

Summary

Early in my career, I focused on discipline-specific research, primarily in the areas of wireless communications and signal processing. My graduate studies, a job in the industry, and then continued academic-professional research provided amazing experience, resulting in grants, a US patent, and valuable publications. This background provided me with rich experiences to take into the roles of teaching and undergraduate advising. Now engaged in the science of teaching and learning, I both receive and provide training and materials locally, nationally, and internationally.

My research has been supported by grants from NIH, NSF, ARO, and SIIP/Wider. I support both curricular and extracurricular research by hundreds of undergraduate students each semester. I have regularly produced publications on various aspects of my research, primarily at the conference level. I have had even larger impact in my involvement with industry such as National Instruments (NI) and Texas Instruments (TI) and other universities including University of California, San Diego (UCSD), International University, Ho Chi Minh City, Vietnam, and Zhejiang University-University of Illinois Joint Institute. I also have the resources to promote best practices through my role as an Education Innovation Fellow (EIF) of Academy for Excellence in Engineering Education (AE3) and as a part of KEEN's Engineering Unleashed.

Contributions to Pedagogical Research

Over the past ten years, I have engaged primarily in pedagogical research. In this work, I emphasize that hands-on activities along with student autonomy improves student engagement. As a teacher, I found that *the allowance of choice, alone, cannot be motivating when students fail to see underlying connections between course content and their own personal interests*. I conceived and implemented an innovation in teaching and learning, now referred to as "content personalization." Developed and researched under an NSF grant, content personalization involved regular surveys for the students on high-level concepts and how those concepts appeared in their everyday lives or within their majors. Content personalization has been shown to build self-efficacy (published in IEEE Transactions on Education).

I have also co-developed a technique for applying second-chance testing. Taking advantage of students' motivation for learning caused by a recent "unsatisfactory" exam grades, the retry exam first requires students to complete a practice exam, then return to the exam center to attempt a new (randomized) version of the exam. While retry exams themselves are not new, our implementation mandates the taking of the practice exam as a mastery-improving task while simultaneously discouraging students from relying on the retry score by using a weighted scale. Students are able to improve their score by a weighted sum of the original and retry exam scores with the largest improvements available to those students with the lowest original scores. Second-chance testing increases assessment frequency for those who need it and can leverage summative assessments as formative assessments. While benefits and hurdles surrounding second-chance testing are known, our method for implementing second-chance testing has eliminated most of the hurdles while retaining the benefits and serves as a model for other courses. I will present results at this summer's ASEE 2020 Virtual Conference.

My pedagogical research has resulted in publications and conference presentations. However, more importantly, it has engaged our students more fully and caught the attention of other universities worldwide. Other universities have recognized the value of what I have implemented at the U of I and have reached out to me to partner with them. In addition, students have recognized the value of content personalization and are motivated to start their own projects, looking to me to be their resource and mentor.

In ECE 463, Digital Communications Laboratory, I was one of the first RF courses to move towards software-defined radio. Our work caught the interest of both NI and UCSD. I presented the material to other educators through NI and provided it for course development at UCSD.

I redesigned ECE 110 *Intro to Electronics* from the ground up, and I continue to serve as course director. To assist, a Community of Practice was constructed to look at course redesign with strong attention to best

practices in teaching and learning (please see my Teaching Statement). As a result, Zhejiang University-University of Illinois Joint Institute (ZJUI) duplicated ECE 110, using all course materials I developed and under my continuing mentorship. Our course redesign has found success in that it is attractive to students and, somewhat surprisingly, is becoming an attractive teaching assignment for faculty despite its large roster.

Our Community of Practice submitted and received a three-year grant from Grainger College of Engineering's AE3 Strategic Innovations Initiative Program (SIIP). Our high-level goals were to implement several evidence-based best practices in teaching and learning to the courses strengthening student engagement and learning while improving student retention. I co-designed Merit sections for both ECE 110 and ECE 120 to improve sense of belonging and improve retention for underrepresented students. In Merit sections, students work in teams on challenging materials related to course topics to form community as well as confidence in their abilities.

I co-designed a hardware-based James Scholars Honors project that serves both ECE 110 and ECE 120. Together, students from these two courses work in teams on open-ended projects. This project originally was ran by the course instructors, but through many years of adaptation, it is now operated by undergraduate course aides under my guidance. The course aides serve as strong mentors to their fellow undergraduates and have expanded the project opportunity to include workshops on 3D printing, soldering, laser cutting, and printed circuit board design. Often serving 60-80 students, these students are better prepared for "doing" engineering throughout their undergraduate experience. In addition, the experience gained by the undergraduate staff in operating the James Scholar program has provided them technical and organizational skills well beyond the traditional academic training (see, for example, the new RSO "Zero2One").

