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Inworks: Making Things that Matter

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Abstract

Inworks is a new initiative of the University of Colorado Denver and Anschutz Medical Campus that draws together faculty, staff and students from across the two campuses, as well as entrepreneurs and leaders from industry, government, education and the community to address problems of importance to human society. The primary purpose of Inworks is to create innovative solutions to some of the world's most challenging problems while, in the process, creating lifelong innovators. We do this by scaffolding collaborative innovation and providing extensive facilities for rapid prototyping.

Through hands-on, human-centered, team-based projects, students at Inworks learn to think critically, creatively, integratively and transformatively; to develop solutions when the problems themselves are not well defined; to embrace innovation and entrepreneurship; to analyze and synthesize vast amounts of information; to have substantial qualitative and quantitative skills; to have both a global perspective and an eye for detail; to collaborate effectively in interdisciplinary teams; and to lead when leadership is called for.

Inworks, drawing upon ideas from modern entrepreneurial practice, was created to provide educational experiences that develop these intellectual capacities. We do this by providing a scaffold for innovation that integrates empathy, creativity and practicality to match human need with feasibility. By helping to create experiences that allow individuals to encounter their own creativity, we show students how to be intentional about the way they work together to solve significant problems.

Inworks opened its facilitites on the downtown Denver campus in the spring of 2015, and began offering courses in fall 2015 at both the undergraduate and graduate levels. Inworks is not situated within an existing department, school or college, providing a unique opportunity for faculty and students from a wide variety of disciplines to collaborate with each other and with off-campus individuals and organizations. Thus, although many Inworks faculty come from engineering backgrounds, our students come from every academic unit on campus. Our courses focus on human-centered design, and include an emphasis on human health, in part due to our connection to the medical campus. This paper describes our origins and approach, and summarizes some of our progress and challenges to date.

Introduction

There is increasing demand for higher education to produce graduates who are job- or career-ready [1,2]. For example, most technical companies expect that new hires will be able to tackle complex multidisciplinary problems, and the ability to innovate is now an "integrative meta-attribute" desired in all engineering graduates [3]. Pulling together disparate fields in innovative ways is now an expectation. A series of reports from the National Academies, e.g., "Educating the Engineer of 2020" [4] and "Rising Above the Gathering Storm" [5] emphasize the need for lifelong learning that bridges multiple disciplines. Engineering educators in particular must create learning environments that adapt to changes within their specific disciplines, as well as

provide opportunities for team-based interdisciplinary projects that focus on real human need. If we wish to educate the innovators and entrepreneurs of tomorrow, we must lead by example.

Change is not easy for any institution; nowhere is this truer than within the modern academy. Universities, sometimes derided for their liberal leanings, can be remarkably conservative and stunningly risk-averse. In his 1908 treatise on academic politics, Microcosmographia Academica [6], Cambridge scholar F. M. Cornford introduced the "Principle of the Dangerous Precedent," in which he cynically concludes that at a university "nothing should ever be done for the first time." Over a century later, Louis Menand, in *The Marketplace of Ideas: Reform and Resistance in the American University*, speaks of the need for prospective reformers to avoid at all costs triggering the university's innate "auto-immune response" to change [7]. Menand goes on to argue that the present day academy's defense of its nineteenth-century approach to education threatens to undermine its very foundations.

This resistance to change permeates many colleges of engineering. Institutional uptake of innovative teaching methods is notoriously slow; certainly this is true within engineering [8]. As described by Henderson, Beach, and Finkelstein [9], change strategies that involve STEM educators developing "best practices" and attempting to engage other instructors to use these curricular materials rarely succeed. Likewise, "top down" change strategies that involve policy changes intended to influence teaching practices are typically met with resistance and seldom create lasting change. Some of the challenges facing change agents include a long-standing commitment to instructor autonomy and the perceived strict graduation requirements for accredited engineering degrees. In addition, successful change strategies must grapple with the often byzantine complexity of the university rules for program change, and the need to create sustainable long-term interventions [9]. Notably, one of the more successful interventions, the SCALE-UP classroom, involves changing the physical spaces we teach in, and thus making it difficult to revert to less innovative pedagogy [10].

