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Development of an Interdisciplinary Engineering Education Research Approach: The perspectives and lessons learned by two early career faculty

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Introduction

The purpose of this paper is to outline the advantages and challenges of an interdisciplinary collaboration in engineering education research based on our experiences as two early career faculty at Fairfield University, as a social psychologist and a biomedical engineer. While still in an early stage, our collaboration has quickly proven to be fruitful, leading to multiple grant proposals, accepted abstracts, and manuscripts in preparation. We attribute much of the success of this collaboration to its interdisciplinary nature. We bring complementary areas of expertise for conducting rigorous STEM education research: Expertise in conducting research on human behavior (specifically student motivation, learning, and STEM pedagogy), engineering content areas, and STEM program development. Our respective backgrounds and strengths have allowed us to develop novel assessments of engineering learning, while also unlocking large populations for future psychosocial research. When reflecting on this synergistic collaboration, we realized that our interdisciplinary collaboration is relatively unique and is largely absent among our early career faculty peers. In fact, our collaboration itself was an unintended product of participation in a campus-wide professional development workshop. We suspect that the relative absence of interdisciplinary collaborations among early career faculty members may be a consequence of the short-term demands placed on early career members (e.g. course preparations, quick turnaround on publications and other scholarly products for tenure dossiers, etc.) and the often-siloed nature of academic departments. As such, in this paper we seek to highlight the underutilized opportunities of interdisciplinary collaborations for engineering educational research. We have framed this paper as a conversation between the two authors, with each sharing their individual responses to specific prompts to provide personal and disciplinary specific perspectives. We hope that this dialogue approach will allow others to situate our recommendations within the context our specific experiences and collaboration. We conclude with our collective insights, based on our experiences, for other early career peers about the potential benefits and challenges of developing working relationships with peers outside of one's home discipline.

Individual Background

Q: What is your current position, research, and training background?

Dr. Hangen (Social-Personality Psychology): I received my B.A. in Psychology with honors from the University of Chicago, my M.A. in Social-Personality Psychology from the University of Rochester, and my Ph.D. in Social-Personality Psychology and certificate in Quantitative Psychology from the University of Rochester. My current appointment is as a Visiting Assistant Professor in the Department of Psychological and Brain Sciences at Fairfield University and Instructor at the Harvard Extension School. My research focuses on how social contexts (i.e. other people) impact college students' motivation and performance. In particular, I investigate how competing with other people, managing the stress of being evaluated by other people, and handling the pressure of expectations from other people affect college students' approach and avoidance motivation, performance, and well-being. My work is grounded in both the achievement goal framework (e.g., Hangen et al., 2019a) and the biopsychosocial model of challenge and threat stress states (e.g., Jamieson & Hangen, 2020). I use multiple methods to assess students' approach and avoidance motivations such as self-reports of achievement goals and cardiovascular assessments of stress states. My perspective is also informed by a variety of education-relevant motivation theories such as achievement goal theory (Huang, 2012; Hulleman et al., 2012), self-

determination theory (Deci & Ryan, 2012), expectancy-value theory (Eccles, 2009), attribution theory (Kelley & Michela, 1980), and concepts such as sense of belonging (Ma, 2003), grit (Duckworth & Quinn, 2009), mindsets (Dweck, 2006), sense of purpose (Malin, 2022), and more. My ultimate aim is to advance motivation theory while developing targeted interventions that facilitate optimal student motivation, performance, and health.

Dr. Drazan (Biomedical Engineering): I am a pretenure assistant professor of Biomedical Engineering at Fairfield University. I received my undergraduate degree in Physics from SUNY Geneseo, my PhD in Biomedical Engineering at the Rensselaer Polytechnic Institute, and completed a postdoctoral fellowship at the University of Pennsylvania in the McKay Orthopedic Research Laboratory. My biomedical engineering research is focused on the development of mobile tools and research approaches to measure human-subject musculoskeletal data outside of the confines of the traditional research laboratory. As a postdoctoral fellow, I worked primarily developing tools for patient assessment in orthopedic clinics, however, as an independent researcher, I have begun incorporating musculoskeletal measurements into community-based venues. I am primarily interested in studying the link between muscle structure and muscle function, especially in the plantar-flexors, using a combination of wearable sensors, ultrasound imaging, and devices such as isokinetic dynamometers.

