The construction industry accounts for hundreds of fatalities and hundreds of thousands of non-fatal injuries annually. The current modes of safety training do not effectively prepare practitioners to build safely. Research shows that safety learning occurs to a great extent through experiential learning - especially when individuals experience or witness an injury firsthand. While these experiences may be impactful for learning, it is impossible to wait for all practitioners to sustain (or witness) a serious injury in order to learn safe construction practices. Therefore, this work aims to explore the use of increasingly affordable virtual reality and haptic feedback technologies to provide realistic, yet safe, learning environments that aim to replicate the types of situations where injuries have historically occurred onsite. The research team will develop construction site training modules where participants may navigate a virtual job site with the aim of identifying safety hazards. Unlike prior virtual-reality-based safety training, when hazards go unnoticed, users will see, hear, and feel haptic feedback to simulate the ramifications of the missed hazard. The research team will collect data before, during, and after experimental treatments to determine the extent to which this mode of simulation supports safety learning among users. The team envisions this work providing evidence to guide both researchers and practitioners interested in using enhanced safety training simulations by studying how immersive virtual experiences can impact learners on a psychological level to make them care about safety in order to catalyze learning related to safe construction practices.

The objectives of this research are to (1) create a novel and fully immersive Virtual Reality safety education environment that provides haptic feedback to users when hazards go unrecognized and unaddressed; (2) measure the extent to which instruction in this environment enhances learning outcomes in construction safety compared to traditional media; and (3) measure and explain the psychological mediators of cyberlearning in this multimedia-rich environment. The following research questions guide this study: How can haptic technology be incorporated with Virtual Reality technology to create an immersive visualization experience for construction safety education; and to what extent does Virtual Reality with haptic activate emotional arousal, generate situational awareness, and foster meaningful safety learning through multimedia? The experiment defined in this work will enable testing of explanatory hypotheses that examine the mediating roles of emotional arousal and situational interest in the cyberlearning process. Qualitative findings regarding multimedia learning will be explained using open-ended constructive interviews with the research subjects. This work will provide a novel approach for developing and using immersive cyberlearning experiences aimed at improving construction safety training. This will advance the body of knowledge related to designing cyberlearning environments, and will also provide empirical evidence of the ways in which this mode of education impacts safety learning. In terms of broad impact, this work directly aims to teach behaviors that will reduce injuries and save lives in construction. Furthermore, this work aims to target this form of learning using a scalable and cost-effective medium, which may broaden access to this critical form of cyberlearning.

Award Amount
$250,000

Project Dates
9/2019 - 8/2022

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The Skillful Learning Institute

Broader Contexts

The Skillful Learning Institute is a virtual short course experience for 25-30 engineering educators to expand the explicit engagement of engineering students in their metacognitive development. Such intentional engagement with students, helping them become more skillful learners, is critically lacking at present. Metacognition is instrumental in being able to independently assess and direct one's learning - a lifelong skill to propel ongoing growth and development. As such, metacognition is important for engineers because it empowers them (i.e., builds their agency and self-efficacy) to handle ambiguity inherent in navigating and solving engineering problems. The ultimate goal is to enhance the education of engineers through explicit metacognitive training, and the focus is on educators for their enduring and multiplicative impact on current and future engineering students, and, secondary impacts on their colleagues. The experience is designed to build educators' capacities to teach metacognition and to continue to use and develop engaging metacognitive activities. Intentional elements are included to build a sense of community and mutual support where participants are actively engaged with each other and the facilitators. The aim is to enhance the translation of the resulting metacognitive activities into practice and to develop a lasting community of support after the completion of the short course.

This project will create a diverse virtual community of scholars organized around the desire to see metacognition explicitly integrated into existing curriculum. By eliminating the time and cost of travel, this project will enable populations that might otherwise be limited in attendance such as professional-track faculty, teaching focused faculty, community college faculty, adjunct faculty. In turn, the diverse participants will reach a diverse mix of engineering students with metacognitive training - supporting all students' success. The short course consists of three two-hour synchronous virtual workshops over a six-week period in the summer. These three virtual workshops will use a flipped classroom pedagogy. During the virtual short course educators will be mentored through the design and implementation of one unique metacognitive activity for their context using a backwards design process. At the end of the short course, participants will have an intervention they can use immediately with their students and the skills to continue to design, develop, and adapt additional interventions they believe will be successful in their contexts. This level of personal ownership, emergent from a supportive and scaffolded environment, greatly increases the likelihood of success. The variety of different metacognitive interventions resulting from the project and that have been tried and tested will be captured in a repository for sharing with the engineering education community. Evaluation data will illuminate the effective elements of virtual, synchronous meetings in facilitating a community of scholars organized around metacognition and aid transferability of workshop features.