How can we teach innovation and entrepreneurship in a system that itself so resists adapting to change? Our answer was to create a new initiative within the University that would function as an academic "start-up." We built a completely new space and program focused on human-centered design and innovation. This start-up is a testbed for innovative teaching, scholarship, and practice.

The design of Inworks space and programs, along with the careful selection of prototyping equipment, was intended to encourage faculty and students to interact across traditional disciplinary boundaries. We knew that any such program would need to be structured to help faculty engage in interdisciplinary research and teaching without endangering their careers. We also knew that we would need strong administrative commitment to make this happen. Inworks was created as a new academic unit reporting directly to the Provost (the chief academic officer of our two campuses) that actively facilitates interdisciplinary collaborations among faculty and students from disciplines across the entire University. One-time funds were invested by campus leadership to facilitate our initial operations.

As we began, we were keenly aware of what Inworks should *not* be. It could not be, in perception or reality, the place where the bright, creative people go, to the detriment of the rest of campus. With this in mind, we designed our programs to complement, not compete with, other academic units on campus. Inworks does not replace any other academic unit. Instead Inworks is

a place where, for example, engineering students can collaborate with faculty and students from architecture, psychology, the arts, public health, and medicine. Inworks does not currently offer degrees; we augment other degree programs by offering an undergraduate minor and certificate in Human Centered Design and Innovation. Inworks therefore represents a new on-ramp for students not typically found in design courses, providing what we characterize as "access to the machine shop of innovation."

Founding Principles

Inworks was developed around four principles: design thinking, computational thinking, disruptive innovation, and radical interdisciplinarity. None of these are new ideas, or unique to Inworks, but they their integration is at least unique to our campus.

Design Thinking

Design thinking is a human-centered process for creatively developing solutions to complex problems. Design thinking integrates empathy, creativity, and practicality to match human need with feasibility, highlighting the critical role of creativity in every human endeavor. Design thinking requires not only the convergent thinking well-represented in engineering courses [11], but also the divergent thinking necessary for innovation [12–14]. By helping to create experiences that allow individuals to encounter their own creativity, we use design thinking to extend the design philosophy to things outside of products and provide a vocabulary for being intentional about the way we work together to solve significant problems.

In addition to the potential value of a solution itself, design thinking transforms its practitioners by providing a scaffold for learning how to innovate. For educators, this is critical. Our objective cannot simply be to create innovations, however valuable those innovations may be. If we also focus on creating innovators, our work will have a much greater and more lasting impact.

Computational Thinking

Computational thinking is a cornerstone of the technological engine that drives modern society [15]. Computational thinking includes the ability to create human artifacts of every kind – structures, art, music, medicine, aircraft, entertainment, entire worlds of imagination – using computing as the instrument of creation. Computational thinking frees us to go beyond what is physically realizable to what is computationally realizable. Engineers, artists, writers, pharmacologists, musicians, and others can imagine and create artifacts that are impossible to realize by human endeavor alone. These forms of creative expression are not represented simply by the ability to use a set of computer applications, or even the ability to write computer programs. Rather, they represent a new way of thinking about what is possible, and using the computer as a tool to realize fully that vision. At Inworks, computational thinking is represented in almost all of our courses and programs as a tool for nearly every kind of creative endeavor.

We also employ computational thinking to help grapple with the overwhelming amount of data associated with all aspects of modern human society. Data analytics, sometimes called data science, is itself emerging as an interdisciplinary paradigm within the domain of

computational thinking. Data from multiple sources – governments, corporations, and social media – can provide deep insights into human social systems. That insight can in turn help us tackle the enormous challenges that confront modern human society. However these same data, used inappropriately, have the potential to undermine the very foundations of civil society. The significant societal value of the information that can be gleaned from these data is in direct tension with the significant potential for negative impact on individuals from the associated loss of privacy and a diminishing "right to be forgotten." [16] This tension is itself an area of new scholarship as legal, ethical and social scholars explore the nature, value, and ownership of personal digital information.

Disruptive Innovation

A disruptive innovation is one that changes the value proposition in an existing market to such an extent that existing market leaders are displaced by newcomers who have been early adopters of the disrupting innovation. Interestingly, case studies of disruptive innovation show that the existing market leaders are typically aware of the innovation in question, but reject its early adoption because of perceived lack of profitability, or competition for limited resources with sustaining (typically incremental) innovations. Thus market leaders tend to place insufficient value on the disruptive innovation to warrant its development, and competing newcomers are able to displace the market leader by being a first adopter of the disruptive innovation. By the time the established market leader is in real competition with the early adopter, its only option is to emulate and hope to survive, rather than to innovate and lead [17].