Q: How did you get involved with engineering education and engineering education research?

Dr. Hangen (Social-Personality Psychology): My experience with engineering education is limited, but my area of expertise includes conducting education research in STEM disciplines. For instance, I have published work showing how stress reappraisal improves math exam scores of community college students in a remedial math course (Jamieson et al., 2016) and improves male students' scores in a math competition (Hangen et al, 2019b). I also am currently working on projects examining the role of stereotypes for the motivation and math performance of female students and students of Asian heritage.

Dr. Drazan (Biomedical Engineering): In addition to my technical training, engineering outreach and education has been a major theme in my scholarly development. As an undergraduate, I was a varsity basketball player and one of my teammates, John Scott, created a non-profit called 4th Family Inc in 2011 after he lost one of youth basketball players to gun violence. I became involved with the non-profit in 2012 during my first year of graduate school. John Scott was coaching high school basketball and he asked if I was interested in getting involved with coaching and running a STEM tutoring program for his players. As I coached and tutored, I realized that the best way to engage these youth athletes in STEM learning while also improving their on-court performance was to combine my background as a developing engineering researcher in biomechanics with my love of basketball. I began creating analytical training programs for my student athletes, as a way to improve performance while also reframing previously dry and inaccessible STEM content within the context of basketball. I began performing additional outreach in the community and created my program called "Science of the Slam." As a result of this work, I received a National Science Foundation GK12 Fellowship through the 3Helix program under the direction Ron Eglash, a social scientist focused on the development of culturally-situated STEM educational tools. This cross-disciplinary experience as a trainee introduced me to perspectives outside of engineering, and also demonstrated the importance of educational assessment for STEM education programs like my own. It also introduced me to the idea of engineering education research, which led me to begin treating my outreach programs as research opportunities to better understand how and why my

programs worked, and increase my ability to scale these approaches. I began assessing my programs and publishing on my findings in variety of venues, including educational conferences, as well as discipline specific conferences and journals.

Current collaboration

Q: How experienced are you with interdisciplinary collaborations and how did it prepare you for this collaboration?

Dr. Drazan (Biomedical Engineering): One of my favorite aspects of engineering is developing solutions in response to user needs. As a biomedical engineer I have the opportunity to work with clinicians on a regular basis for both research and education projects. In these projects, there is a bidirectional flow of value. The clinician receives a tool or analysis pertaining to patient care and I get to collect relevant research data, test a device, or provide a meaningful educational experience for my students. In the vast majority of these prior collaborations, I am not the practitioner, I am coming into a situation to apply my engineering expertise to a pre-existing problem or situation. What is different and exciting about this collaboration with Dr. Hangen is that, in this case, I am the practitioner with a problem or unmet need, and Dr. Hangen gets to apply her research expertise in social psychology to help address my identified research issues. This collaboration fits the overall patterns of my prior work, with the roles reversed.

Dr. Hangen (Social-Personality Psychology): As a social psychologist who studies student motivation I anticipated collaborating with colleagues in education departments. While in graduate school I took elective courses through my institution's education school and I have situated myself to be in contact with education researchers as a member of the American Education Research Association (AERA) and conference participant at AERA's annual conferences. I generally seek out fellow scholars who have vested interest in pedagogy such as other psychologists in neighboring subfields (e.g. cognitive psychology, development psychology, etc.) and in technological pedagogy (e.g. discussion principles of student motivation in design of remote courses with colleagues at HarvardX). However, my research-productive collaborations have almost exclusively been with other psychologists before this.

Q: From your perspective, how did this collaboration come about?

Dr. Hangen (Social-Personality Psychology): I met Dr. Drazan at a university-wide faculty development workshop. Dr. Drazan was a roundtable speaker on the topic of effective undergraduate mentorship. Although I have experience mentoring undergraduates, as a visiting assistant professor my time and resources for research had been limited, and I wanted to get my mind back into setting up a productive lab working primarily with undergraduates. I appreciated Dr. Drazan's mindful approach to mentorship– a thoughtful balance of logistics and how to make the experience mutually beneficial for both mentor and mentee.