Award Amount
$39,807

Project Dates
1/2020 – 12/2022

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Building Capacity to Support Career Acceleration and STEM Workforce Development

Broader Contexts

This project aims to serve the national interest by creating and then assessing the impact of a workshop series designed to engage students from underrepresented racial/ethnic groups to consider entering the corporate world. The goal is to build the capacity of the National Action Council for Minorities in Engineering (NACME) to advance knowledge related to broadening participation and STEM workforce development. NACME is the largest provider of scholarships for college students from underrepresented racial/ethnic groups pursuing undergraduate engineering degrees. Through collaborations with partner institutions and corporate supporters across the country, NACME also provides students with other resources and professional development opportunities. Leveraging the NACME infrastructure, the project team will first develop a workshop series envisioned to better prepare students of color (e.g., African Americans, Hispanic Americans, Native Americans) to enter the corporate world. An internship will also be part of the activities. Concurrent with the operation of the series the project team will collect information from participants that can help companies improve student internship experiences. The workshop series will begin before students report to their internship assignments and participating interns will be introduced to coping techniques for navigating corporate environments, including potentially hostile workspaces.

This project will engage an interdisciplinary team of STEM educators, social scientists, industry professionals, and event planners. The proposed activities will be grounded in Career Construction Theory (CCT). CCT is primarily used within career counseling spaces to help people cultivate and apply their vocational self-concept. The specific part of CCT that the research team will use is Career Adaptability Resources and Adapting Responses, which will represent the manner in which each intern is able to cope with workplace challenges and responsibilities. Over the course of the project, the research team will use a two-phase strategy to aid corporate sponsors with offering high-quality internship experiences. Phase 1 will focus on developing, delivering, and evaluating the professional development workshop that is central to this project. Phase 2 will focus on collecting and analyzing additional information about the internship experience from the perspective of the undergraduate students. The overarching goals are to (1) monitor students' development of adaptability resources, vocational identities, and organizational commitment during the internship period; (2) study how interventions offered by NACME impact the internship experience; and (3) identify areas of opportunities for corporate partners to improve the internship experience. These goals will be achieved through a pre-test, post-test quasi-experimental design, followed by in-depth interviews, that are intentionally integrated with the evaluation plan. The intellectual merit of the project lies in its potential to contribute to foundational knowledge related to providing inclusive and welcoming workspaces as students transition from academic settings to internships at technical companies. This project is funded by the NSF IUSE: EHR Program which supports research and development projects to improve the effectiveness of STEM education for all students. Through its Engaged Student Learning track, the IUSE program supports the creation, exploration, and implementation of promising practices and tools.

Award Amount
$79,980

Project Dates
10/2021 – 9/2022

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Developing Effective & Culturally Appropriate Alaskan Housing: Performance metrics for future builds based on an Interdisciplinary Ethnography

Broader Contexts

This SAI EAGER award supports an interdisciplinary team of anthropologists, educators, builders, and engineers investigating the successes and failures of past housing projects in remote Alaskan communities. They are working with local research assistants to combine building diagnostics, local insights, socio-economic data, and culturally specific housing design. The team is working towards the creation of a repository of designs and findings that is available on an open-source platform. The data produced from this study will inform and strengthen future Alaskan infrastructure investments, and the research methods will lay the groundwork for similar research investigations in dozens of communities. The project broadens participation in engineering through collaborative research activities, makerspace activities, and community engagement.

The housing security crisis in rural Alaska, exacerbated by climate change and highlighted by the recent pandemic, places immense burdens on resource-strapped communities. While large-scale investments to address these problems may be on the horizon, there is a clear need for cutting-edge research and socially rich data on rural Alaskan housing to guide future projects and avoid mistakes of the past. This research project tackles this knowledge deficit with an experimental collaboration of experts and community members from inside and outside Alaska who are developing integrated techniques and ethnographically informed understandings of the infrastructural impacts that recent cold-climate demonstration homes have on the lived experiences of Alaskans. The research team is investigating the successes and failures of cold-climate demonstration homes in two distinct eco-regions (inland Brooks Range and coastal Yukon-Kuskokwim Delta). They are integrating ethnographic data with building diagnostics using human factors and engineering methods to assess the performance of construction practices. Data will be shared and co-analyzed during online participatory design workshops involving experts and community stakeholders who are invested in rural Alaska housing security issues. The community approach will reveal experiential knowledge of housing affordances, burdens, and expenses, and will result in a collection of post-design data related to housing security in rural Alaska. Data is also being used to develop performance metrics and guidance for future building projects in formats that meet the needs of communities or agencies. Taken together, these materials are providing content for an eventual design repository. Finally, the integrative methodology developed in this project lays the foundation for longer term research examining additional post-design sites. This project's focus on the effects of the built environment on communities and the generalizability of the methods from the case studies will be replicable not just in other regions of Alaska, but in other appropriate regions of the U.S.