For universities, a case in point is the emergence of massive open on-line courses (MOOCs). Although still very much in their infancy, and there are valid reasons to be skeptical, MOOCs raise important questions about the future of university education, the future value of a university degree, and the effect technology will have on how the academy operates. For example, job candidates (particularly in technical fields) are increasingly evaluated based upon actual competencies rather than educational pedigree; costs to attend a brick and mortar university are increasing at a rate far outpacing other costs of living; and for two-thirds of the world's population, a traditional university education is simply out of reach. It is no wonder that students are eager to try lower-cost alternatives and the academy is increasingly under attack for producing graduates who are not ready to practice their chosen profession, e.g., engineering graduates who are well-grounded in theory but who are not ready to join a design team.

From a learning perspective, many MOOCs are disruptive only in the sense of their delivery system. They remain transmissionist methods of education: the textbook is now on a screen, the lecture is now a video. In contrast, Inworks attempts to employ a constructionist learning model [18] to enable self-directed learning [19].

Most of the MOOC curricula offered today relates to technology, in part because it is easier to construct course materials for objective subject matter. In addition, the majority of existing courses focus on transferring knowledge that is relevant today, with little thought given to the preparation of students for tomorrow. We also continue to apply old values to this process: how to monetize the transfer of knowledge; how to credential the result; how to address issues of academic integrity. Universities should be engines of disruptive innovation, not its unwitting target.

Further, we need to remember that there are significant cultural and generational issues between faculty and students. Our students matriculate profoundly conditioned by modern

culture in ways not generally anticipated or well understood by the faculty. Students today represent the first generation of what Prensky calls "digital natives." "Today's students are no longer the people our educational system was designed to teach"[20]. At Inworks, both our curriculum and our pedagogy attempts to be responsive to the ways in which our students best learn.

Radical Interdisciplinarity

The way the academy structures knowledge perpetuates disciplinary silos and helps create profound social barriers among both faculty and students. This is increasingly counterproductive, for several reasons. First, solutions to hard problems, especially those that confront modern society, generally require more than one kind of knowledge. In an age where everything is connected to everything else, the knowledge needed to solve a problem is often to be found in a completely different domain than the problem itself. Interdisciplinary innovation is thus an essential tool for solving challenging problems, and an essential skill set for people entering the future workforce.

This is hard, and made harder by the self-imposed barriers to interdisciplinary work common at most universities. Consider bioinformatics as a concrete example. At most universities, faculty and students working in this area might be found in Computer Science, Molecular Biology, Philosophy (ethics), Law, Biological Engineering, Business and Medicine. While successful interdisciplinary research collaborations likely already exist in bioinformatics, any faculty member or student seeking to work in this area must typically align her/his activities with respect to advancement along dimensions defined by a particular home department. This makes it difficult to build strength at the center of the field, and represents a particular challenge for new tenure-track faculty.

In response to this challenge, Inworks programs are intended to teach students (and faculty) to develop deep empathy for those they seek to serve, to interact with individuals from other disciplines, to respect expertise not their own, to communicate using common vocabulary, and to compellingly articulate their ideas to those who do not share their common background. In short, they provide experiences that help develop the "T-shaped" expertise championed by Tim Brown of IDEO [21].

Launching Inworks

Creating Inworks has been a process similar to that of all start-ups. The initial idea was pitched to University administrators and donors, not unlike the process of pitching to investors. The initial pitch was made in late 2013. The founding staff was hired in mid-2014, including the director, associate director, and program manager. Appropriate physical space was located, and renovation was completed in March 2015. The prototyping equipment installed in the space is listed in Appendix A. A full-time prototyping manager was hired in February 2015. Two inaugural courses ran fall of 2015, taught by the director and associate director. Two assistant professors came on board full time in January 2016, and a more complete slate of courses was offered in spring 2016. In addition to the Inworks core courses, we created a Call for Proposals (CFP) to support faculty across the two campuses in creating interdisciplinary courses. These CFP courses also were offered starting fall 2015.

