I create learning environments that provide undergraduate and graduate students with opportunities for authentic practice in design, technology, and research. Such practice is often lacking in the classroom yet is crucial for preparing students to design and implement innovative solutions to social and technical problems upon graduation [2]. These opportunities for authentic practice help students develop deep subject-area expertise, but more importantly, explicitly support students to build *regulation skills*, i.e., cognitive, metacognitive, motivational, emotional, and strategic behaviors for reaching desired goals and outcomes [3]. Regulation skills help students plan, execute, overcome challenges, seek help, and reflect. Regulation plays a crucial role in student learning, but also in how students view themselves as learners. My goal is to design learning environments that support students growing over time, and throughout their lives.

Design, Technology, and Research (DTR)

I founded and direct Design, Technology, Research (DTR), a research program and learning community that supports about 20 undergraduate and graduate students learning to self-direct complex work through independent research across multiple quarters.[1,2] Students' research projects are broadly in the area of human-computer interaction (HCI). All DTR students, regardless of seniority, conduct independent research and receive authentic research practice. By authentic research practice, I mean that students lead all core research activities, including creating research plans, forming research arguments, building prototypes and systems, designing studies, and preparing manuscripts. To enable novice researchers to drive complex research projects, I teach students effective representations and processes for thinking about their research problem and solution space through *research canvases* that I have developed. Through weekly planning meetings and coaching sessions, DTR students learn how to lead their own projects, to thoughtfully formulate plans for next steps and present them to peers and mentors. They learn how to recognize risks and obstacles in their research, and to devise strategies for overcoming them.

DTR students learn to not only rely on themselves, but to collaborate and learn from others. Students learn that self-directing complex work benefits from having a supportive community, and that self-direction requires learning to allow others to help you. To support DTR's culture of help-seeking and collaboration, I created the pair research (http://pairresearch.io) platform, which engages students to identify their needs and who they can help, to then automatically pair up students who can best help one another in any given week. In a quarter, my mentees can receive support on a variety of needs that arise in their research (e.g., coding, study design, writing, prototyping) from a dozen of their peers. This service to others, and community mentality that "it takes a village" results in a very different learning environment than much of academia, where excessive and unhealthy competition can lead to isolation and negative experiences that deter students from continuing in research, computing, or even STEM.

Through DTR I have mentored 160 students to self-direct independent research (76 since tenure). 73 of my mentees are female (46%), far surpassing the national average of 22% as reported in the latest CRA Taulbee Survey. My students published 28 papers at major computing research conferences (13 since tenure) and placed at 7 major student research competitions, including 1st and 2nd at the 2022 ACM CHI Student Research Competition. My students won 65 undergraduate research grants (26 since tenure) from Northwestern, the most of any research lab or group on campus. 40% of DTR undergraduates (44 out of 110) placed at Microsoft (15), Apple (12), Google (10), Meta (5), and Amazon (2). DTR has been recognized at Northwestern University through eight Murphy Society Awards for Advancing Undergraduate Engineering Education, and an Office of the Provost award for advancing associated learning technologies. Since tenure,

[1] CTEC score (out of 6.0) for DTR: Overall Instruction Rating (5.5) and Overall Course Rating (5.5)

[2] To learn more, visit the DTR website (dtr.northwestern.edu), read the DTR annual letters (dtr.northwestern.edu/letters), and watch the DTR documentary (http://forward.movie).

my efforts to advance undergraduate research mentoring have been further recognized with the Office of Undergraduate Research Faculty Honor Roll, two departmental nominations for the CRA-E Undergraduate Research Mentoring Award, and an invitation to join the CRA-E board of directors.

