

Introduction

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Abstract Innovative teaching can be achieved through many strategies—leveraging what students already do, know about, and think about, relying on student engagement, self-regulated activity, and collaborative activity, and embedding teaching discourses in the values, practices, and institutions of the domain. Teaching innovation is especially critical and appropriate in computer and information sciences and engineering (CISE): *Critical* because of the need to enroll and graduate more students in these areas, and *appropriate* because these areas depend upon and consist of continuous innovation. A diverse set of innovative teaching practices across a CISE faculty, and pervasive across their courses and curricula, could evoke a faculty culture of teaching innovation.

The very premise of teaching is a bit outrageous: It's possible of course to explain something to someone else with the longer term effect that he or she actually understands and can use what was explained. But the notion that such events could be scheduled to occur regularly and on a vast scale, that a relatively few could “teach” many, even everyone, a complex body of concepts and skills comprising history, citizenship, the arts, communication, science, and engineering is remarkably ambitious, and quintessentially human (Dewey 1938). Indeed, notwithstanding the counter-insurgencies of conservative clerics and corrupt politicians, we clearly live in an age when the educational ambitions of humanity have reached a pinnacle. Even universities have transcended their traditional snobbery about research, and embraced teaching innovation as a first-class objective for faculty. Contemporary discussions of university innovation are focused squarely on teaching innovation (Biggs 2001; Christensen and Eyring 2001; Neary and Winn 2009; Laurillard 2002).

The focus of teaching innovation is making deep learning more engaging in its experience and more effective in its outcomes. Achieving this, and verifying its achievement, is no easy matter. Many approaches are possible and desirable; not every approach will necessarily apply as well in every context, for every student, or for every teacher. Nevertheless, at a high level there are *kinds* of strategies, for example, building on what is familiar in teaching that which is novel, allowing students to be active participants in their own learning, incorporating real-world practices

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and pragmatics into learning activities, teaching and employing collaborative learning approaches, and allowing flexibility with respect to learning materials and the organization of learning activities.

One strategy is to *leverage what students do, know about and think about*. This strategy reflects the principle that learning is always a process of sense making, making new meanings by leveraging and reshaping what is familiar. New information, interactions, and experiences are assimilated to what was already mastered, at the same time as existing masteries change and develop to accommodate new insights, new ways of seeing, and new ways of doing (Bruner 1966; Piaget 1985; Vygotsky 1978). An example of the strategy of leveraging the familiar as a scaffold for learning is using analogies to help students grasp and elaborate new concepts.

A second general strategy reflects the principle of active learning, that is, the principle that people learn by doing and engaging better than by only being told. Learners need to be participants, not just witnesses (Dewey 1938; Vygotsky 1978). Concrete consequences of this principle for teaching are to *rely more on discussion and activity, and less on lecture and description*. Thus, instead of reviewing the content of a reading assignment, a teacher might pose questions about it to the class, or invite students to compare and contrast readings with respect to themes and issues.

Action-oriented teaching and learning is most effective when it is *authentic*, that is to say, when it is pragmatically embedded in the values, practices, and institutions of the subject domain (Lave and Wenger 1991). A vivid illustration of this is rote practice, a kind of traditional pedagogical activity in which students repetitively practiced a concept or skill, but without any sense of context or purpose. For example, as an undergraduate student in mathematics (in the late 1960s) I proved many theorems, but I did this mechanically to work through a problem set. This is not how mathematicians work. They prove theorems strategically to build tools that enable further results and questions. In this sense, I feel that while much of my mathematics learning was active, I did not engage mathematics authentically. At the end of my degree, I still had no idea what it would mean to be a mathematician. This is a bad educational outcome.

The principle of authentic learning specializes active learning by emphasizing the situated activity that comprises the learning domains. Thus, a third strategy for innovative teaching and learning is to emphasize *signature projects and practices, not just formal foundations of principles and procedures*. For example, courses in mathematics might explicitly emphasize how mathematicians work, how they practice mathematics, as opposed to emphasizing only how a series of results constitute a foundation of mathematical knowledge.