During the workshop I shared that my area of research expertise was in college student motivation and Dr. Drazan mentioned he had developed and was successfully running a STEM outreach program. When learning about his STEM outreach program, I recognized the value of the work he was doing and its intersection with my work on student motivation. He shared that he was looking for someone who had

skills in program assessment and evaluation to join the project as a way to more formally investigate the effectiveness of his program, so we agreed to discuss more about a potential collaboration.

Dr. Drazan (Biomedical Engineering): I lead an active undergraduate driven research program at Fairfield and I was invited to serve as a moderator for the Faculty Development Day in May 2023. The focus of my group was discussing effective undergraduate mentoring in research. This is a topic that is close to my heart and I have given several talks/workshops in my national societies on the topic. I checked the date and said "Sounds great!" There were several rotating rounds and Dr. Hangen was in the last group. Over the course of the group discussion, I shared several different ideas/approaches that I use in managing my research lab of 8-12 undergrads and facilitated an idea generation session for next steps. Dr. Hangen stuck around to discuss a few more things regarding her own social psychology work. The more we talked, the more excited I got because I realized that Dr. Hangen's expertise in motivation theory and assessment was a nice compliment for my own research in engineering education and outreach. I had not met Dr. Hangen before and I asked how she was settling in as a first-year faculty. I was very surprised to learn that she had been on campus the past two years (just as long as I had been). We had just never happened to meet. This highlights a challenge associated with the developments of inter-disciplinary collaborations, it can be difficult to meet researchers outside of your discipline, even while sharing a campus.

Q: How are you collaborating and what are some of the products of your collaboration?

Dr. Drazan (Biomedical Engineering): I have experience with developing assessments, STEM educational programs, and I have a 3-3 teaching load which is higher than most other faculty in the orthopedic research field. In community partnerships, I am often the only stakeholder with experience with statistical testing, IRB approvals, or anything related to academic research. As such, in the circles that I traditionally work in, I am often one of people who needs to perform these tasks. When I began collaborating with Dr. Hangen, I was very excited to work with someone who could authentically use the programs and approaches that I use as a venue for their own research, thereby performing high level assessment to demonstrate efficacy, while also bridging the gap between what our programs do in practice and academic research. Dr. Hangen has been invaluable in developing new, validated assessments for different programs, both in the classroom with college students in an introductory engineering course, and for larger outreach programs in the community.

Specifically, our first collaboration was having Dr. Hangen assist with the final report of an engineering education grant for updating curriculum in our Fundamentals of Engineering class in the School of Engineering and Computing. We had administered surveys as part of the program evaluation and assessment, and I was in the important, but time consuming, process of analyzing the student responses for the final report. After meeting Dr. Hangen, I realized that she could do a much better job, in half the time. We had unused money in the grant for evaluation, and I was able to pay her a small stipend to complete these analyses. Following submission of the grant report, we had a meeting to discuss best practices moving forward and I realized that she was an ideal collaborator for not only the assessment piece, but also in development of theory grounded interventions for future programs

Dr. Hangen (Social-Personality Psychology): Currently Dr. Drazan and I meet weekly to advance our work. Within 11 months of beginning our collaboration we have worked across at six projects which have resulting in various scholarly products such as a co-authored podium presentation at the Orthopedic

Research Society Annual meeting that was recognized as a Finalist for the New Investigator Recognition Award (NIRA), co-authored a manuscript on a sports biomechanics STEM outreach intervention (in prep), and as co-PI's (along with another colleague) a National Science Foundation S-STEM proposal. These early, tangible, outcomes have laid the groundwork for future projects and collaborations at the boundary of our respective fields.

More broadly, I have noticed a generative and complementary nature of our collaboration. I contribute my scholarly expertise in motivation theories and quantitative skills of assessment to validate and assess the interventions Dr. Drazan has designed. Dr. Drazan contributes well-designed interventions and a far-reaching platform for practical impact and implementation of such theories.