Many of my former students refer to DTR as the most important part of their CS education, what defines them as a CS student from Northwestern.[3] They talk about how DTR instilled in them the mindset of being a life-long learner, and the skill and confidence to be able to tackle large problems that don't have an immediate or clear answer. One DTR student notes: "I learned how to be curious, to think critically, to self-reflect, to seek help. It is because of DTR that I am confident in my work to tackle ambiguous problems, design entirely new systems, make important product decisions, talk with stakeholders, and collaborate with dynamic teams." Students also highlight the value of being in a community of supportive peers and mentors: "DTR's unique teaching approach puts me in the driver's seat from Day 1, for everything from setting high-level goals to planning weekly tasks. I never thought I could do research, but Haoqi and the community had so much faith in me even when I, myself did not."

The learning that DTR facilitates goes far beyond making research progress; put simply, DTR helps students grow as people. To do this, I create space each week for students to reflect on their personal growth and struggles through *circle time* during studio meetings. I engage students to reflect on their *metablockers*, or what prevents them from engaging effectively and growing in the ways that they wish to grow. I also make time to talk to each student during 1-on-1 exit meetings at the end of each quarter; these meetings focus solely on each student's personal learning and growth. These efforts foster students' wellbeing, communication skills, and grasp of their cognition, metacognition, emotions, values and goals – all crucial life skills building that I have incorporated into research mentoring.

DTR students learn how to navigate the unknown, with confidence and with resilience, and with kindness towards themselves, as learners and as people. One former students shares: "I have always been worried about getting things right, sometimes losing track of the learning itself. DTR has helped me break out of this mindset, by shifting my focus to the learning process itself and caring less about the outcome. It's okay to struggle! This idea is something I have been uncomfortable with throughout my life - I think most students at Northwestern are uncomfortable with it. But DTR has given me the tools to face my struggles and to use them as learning opportunities." Another student, who had become afraid of failure after her early successes in college, credits DTR for "teaching me how to advocate for myself and my ideas, embrace failure and inexperience and search for truth rather than bullshit." It is these kinds of learnings and transformations that my mentees are leaving Northwestern with, that they are taking with them into their careers and lives.

My students have also taken the value of fostering community in DTR to then make significant contributions to the larger CS community at Northwestern. They have served on the executive board of Women-in-Computing; created a highly successful student mentorship program; organized large-scale hackathons and community events; and developed course materials and advancing pedagogy in intro computer science courses. Last year alone, two of my students were recognized as 2 of the 3 outstanding Weinberg CS seniors, for their contributions to the CS community at Northwestern.

Beyond directing DTR at Northwestern, I have played a leading role in improving the research mentoring ecosystem worldwide. I founded Agile Research University (http://agileresearch.io) to support other faculty who use the research mentoring tools, resources, and starter kits that I have developed. I also made a documentary film on DTR to share our culture and practice (see http://forward.movie). I write the DTR annual letter (http://dtr.northwestern.edu/letters) to share how we coach and teach design research, and to share reflections on the challenges that students and mentors face in working with themselves and with

[3] See dtr.northwestern.edu/what-we-learn for student stories on how DTR helped them learn and grow.

research. As the long-term sustainability of having good, dedicated faculty mentors requires us to do a better job of sustaining and advancing the wellbeing of our junior faculty, I also founded and facilitate a cross-institutional support group for junior faculty in computing (http://haoqizhang.com/group). The support group provides a space for sharing and listening to junior faculty's experiences on many facets of academic life, and for us to raise larger questions about how we want to be as academics, and as people.

Learning regulation skills in single quarter, project-based classrooms

While regulation skills are best developed over time through long-running programs such as DTR, many students' only exposure to open-ended problem-solving is through single quarter project-based classes. Given time and resource constraints, these classes often (1) lack the authenticity of professional work; (2) evaluate students on outcomes instead of process and practice; and (3) offer few opportunities for reflection and learning from failure. When developing a new seminar course, EECS 397/497: Social Computing & Crowdsourcing (2014, 2015, 2018),[4] for advanced undergraduate students and graduate students, and redesigning DSGN 401-2: Interaction Design (2015–2019),[5] for masters students in the Engineering Design Innovation (EDI) program, I sought to address these shortcomings by (1) engaging students to work on real problems, and for actual clients; (2) coaching students to reflect on their process and devise strategies for improving it; (3) using studio critiques to assess student learning, bring awareness to failures, and promote learning more effective strategies. These approaches are informed by best practices and theories of cognitive apprenticeship [1]; students' assessments of their learning suggest that these interventions helped them develop regulation skills and build core research and design skills.