Inworks Space

We considered it critical to the success of the Inworks that it be housed in space that supports communication, collaboration, and experimentation. This is because that physical space represents one of the tools used to bring people from different backgrounds together. Our space had to be warm, inviting, and supportive. People should want to spend time there, and it should be possible to spend large amounts of time there comfortably. There needed to be a place to prepare a light meal, and to relax. Our space did not have to be modern or upscale. Power and connectivity are essential; carpet and acoustic ceiling tile are not. Figure 1 shows a view of the Inworks workshop area.

Figure 1: The Inworks Workshop

Inworks space also conveys a sense of ownership. Faculty, staff and students of Inworks are comfortable putting holes in the walls or hanging things from the ceiling. Furniture is movable, light is abundant, and whimsy with respect to creative use of space is encouraged.

Our goal was to structure the space such that collaboration was not only possible, but inevitable. In creating our physical space, we borrowed shamelessly from others, most notably the Stanford d.School, whose staff were patient with our many questions. The workshop and office are open, shared spaces. At Inworks, almost everything is on wheels: chairs, whiteboards, benches, tables, AV equipment, etc. The teaching space tables are round. The smaller tables in the workshop are standing height and on casters for quick reconfiguration. The conference room is glassed in, and features an Oblong Mezzanine system to facilitate both local and remote collaboration [22].

Program Design

We have focused our curricular design to date on ways to augment existing degree programs. Here, we highlight our undergraduate offerings.

The Inworks Undergraduate Certificate in Human-Centered Design and Innovation (HCDI) provides a basic understanding of design and innovation processes used to collaboratively address important human problems. Figure 2 outlines the certificate program. The program prepares students to contribute to interdisciplinary teams that seek to address complex problems. Students who undertake the Inworks HCDI Undergraduate Certificate acquire basic abilities to:

- collaborate effectively in interdisciplinary teams;

- contribute meaningfully to the development of innovative solutions to complex and challenging problems; and
- implement potential solutions using a variety of prototyping techniques.

Students undertaking the Inworks Undergraduate Certificate must complete a minimum of 13 credit hours, made up of the three required foundations courses, plus one elective course.

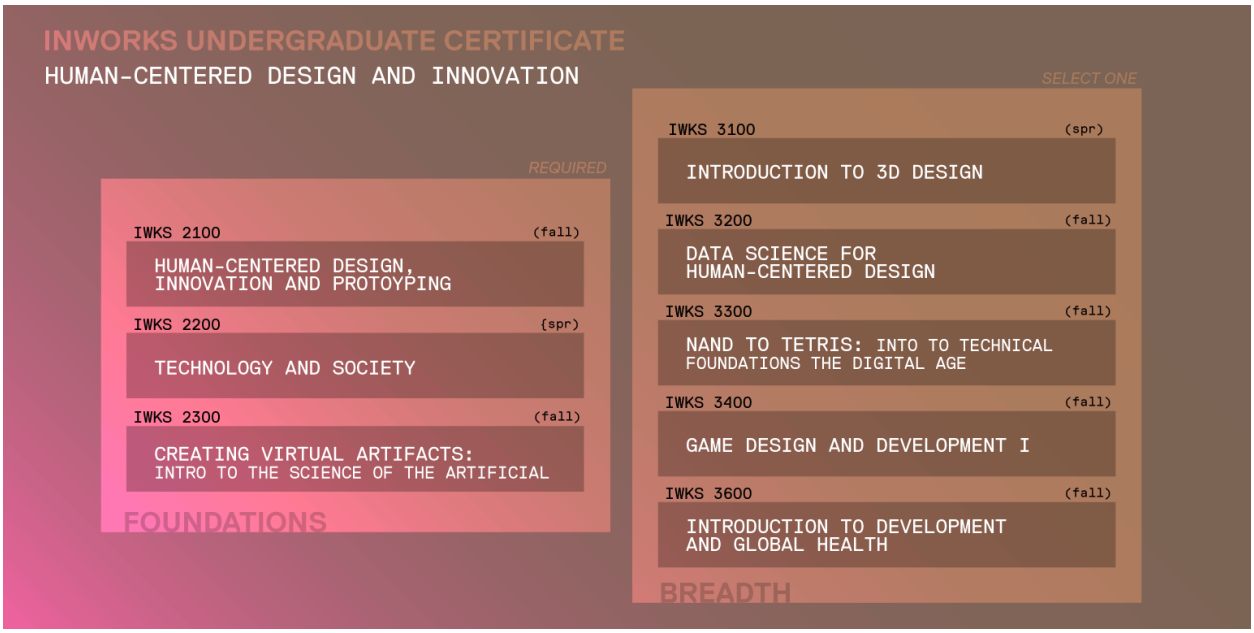

Figure 2: The courses for the Inworks Undergraduate Certificate in Human-Centered Design and Innovation.