Challenges and Benefits of this Current Collaboration

Q: What are some of the challenges you have found in this collaboration due to its interdisciplinary nature? (specific to this collaboration)

Dr. Drazan (Biomedical Engineering): I think one of the most exciting/challenging aspect of this new cross-disciplinary collaboration is learning and navigating discipline specific knowledge and standards. While I may think that a motivational research question within the context of my teaching or outreach work is novel, there is a good chance that it is very well-established in motivational psychology. It can be somewhat deflating to learn that the exciting project I have been tirelessly working on represents, at best, the reinvention of the wheel in terms of contributions to the literature of motivational psychology. This is not to say the work is not meaningful, but there are differences between fields that need to be accounted for when beginning new collaborations. Navigating these initial challenges are important because, while difficult at the start, it sets the stage for meaningful projects down the line. As an engineer, my research is very translation and application focused. I want to develop solutions, validate them, and disseminate my findings/devices/programs through the literature, community partners, and clinicians. As a STEM education practioner, I am even more focused on the implementation portion where I really want to learn what works and put it into practice. I view publications as a way to disseminate my practical approaches to a broader audience, rather than as contributions for fundamental research into the science of motivation or social psychology. Situating research collaborations such that methods and analysis are applicable across disciplines is very important.

Dr. Hangen (Social-Personality Psychology): When working together, it is common for Dr. Drazan to mention a concept, term, or person that is common in engineering education, but uncommon in my field. This means I learn a lot working in this new collaboration and also that I am required to learn a lot in order to effectively work in this new discipline. We spend a fair amount of time asking for clarifications and explaining field-specific jargon, acronyms, or other unfamiliar terms for the other. In this interdisciplinary collaboration there is what could be described as a mild communication barrier because we are accustomed to using discipline-specific jargon.

I have also been surprised to discover the many ways fields can differ from each other–not only in content, but in methods used and slightly different norms and values when it comes to publishing work. In running analyses of shared data, not only do Dr. Drazan and I have our different preferences of

applications and software used to manage and analyze data, but more substantially, our familiarity and choice of what statistical analyses can differ.

Q: What do you think are the benefits of this interdisciplinary collaboration?

Dr. Drazan (Biomedical Engineering): It has been wonderful working with Dr. Hangen and it has significantly improved a lot of my own projects. I remember being introduced to the concept of "Comparative Advantage" within the context of high school economics. To attempt a somewhat tortured explanation, take two people, person A and person, who both need a shirt and a pair of shoes. It takes person A 3 hours to make a pair of shoes, and 1 hour to stitch a shirt, while person B takes 1 hour to make a pair of shoes, but 3 hours to stitch a shirt. If they worked apart, without collaborating, it would take 4 total hours each for them to get both a pair of shoes and a shirt. If they collaborate to focus on their comparative advantages (person A makes 2 shirts and person B makes two pairs of shoes) and trade, they both get what they need in only 2 hours. Now replace pairs of shoes and shirts with content in engineering education research and hopefully you will see where I am going with this.

While I am familiar and can apply different assessment techniques to my own programs, my strengths lie in program development and implementation, teaching, and biomedical engineering research. On the other hand, Dr. Hangen is an expert in survey design, motivational theory, and program assessment, however, I am not sure if she would be well positioned in the near term to run an 8-week informal STEM program with 100 middle school children. By capitalizing on our relative comparative advantages, Dr. Hangen can get really unique opportunities to test theories and collect data relevant to her field, while I can get better, faster, and more expert assessments of my work that, if I performed them, would take me away from the things I am good at and that I really enjoy doing. I have found this collaboration to be a significant force multiplier, allowing me to be significantly more productive in terms of proposals, manuscripts, and project implementation, simply because having an expert collaborator in assessment and theory allows me to focus on my own comparative advantages.

Dr. Hangen (Social-Personality Psychology): I can point to many professional benefits I have received through this interdisciplinary collaboration. One is my own enhanced productivity. In my current role as a Visiting Assistant Professor, it can be difficult for me to find the time and resources to advance my research while managing a heavy teaching load (4-4+). Working with productive collaborators helps me by lessening the work, providing momentum, and offering accountability so that I do not defer research progress in favor of short-term teaching responsibilities. Due to my collaboration with Dr. Drazan I have manuscripts in preparation and grant proposals submitted or in progress that I otherwise would not likely have undertaken on my own. Furthermore, as an interdisciplinary collaboration, I have broadened the range of journals to which I submit and the organizations from which I apply for funding.