The rapidly increasing enrollment in Computer Science demand that we scale project-based classes to support a larger number of students, but doing so often compromises the effectiveness of such learning spaces for developing regulation skills. A critical barrier to scaling is providing effective coaching to more than a handful of student teams. Post-tenure I spearheaded a complete revamp of the intro HCI curriculum in CS. I created a new class, CS 329: HCI Studio (2021, 2023, 2024), that provides a model for teaching HCI through design argumentation and design sensibilities, using much of our learning from DTR and adapting them to this context.[6] To scale coaching to 50 students, I focused on helping students build an effective practice of their own, so that I can sustainably train increased numbers of students in such complex learning scenarios. This curriculum is used by three faculty to teach HCI Studio each year, and was also used by Harvard HCI faculty. To further scale coaching to support CS 330: Intro to HCI (2022),[7] a class with 100+ students, I created a 10-week peer mentor training program that resulted in CTECs above 5.7 out of 6 for all five peer mentors, none of whom had any prior experience with design coaching.

Transforming large lectures into active learning environments

The rapidly increasing enrollment in Computer Science challenge teachers of traditional, lecture-based classes to engage large numbers of students and to challenge them to think actively and critically about problems. Students all too frequently become passive consumers of content. In helping to redesign *EECS 330: Human Computer Interaction* (2014),[8] and *EECS 101: An Introduction to Computer Science for Everyone* (2014, 2015)[9], I developed, within a flipped classroom model, in-class activities that use the diversity and scale of a large class as a means for enhancing learning. For example, in EECS 330, we used Google

[4]CTEC score (out of 6.0) for Social & Crowd Computing: Overall Instruction Rating (5.6) and Overall Course Rating (5.4)
[5]CTEC score (out of 6.0) for DSGN 401-2: Overall Instruction Rating (4.2) and Overall Course Rating (4.6)
[6]CTEC score (out of 6.0) for CS 329: Overall Instruction Rating (4.9) and Overall Course Rating (4.8)
[7]CTEC score (out of 6.0) for CS 330: Overall Instruction Rating (4.6) and Overall Course Rating (4.1)
[8]CTEC score (out of 6.0) for EECS 330: Overall Instruction Rating (4.8) and Overall Course Rating (4.6)
[9]CTEC score (out of 6.0) for EECS 101: Overall Instruction Rating (4.1) and Overall Course Rating (3.6)

forms, spreadsheets, and app scripts to collect, aggregate, and visualize student responses to frequent design challenges in real time. In EECS 101, working with weekly guest lecturers, we devised activities that empower students to construct arguments and engage in debates about net neutrality, construct cryptographic schemes, and devise workflows for solving problems with a crowd. To promote students learning from each other, we made frequent use of *think-pair-share* so that students think on their own, construct knowledge with their peers, and then share their understanding with the class as a whole.

Delta Lab: An Interdisciplinary Research Lab and Design Studio

I co-direct the Delta Lab with Liz Gerber, Matt Easterday, and Nell O'Rourke.[10] Delta Lab is an interdisciplinary research lab and design studio with faculty and students from computer science, design, engineering, and learning science. Such interdisciplinary teamwork is critical in our efforts to study and design systems that fundamentally improve the way we design, work, learn, play, and interact. To create an environment of peer learning and mentoring, students present their work frequently throughout the research and design process, and help one another on their projects to enhance productivity, collaboration, and informal learning.

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