Collaborative learning is a fourth strategy for innovative teaching and learning. It is of course normal, active, and authentic to learn with others (Dewey 1938); in real cultures of work people pool and coordinate what they know and what they can do. They switch between the roles of teacher and learner, and they learn to use the specialized skills and knowledge of their partners in a collective effort, as well as to cultivate and contribute their own special skills and knowledge. This kind of project-oriented collaborative learning is not guaranteed to work optimally, but it is inevitable that today's university students will need to engage in this sort of learn-

ing throughout their lives. For this reason, it makes sense for them to acquire and practice collaborative learning skills while they are students.

The fifth kind of strategy is *flexibility*. Traditional learning regimes are bound to the presence of the teacher: Apprentices watched a master; students transcribed lectures. One revolutionary contribution of printing was to decouple formal learning from teachers at scale. Today, further revolutions have enabled nearly complete decoupling: Students access course websites, learning management systems, and MOOCs (Massive Online Open Courses); they track down, evaluate and integrate information from across the Internet and from diverse sources and perspectives; they interact synchronously and asynchronously with classmates and teachers; using personal devices, like laptops and smart phones, they interact and learn while they are mobile. This does mean that anyone learns continually throughout the day, but it means they *can* do that. Most importantly, it allows flexibility for teachers and for learners to use a wide range of media and interactive arrangements.

Teaching and learning innovation is especially critical, and especially appropriate in the disciplines and programs of computer and information sciences and engineering (CISE). It is critical because, even though today's students have been immersed in information technology since they were toddlers, US enrollments in CISE disciplines and programs in 2007 were half of what they were in 2001, and, though enrollments have recovered through the most recent five years, they are still 75% of what they were in 2001 (Computing Research Association 2013). Females and most minority groups are highly underrepresented in CISE student cohorts, and the participation of some of these groups is trending downwards. These trends are challenging with respect to future labor force needs and opportunities; for example, the entry-level job category with the highest projected need, highest growth rate, and highest salary for the United States is "software developer" (Bureau of Labor Statistics 2013). Thus, at least in United States, there is a sharp need to attract more student participation, and greater innovation in teaching and learning could support that.

It is also especially appropriate for CISE disciplines and programs to focus on teaching and learning innovation. Much of the subject matter in CISE courses, right down to conceptual foundations, evolves rapidly, as does the preparation, expectations, and motivation of student cohorts. Indeed, the knowledge and practices that constitute the CISE area change more rapidly than any other in the university. Of course constant tinkering and revision is not the same thing as strategic innovation, instead they continually present opportunities for innovation. Moreover, much of the innovation in teaching and learning in contemporary times involves the development and reappropriation of learning technologies that are themselves examples of the application of CISE knowledge and practices. Given this kind of context, universities cannot afford *not* be innovative in CISE.

This book describes classroom experiences in teaching innovation in the College of Information Sciences and Technology at the Pennsylvania State University, hereafter referred to IST. IST is a CISE program, but was deliberately crafted to support quite broad investigations of human capacities, activities, and concerns—at a variety of scales, individuals, groups, communities, organizations, and societies—as they are directly and indirectly enabled, transformed, and sometimes obstructed by new

information technology. The faculty represents a wide range of disciplinary origins and perspectives, computer and information science, psychology and sociology, economics and political science, as well as lawyers and engineers, and people who themselves came from interdisciplinary programs.