An unexpected secondary benefit of this interdisciplinary collaboration is my heightened awareness of my unique expertise even within academia. Too often when I am surrounded by peers in my discipline who have similar training, I become slightly blinded to the unique skills and knowledge I have and the contributions I can make more broadly. In working with Dr. Drazan and consulting with others in the school of engineering and computing, I have begun to more fully recognize the scholarly and practical value of my research lines (e.g. scientifically-validated strategies for improving individuals' motivation)

and my needed skills (e.g. advanced data analysis, scale development and validation, etc.) that I previously underestimated.

Lastly, working in an interdisciplinary collaboration has reminded me of the original reasons I chose to become a scholar and clarified for me the ultimate aims that guide my research interests. I can all too easily get caught up in the publish-or-perish pressures and lures of prestige that can accompany research productivity which can cloud my long-term ambitions of the practical impact I wish to make. Our collaboration was developed because we had a shared underlying vision of having a practical impact on improving STEM education instead of being developed out of shared methodologies and approaches.

Q: From your perspective, what does this collaboration add to your existing work?

Dr. Hangen (Social-Personality Psychology): Collaborating with Dr. Drazan is extremely helpful to furthering my existing work on understanding and intervening on college students' motivation in STEM disciplines. My work focuses on identifying underlying motivational processes that explain how students' mindsets and circumstances (e.g. classroom environment, the particular instructional practices they receive, etc.) have an impact on their academic performance and health. Dr. Drazan's role as an engineering educator offers me an opportunity to test motivation theory and implement findings in a context that has real-world practical impact (e.g. current and potential engineering students). Additionally, Dr. Drazan's development of a STEM outreach program and securing the logistical resources necessary for broad implementation, allows me the opportunity to both measure this program's impact and to investigate the underlying processes in order to advance our understanding of motivation and intervention design. Lastly, working with Dr. Drazan expands my existing work by assisting me in generating novel ideas about why certain STEM interventions work.

Dr. Drazan (Biomedical Engineering): As a biomedical engineer, I am very interested in developing a mechanistic understanding of the systems that I am working with. When I first began my STEM outreach programming 10 years ago, I developed programs that I thought would engage and benefit the student athletes that I was working with, primarily based on my understanding of sports as a former collegiate athlete. Looking back, I was more or less "going with my gut" in terms of program development. Collaborating with an expert in motivational psychology has helped me develop a more mechanistic understanding of how and why my approaches work, as well tailoring assessments to gain a mechanistic understanding of the program. This mechanistic understanding of student motivation has helped me develop new programs more effectively.

My work with Dr. Hangen has also given me some new ideas for my more technical work on clinical problems. For example, I have been involved in projects with clinicians in the past to develop take-home devices to monitor patient recovery and activities after surgery. One benefit for these devices is that the act of recording data may improve patient compliance with a specific recovery regimen. My work in motivational theory in STEM education with Dr. Hangen has gotten me thinking about how motivation, data collection, and device design could all intersect to address real-world issues in patient recovery. I feel like a have a deeper understanding of user-focused design now as well as a person to bounce ideas off of.

Thoughts about Interdisciplinary Collaborations in General

Q: What do you see as general barriers to collaborating across disciplines for academic researchers?

Dr. Hangen (Social-Personality Psychology): A major barrier I have noticed for interdisciplinary collaboration is the limited opportunity to find potential collaborators because education institutions are usually subdivided by disciplines. In my own experience, the conferences I attend and the scholarly societies I associate with, tend to bring together scholars from within my shared discipline. Even on a daily basis, I am more likely to physically cross paths with faculty within my own department. Quite simply, as academics we tend to move about in discipline-specific spaces and this offers fewer opportunities for us to learn about the work being done by faculty outside of our disciplines. Even when there are events that bring together faculty across disciplines, I have found that these events typically do not foster conversations on shared research interests but instead center on non-specific discipline topics such as faculty governance, pedagogy, or strategies for scholarly productivity. Ultimately finding an interdisciplinary collaborator typically requires individual initiative because there are few systems, if any, that foster interdisciplinary collaboration.