The Inworks Minor in Human-Centered Design and Innovation (MHCDI) provides educational experiences and a broad interdisciplinary perspective in design and innovation that integrates human-centered design thinking with collaborative problem solving. Figure 3 outlines the coursework for the minor. Students in the MHCDI learn to collaboratively create impactful solutions to important human problems. Students who undertake the MHCDI acquire the ability to:

- collaborate effectively in interdisciplinary teams;
- contribute meaningfully to the development of solutions to complex and challenging problems;
- synthesize available information into actionable alternatives;
- think critically and conceptually when confronted with challenging problems;
- develop potential solutions when the problems themselves are not well defined;
- embrace innovation and entrepreneurship;
- evaluate ideas using both qualitative and quantitative analysis tools;
- implement potential solutions using a variety of advanced prototyping techniques;
- have both a global perspective and an eye for detail; and
- lead when leadership is called for.

Inworks MHCDI students complete a minimum of 23 credit hours, essentially completing the certificate, plus two additional courses in a focus area of their choice and a capstone experience. MHCDI students must choose between two capstone options. The first is a more traditional team-based semester-long project. In the second option, teams of students envision and create a company in a single semester. Their final exam is, literally, pitching their company and product to a group of local entrepreneurs and venture capitalists.

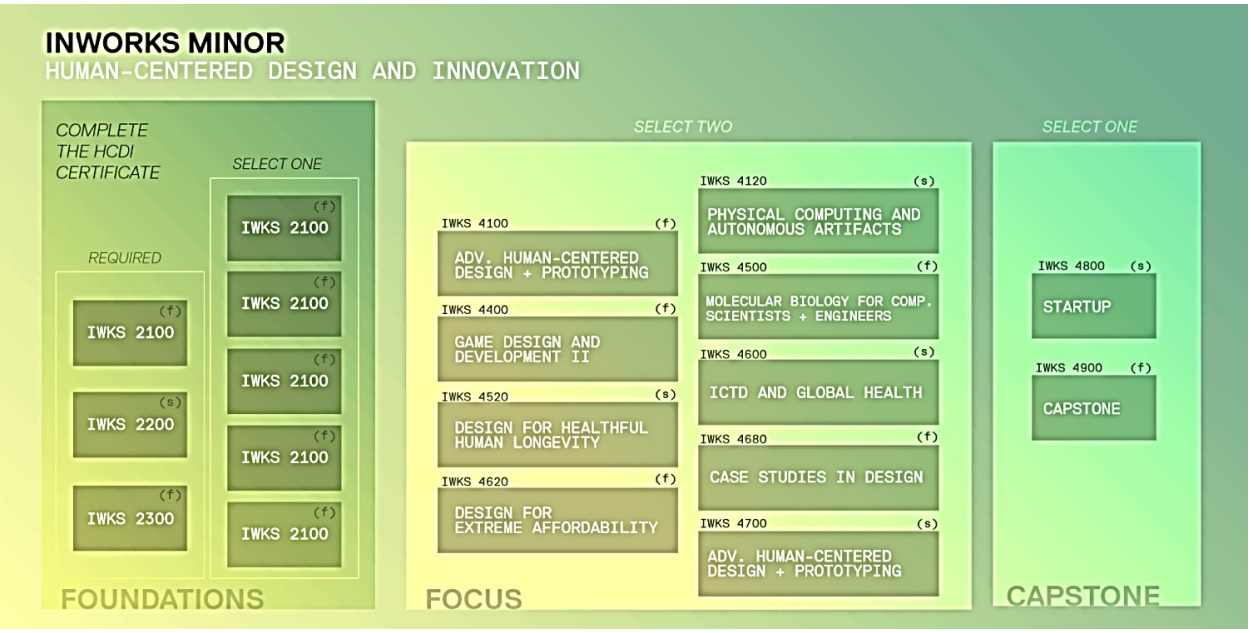

Figure 3: The courses for the Inworks Minor in Human-Centered Design and Innovation.