One of the founding commitments of the IST faculty was to pursue innovation with respect to teaching and learning. In the early years of IST, this was labeled “problem-based learning”, which maps to the second, and especially the third types of teaching innovation sketched above. The IST implementation of problem-based learning usually incorporated collaborative learning as well. Each week, about 1/3 to 1/2 of the faculty shared a PBL lunchtime meeting, where we discussed a particular innovative technique or course experience. However, there was never a top-down directive regarding innovative teaching, it was rather a culture of teaching, that was encouraged, basically by faculty peer interactions, and good experiences in classes. IST is now nearly 15 years old, and although the emphasis on and manifestations of the commitment to teaching and learning innovation have changed through the course of several deans and with faculty growth (from 4 to about 50 now), teaching and learning innovation has been a continuous thread of collegial discussion and activity.

The chapters of this book are experience reports and reflections on teaching practices from the IST faculty. Each essay briefly describes specific pedagogical challenges and goals that a particular instructor addressed through his or her personal educational vision and values. We have tried to keep these reports succinct and concrete, in some cases pointing to other publications and web resources. The objective was to be inspiring, but more importantly to be grounded enough that a colleague could do something, emulate, adapt, appropriate a technique in his or her own courses.

I have focused on the innovative practices of a single CISE faculty. Thus, this collection of experience reports is more a faculty case study than the sort of convenience survey one generally sees in an edited collection. I couch the distinction this way because, in discussing this project with several colleagues, it seemed one reaction was to question the validity of concentrating on a single faculty. I think this is a serious point, but it needs to be considered in the context of standard practices, which often hinge on oversampling members of the editor’s professional network. Thus, even though the authors of the typical edited collection appear to be a diverse group, in some senses they are not diverse, and not a valid sample of instructors.

Moreover, I think that focusing on a single faculty case study allows recognition and exploration of the thesis that teaching innovation is an issue of faculty culture, not merely a matter of individual instructor choice and initiative. I think this is also a serious point regarding what teaching innovation is, how it emerges, and how it is sustained. The typical approach of reporting and examining teaching innovations course-by-course or instructor-by-instructor, and sampling widely across universities and countries does not address this question.

CISE professionals design, implement, evaluate, maintain, use, and adapt various kinds of information systems and applications. Programming and discrete mathematics are core skills and a lingua franca. A distinctive teaching challenge

is that although programming and mathematical problem analysis is taught to all of our students, for some it becomes a primary component of their professional identity, where for others it becomes part of a foundation for a wide variety of other professional skills and specializations. The next three chapters, report and reflect on innovative approaches to teaching programming and discrete mathematics in our College—perennial discussions in all CISE faculties. Fred Fonseca and Larry Spence, in “The Karate Kid method of problem based learning,” describe teaching programming concepts by embedding them in complex and realistic team projects. In “Hungry Wolves, Creepy Sheepies: The gamification of the programmer’s classroom,” David Reitter describes a software infrastructure for tournaments among student-created semi-intelligent agents, evoking competitive motivation for learning and teamwork. David Mudgett, in “Teaching and learning in technical IT courses,” reflects on his extensive experience applying problem-based learning to teaching discrete mathematics to IST students.

More broadly than programming and mathematics, courses in the IST curriculum emphasize teamwork, analysis, and design. There is heavy emphasis on authentic learning activities, and on students playing a primary role in organizing and carrying out learning activities. In “Towards an egalitarian pedagogy for the millennial generation,” Sandeep Puro describes education in IST as necessarily mutual teaching and learning. In “Higher education classroom community game,” Ed Glantz describes a semester long community game, in which students are rewarded for contributing to the learning of their teammates, thus learning about teamwork and sharing in learning by practicing it. Irene Petrick describes her use of a concrete design project to help students appreciate and learn to manage typical characteristics of design such as incomplete information about stakeholders and needs, starting points, constraints, and final goals in “The Tinker Toy Challenge—Peeking under the cloak of invisibility in information system design”. Mary Beth Rosson, in “Introducing information science by design,” describes her use of design activities in the introductory course for the IST major.