Another potential barrier to interdisciplinary collaborations is lack of awareness of the compounding benefits of interdisciplinary collaboration. Perhaps these benefits are underestimated because they are time-lagged and overshadowed by the more immediate and readily apparent costs of interdisciplinary collaboration. Indeed, there is upfront labor required in interdisciplinary collaborations that is relatively absent in within-discipline collaborations, such as overcoming the lack of shared knowledge, terminology, theory, and scholarly conventions. Unfortunately, I think these challenges tend to discourage scholars from seeing interdisciplinary collaborations as not just viable, but even desirable, by masking the subsequent and unique benefits of interdisciplinary collaboration (see Table 1 for list of benefits).

Dr. Drazan (Biomedical Engineering): An analogy that I have found useful in thinking about collaborations are chemical reactions. There are three key points that I think make this analogy useful, 1) Activation energy, 2) Chance of reactants coming into contact, and 3) The presence of catalysts. For a reaction (or collaboration) to occur, the activation energy, a threshold amount of available energy (or effort), must be reached. If this threshold it is not reached, the reaction does not occur, in effect wasting the mustered energy. I believe that the activation energy for collaborations within a given discipline is lower than cross-disciplinary collaborations. After all, within a given discipline, we are already familiar with specific jargon, have agreed upon methods, and share publication venues, granting agencies, and a literature base. Therefore, I believe that intradisciplinary collaborations take less time and effort to form, which reduces the risk of wasted effort and time for both parties if a collaboration does not work out. It is also easier to meet people and be aware of overlapping research interest due to shared networks within a discipline. As such, there is a higher chance that potential collaborators (reactants) within the same field will happen to come into contact with each other to form the basis for a collaboration (reaction). Finally, just as the presence of a catalyst can reduce the required activation energy for a reaction to occur, support and incentives for early stage collaborations make collaborations easier to form at the outset. As intradisciplinary collaborations are the norm, there are a number of catalysts available, such as small pilot grants from discipline specific organizations or co-advising a research student, but it is more difficult to find catalysts for interdisciplinary research collaborations. Taken together, the time of early career faculty is limited and the stakes are high in terms of tenure and promotion. Interdisciplinary research collaborations can be risky due to a higher activation energy, the effort required to find suitable collaborators, and the relative dearth of easy to find catalysts to get a collaboration started. These issues

are especially difficult for starting research collaborations in engineering education projects for pre-tenure engineering faculty because of the importance of contributions in technical engineering research relative to educational research in the tenure and promotion process.

Q: Who do you think would benefit from interdisciplinary collaborations and who would might not?

Dr. Hangen (Social-Personality Psychology): I think individuals who prioritize either high-quality scholarly output or who aim to have a practical impact can especially benefit interdisciplinary collaborations. Some of the major benefits I see to interdisciplinary collaborations involve greater clarity and increased novelty of research ideas. Although idea novelty can occur without interdisciplinary collaborations, such collaborations can more readily foster creativity. Furthermore, by using the comparative advantage of working with someone with a different background of training can lead to higher-quality work because each person is operating more exclusively in their niche area of training. Additionally, in my own experience I have found that interdisciplinary collaboration is hugely beneficial for increasing the practical impact of my work. By stepping outside my discipline, I am able to disseminate my findings to a broader audience and implement motivation theory into STEM interventions that directly impact students.

Despite my positive experience with interdisciplinary collaboration, I recognize that it may not be suitable for all scholars. In particular, early-career faculty whose tenure requirements do not flexibly accommodate or recognize the value of interdisciplinary products would likely disadvantage themselves by pursuing interdisciplinary work pre-tenure. That said, early career faculty could also be some of the biggest beneficiaries of the compounding benefits of interdisciplinary collaborations because once the ground-work is laid, interdisciplinary collaborations can offer more funding opportunities, enhance the reach and recognition of one's research, and be highly productive at a time when career livelihood is more contingent on scholarly productivity.

Dr. Drazan (Biomedical Engineering): I believe that interdisciplinary collaborations have potential to provide significant benefits for most researchers. We can't be expert at everything relevant to our research and time is limited. Interdisciplinary collaborations allow researchers to exploit the comparative advantages of our respective fields such that we maximize on our respective expertise. Depending on tenure expectations and culture at a specific institution, the degree of novelty, risk, and scope of a new collaboration has to be considered by early career faculty.