Award Amount
$300,000

Project Dates
9/2021 – 8/2023

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IRES: Multidisciplinary Water Engineering Research and Education to Protect and Enhance Ecosystems in Complex Environments

Experiential Programs

This IRES program will offer water engineering research experiences to civil and environmental engineering students who are making the transition from undergraduate-to-graduate study. Participants will conduct research within one of the leading water engineering units in the world, in some of the finest labs globally, and within extremely complex environments. They will tackle one of three environmental fluid mechanics project areas using field measurements, physical modeling, and numerical methods: 1) Coastal hazard mitigation ecosystem services; 2) Contaminant remediation; and 3) River bed destruction. Each of these areas connect to ongoing research at the University of Queensland sponsored by major government, nonprofit, and industry agencies.

As the strain on water resources and ecosystems intensifies, it is becoming increasingly important to educate engineers to be ready to face complex issues related to water monitoring and management that stretch across national boundaries. The field of water engineering requires a broader educational approach beyond traditional curricula, as today's water engineers face challenging and interdisciplinary issues that combine concepts and methods beyond existing theories and data and instead require a research focus. In addition to the water engineering research component, this IRES program will make important contributions to water engineering education more broadly, as it will produce research focused on how to enhance the education of water engineers and how and why students develop in these kinds of international research experiences.

Award Amount
$299,743

Project Dates
3/2017 – 2/2022

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Energy, Environment, and Future Electric Transportation Systems (E-FETS)

Experiential Programs

Approximately 95% of all land, sea and air vehicles in the world today rely on petroleum to move passengers and freight both locally and internationally. This transportation fuel mix produces ~25% of all greenhouse gas emissions and is projected to grow in the future with modernization of developing countries. International energy agencies note that if transport is to contribute to CO2 reductions to meet the 2 degree C global average temperature target, use of technologies such as hybrid electric and all electric transportation will have to increase in the future. Thus, advances in transportation technologies are clearly a national and international issue, and require globally-minded engineers and scientists to advance interdisciplinary technologies to develop cleaner regional and global transportation systems. Virginia Tech (VT) proposes to expand upon the Future Electric Transportation Systems (FETS) IRES partnership with the University of Nottingham (UoN), with a broadened scope and stronger engagement with industry and the UK government to establish the Energy, Environment, and Future Electric Transportation Systems (E-FETS) IRES program. E-FETS cohorts of ~9 per year will investigate next generation electrical power systems for environmentally-friendly fuels and extraction methods; energy-efficient, hybridized power train vehicles and systems; light-weighting of vehicle structures; and the human factors issues that accompany their use and adoption. Among the broader impacts of this IRES program are the promotion of international research collaborations that foster innovative technical leaders capable of creating and effectively integrating electric transportation systems into our society as a means to address efficient energy use.

E-FETS will provide an intensive ten-week research experience to undergraduates and graduate students with five of the University of Nottingham's internationally recognized research groups. These include power electronics, human factors, geo-energy, composites and manufacturing, and aerospace propulsion and advanced diagnostics. The program will consist of two phases. The first phase includes three pre-departure workshops plus three weeks of mentorship and research preparation at VT to orient students to the experience and the project scope. This pre-departure preparation aims to build the E-FETS student cohort team in preparation for their work individually and together. The second phase consists of 7 weeks at the UoN engaged in concentrated research with UoN faculty mentors and facilities. In addition to supervision from a VT and UoN faculty member, students will work collaboratively as part of a large research team including faculty, Ph.D. students and postdoctoral research fellows. To facilitate additional professional development, students will also be matched with an industry mentor who will meet with the student before, during and after their research experience. These mentors will enhance the students? experience with international career exploration, professional development, and networking in their field and industry. Seminars focused on the scope of E-FETS research goals are planned during each phase of the program, providing students with the opportunity to connect their individual research projects with the unified research theme of E-FETS, and present and get feedback on their IRES experience. By engaging industry partners with IRES projects, the E-FETS IRES seeks to leverage industry and UK government to grow the IRES program and develop a basis for sustainability beyond the grant.

Award Amount
$360,000

Project Dates
3/2019 – 2/2023

EngE Collaborators
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