Guoray Cai, in “Teaching structured analytical thinking with data using visual-analytic tools” discusses his use of visualization, critical thinking, and application domains to teach analytical thinking. In “The Analytic Decision Game,” Jake Graham describes his use of large-scale problem scenarios, patterned after military war-game exercises, and used to immerse students in analytical thinking. Students engage with these vivid scenarios as if they were real, they are learning not just the principles, but the embodied and embedded practices and interactions that constitute the work of information analysts. John Bagby describes his use of immersive debates of current issues in teaching information technology policy applied to real world problems, in “The Cyber Forensic War Room: an Immersion into IT Aspects of Public Policy”.

One quite dynamic way to inject authentic content into student projects is to involve students and teams in partnerships with external entities that often act as clients. This approach is widely used in IST teaching. Frank Ritter in “Semester projects on human-computer interaction as service and outreach,” describes how he engages students with local organizations to carry out website design projects as part of his course in human-computer interaction. In “Enterprise Integration: An

experiential learning model,” Brian Cameron describes how he has worked with corporate partners to engage his students in real world capstone project experiences.

Like many faculties, and, at this point in time, like most CISE faculties, my colleagues and I are focused increasingly on online learning, as a component of traditional campus-based courses, as a hybrid infrastructure in which face-to-face and remote students learn together, and as a paradigm itself in which students may never meet one another or their instructor face-to-face. Students in campus-based courses can engage in technology-mediated learning activities anytime and indeed anywhere. In “Immersive learning,” Jack Carroll describes his efforts to keep students continuously engaged in course activities through the use of many small graded activities, online discussions, and distributed collaborative homework activities. Jim Jansen, writing with Partha Mukherjee, Brad Kozlek and Cole Campese, in “Leveraging mobile technology to enhance both competition and cooperation in an undergraduate STEM course,” describes how they used mobile technology to support immersive collaborative learning, incorporating both competition and cooperation, in the context of the Google Online Marketing Challenge. In “Teaching information security with virtual laboratories,” Dinghao Wu, John Fulmer, and Shannon Johnson describe their development and use of hands-on laboratory activities that students access and carry out online, an approach that is being widely applied in IST.

Information and communications technology also enables learning interactions that occur mostly or entirely online, raising new challenges and possibilities. Gerry Santoro in “Using video to establish immediacy with students in distance education courses” describes how he addresses the challenge of creating class sociality online. In “Reflections on blended learning,” Eileen Trauth and Kayla Booth describe a course that was offered to students at 20 Penn State campuses; thus, some of their students were remote/online learners, and others were local and could physically attend classes. Students appropriated the opportunity to learn online in surprising ways. Rosalie Ocker describes experiences with a course in which her students collaborated with peers at universities from a dozen countries across five continents in “Chronicles of the partially distributed team project: Learning to teach students to collaborate in global teams.” Many of these students will no doubt work in global teams at some point in their futures.

I joined IST in 2003. I was a bit past mid-career. I believe I had always tried to be innovative in my teaching, but I appreciated and was inspired and encouraged by the collegial validation and support for this in IST. I think it helped me to become more innovative, and to keep trying to be innovative for longer than I might have done (I am still trying).

Though I was motivated to organize this book by a sense that many of my colleagues were innovative teachers, I have ended up impressed at just how innovative they are. Strategies like leveraging what students do, know about and think about, relying more on discussion and activity than on lecture and description, employing collaborative learning, designing course activities that are authentic to real world domains, and using signature projects and practices are not exceptional or radical practices in our College, they are teaching norms. This is quite exciting. It was not what I experienced myself as a student, nor is it what I saw when I first became a faculty member.

This book is not a claim that my colleagues and I are more innovative than other faculties. Rather, it is an acknowledgement that the culture of teaching and learning in a faculty is more than the practice of any faculty member. This collection of reflective essays on teaching practices is a vehicle to begin exploring that proposition, and more specifically, to reflect more broadly on innovative teaching in IST, to continue to learn from one another, to help one another achieve more. This book is a vehicle to share a collection of innovative practices and experiences, and IST's emergent culture of teaching innovation with other colleagues.

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