Conclusion and recommendations

We believe that interdisciplinary collaborations represent a highly valuable, but underutilized avenue for productive research among early career faculty. Just as few research projects are identical, there are a wide variety of different collaboration opportunities which are not easy to generalize across all situations. As such, we have provided significant context for our individual backgrounds, research interests, and goals, generated and presented independently, to situate our collaboration within our specific experiences. This approach facilitated a discussion between us to identify challenges, solutions, and benefits that we hope are generalizable and actionable for our fellow early career faculty. (see Table 1).

In conclusion, we recognize that interdisciplinary collaborations present unique challenges and require greater upfront initiative than traditional intradisciplinary collaborations. We have found our

interdisciplinary collaboration to be highly productive, generative, and worthwhile as our areas of expertise complement each other. Dr. Hangen's expertise in student motivation and assessing student motivation, learning, and behaviors complements Dr. Drazan's expertise in biomedical engineering, engineering pedagogy, and STEM outreach. We have found that well-conceived interdisciplinary collaborations are highly synergistic and often undervalued and underutilized. We encourage other early career faculty members to consider intradisciplinary research and to consider the recommendations we have offered and benefits we have experienced.

Table 1. Common challenges, respective solutions, and benefits of interdisciplinary collaboration for Engineering Education research

Challenge	Recommended solutions	Benefits
Finding a collaborator outside one's discipline	• **Put yourself out there:** Seek out and attend events that draw faculty across disciplines (university-wide events, interdisciplinary conferences, etc.) • **Talk about your research:** When encountering faculty outside your department, inquire about their research projects and share information about your research and interest in finding an interdisciplinary collaborator. • **Scout Opportunities:** Examine faculty profiles and reach out to faculty in disciplines that have complimentary expertise for a given project. • **Build a network:** Connect with faculty of different disciplines, even if they aren't a potential collaborator, they could introduce you to someone else!	• Interdisciplinary collaborations can offer benefits that complement and cannot be replicated in traditional disciplinary collaborations (see benefits stated throughout this table). • Expanded network of resources (funding, collaborators, participants, etc.) because resource networks are likely less overlapping with interdisciplinary colleague than with colleague from within same department or discipline.
Additional time required to find and develop interdisciplinary collaboration	• **Get early wins:** Begin with projects that have short-term individual benefits for both persons so if interdisciplinary collaboration does not continue the time and effort spent remains worthwhile (e.g. honorarium, co-authorship in publication outlet that are individually valued, etc.) • **Don't do too much too fast:** Test out potential interdisciplinary collaboration with small projects (e.g. pilot study, act as consulting author, conference poster) and be quick to discontinue costly collaborations or build a foundation for effective collaboration before committing to larger projects (e.g. joint external grant submissions, etc.)	• Comparative Advantage: Time is saved on projects that have aspects to them that are more easily completed by an interdisciplinary collaborator and this time advantage only compounds across projects (e.g. psychology faculty saves time designing complex online simulation by collaborating with computer scientist, engineering faculty saves time developing scale and assessing student performance by collaborating with education research or psychologist, etc.)
Navigating differences across discipline	• **Be curious, not judgmental:** Establish a norm early on with collaborator of asking for clarifications when unfamiliar terms and approaches are introduced. • **Allocate Time:** Plan for additional time in meetings (at least early on in an interdisciplinary collaboration) to clarify and explain discipline-specific jargon and especially discipline-specific conventions. • **Humility is key:** Recognize boundaries and limits to your expertise and value what each collaborator brings to the table.	• Expanded perspective about one's own research by examining one's work from a different lens • Better able to communicate the value of one's work to people outside of one's discipline (particularly useful in securing external funding) • Deeper clarity about one's own research ideas as a result of articulating them in greater depth • -Heightened awareness of one's unique expertise and contributions
Optimizing scholarly output for all involved	• **Be up front:** Discuss early on what publication outlets will be targeted and consider each collaborator's outlet requirements for tenure, alternating discipline-specific outlets, etc. • **Be transparent:** Disclose ideal outcomes of the collaboration for your career goals and future work.	• Research has broader reach; research findings can be disseminated to audiences that otherwise would not have been exposed to your research • Documentation of interdisciplinary collaboration can be seen as a strength supplementing within-discipline work

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