By encouraging students to construct projects around personal interests in such a large course, I suddenly found myself inundated with requests for undergraduate research which I gladly mentor. One of these students, Jimmy He, became the student "founder" of an undergraduate research team, *WaggleNet*. As an amateur beekeeper, I wanted to extract information from a working honeybee colony without disrupting it. The student, who had experience with the Internet of Things from his own personal hobbies, took off with the idea. *WaggleNet* soon became a popular sensation for undergraduates, contributing to many different aspects of a startup-like business. Unlike a startup, however, there are not profits and no income. Surprisingly, most students continue the work on the project without credit through Individual Study. They instead work because they enjoy the autonomy of the research and design and understand that it provides something that the typical classroom cannot. *WaggleNet* has provided valuable research tools to the Carl R. Woese Institute for Genomic Biology (IGB) with Dr. Gene Robinson as well as the Dolezal Bee Lab with Dr. Adam Dolezal. I continue to serve as mentor and steering committee for *WaggleNet* as well as providing honeybee colonies for data collection.

Another undergraduate student, Johnny Chang, attributes his training as a course aide in the ECE 110/120 James Scholars Project plus his membership in *WaggleNet* as the impetus for starting a new RSO called *Zero2One*. *Zero2One* serves as a "technology project incubator community with students from engineering, business, and design" where students and professors across disciplines work on project ideation and assist in moving them forward. Although less than a year old, *Zero2One* is evolving and growing quickly. I continue to work as a mentor to this organization and am looking forward to great things from this group.

To conclude my impact in pedagogical research, I'd like to emphasize my role as a leader in Engineering Education through my role as an EIF for AE3 and in the department as a leader in our own Community of Practice. I have offered my own innovations in content personalization to enhance satisfaction in the selection of projects as well as in using open-ended design though out all of my courses as an engagement tool. Finally, I have furthered this engagement of students by providing guidance, support, and autonomy outside the classroom for Individual Study, James Scholars, MRDC, Zero2One, and WaggleNet. The value of my work has been recognized by the Grainger College of Engineering, the Department of Electrical and Computer Engineering, a large number of undergraduate student researchers, and the recruiters of those students.

Educational Materials

Free online education is a valuable resource in today's world. Most of the materials used in my courses have always been made available in online format and some have been published on academic centers like the academic bundle provided by NI or Connexions through Rice University. They can also be found in hardcopy form by Stipes Publishing. Some of the more-visible contributions are listed and described below.

- By providing my ECE 463 lab procedures and code as well as illuminating lab experiences to Prof. George Papen at the UCSD, I sped his development of an RF lab and spawned a multi-year course collaboration.
- I shared my experiences with several thousand people as part of the keynote address and presenter session at NI Week and co-hosted (with Prof. Papen) at NI's RF Summit.
- I co-authored a free online textbook that is concise and complete, available to instructors worldwide.
- Free online lecture slides also available through Stipes Publishing provide new instructors stated learning objectives and a model for achieving them while presenting content drift.
- Free online modular lab series, also available through Stipes Publishing, allow for weekly autonomy in student choice over parts of the material and culminates in an end-of-term open-ended design.

Impact

Below, I have outlined my known impact across the world.

Departmental

- I have made ECE 110 both a showcase and a model to the department on best practices in teaching.
- I lead the local Community of Practice in ideas for course improvements through best practices and innovations in teaching and learning.
- I train and lead approximately 20 TAs, 40 undergraduate course aides, and 3 instructors at the University of Illinois each semester.

College & Campus

- I serve as an AE3 member to evaluate and award SIIP grants.
- As an EIF, I promote teaching excellence through mentoring SIIP teams.
- I support collaborative research between *WaggleNet* and IGB as well as with the Dolezal Bee Lab.

National, Academic, and Industry

- I provided course materials to the UCSD to form the foundation of their own RF course.
- I was a keynote contributor and session presenter at National Instrument's yearly conference.
- I co-hosted a presentation at National Instrument's RF Summit event for RF educators.
- I contributed to the development of National Instrument's RF Academic Bundle.
- My Content Personalization technique studied under NSF grant was shown to improve self-efficacy.
- I am working with TI to generate an analog component to their online robotics training materials.

International

- I spent two weeks at International University, Vietnam, to train staff on the use of equipment and provide advice regarding RF course development.
- I provide the course infrastructure and mentor the ECE 110 staff at ZJUI in China.
- *WaggleNet* has begun to distribute hardware and software solutions to honeybee monitoring enabling researchers and beekeepers to aid the plight of these important pollinators.

Conclusion

My research in pedagogy over the past ten years has been instrumental in teaching and mentoring tens of thousands of students. But beyond this, it has allowed me to become a resource to students and instructors within the University of Illinois family, who are continually pushing beyond the borders of the Urbana-Champaign campus. It has also allowed me to become recognized worldwide as a resource in course development and the science of teaching, and I look forward to continuing my work with other US and international universities and industry leaders.