Initial Challenges

We were at first disappointed by low enrollments in our initial course offerings. Then we realized that while our status as an academic unit outside of the mainstream gave us great flexibility, it also made all of our courses general electives. At a university where 40% of the student population are first generation students, and our underrepresented minority enrollment approaches 50%, students are intensely focused on their path to graduation. Elective courses, even highly desirable ones, are not on the radar, or even affordable, for many students. We anticipate that this issue will be ameliorated as other academic units begin to “count” Inworks courses for degree credit for their majors. We have met with course advisors in various departments to better communicate how our courses can benefit their students. This process is also happening organically as Inworks students petition their advisors and chairs to have their Inworks courses count. In addition, we are encouraged that the newest degree program on campus proposes to require a minor, and includes the Inworks MHCDI as one of the options available.

Our second observation was less logistical and more cultural. Many of our students come from backgrounds fundamentally different from that of students who have known privilege. Many of our students have never had a teacher or parent tell them to have faith in their abilities, or that they are truly capable of realizing what their intellect might imagine. Creating experiences that help such students find and respect their own creativity has been an intense focus of our curricular development.

Finally, our approach to community engagement continues to evolve. We initially offered general open hours to individuals from the community with little attention to what those individuals actually wanted to do. Some participants from the community saw Inworks as just another "Maker Space," albeit, and very well-equipped one. It took a while for us to articulate the message that while Inworks is indeed a Maker Space, it is a place where people make things that matter, rather than just making something for the sake of making it. Thus, while we celebrate and embrace the "Maker Movement," we are on a somewhat different path. Our new approach to community engagement provides increased project evaluation and scaffolding, as well as an intense human-centered focus.

Next Steps

We have nearly completed our build-out on the main campus in downtown Denver, and renovation of our space on the medical campus is well underway. The Anschutz Medical Campus site will provide a more comprehensive array of biotechnical equipment, which will support our proposed new interdisciplinary graduate degree in biodesign. This degree, offered with the active support of the departments of surgery and emergency medicine, will train engineers and others to design and develop products intended to improve healthcare delivery in operating and emergency rooms. We expect to use the Oblong Mezzanine systems that connect the main and medical campuses for both collaboration and teaching.

We are also focusing our efforts on growing our own student pipeline. To that end, we have recently helped a local high school develop space and curricula complementary to Inworks, and have created a new dual-credit alternative admission pathway program for students from that urban school.

Finally, we sponsor two active extracurricular groups, the project-focused student team entrant in the Space X Hyperloop Competition, and a topic-focused campus/off-campus group focused on the emerging area of "DYI Bio."

1. Duncan, A. Educating Every Student for College and Career Success. (2013). at <http://www.ed.gov/news/speeches/educating-every-student-college-and-career-success>
2. Obama, B. State of the Union 2016. (2016). at <https://www.whitehouse.gov/the-press-office/2016/01/12/remarks-president-barack-obama-%E2%80%93-prepared-delivery-state-union-address>
3. Radcliffe, D. F. Innovation as a Meta-Attribute for Graduate Engineers. *Int. J. Eng. Educ.* **21,** 194–199 (2005).
4. Committee on the Engineer of 2020. *Educating the Engineer of 2020: Adapting Engineering Education to the New Century*. (The National Academies Press, 2005). doi:10.1115/ESDA2008-59324
5. Members of the National Academies. *Rising Above the Gathering Storm, Revisited: Rapidly Approaching Category 5*. (The National Academies Press, 2005). doi:10.5810/kentucky/9780813125763.003.0008
6. Cornford, F. M. Microcosmographia Academica. *Politics* (Cambridge University, 1908). at <www.maths.ed.ac.uk/~aar/baked/micro.pdf>
7. Menand, L. *The Marketplace of Ideas: Reform and Resistance in the American University (Issues of Our Time)*. (WW Norton and Company, 2010).
8. Borrego, M., Froyd, J. E. & Hall, T. S. Diffusion of engineering education innovations: a survey of awareness and adoption rates in U.S. engineering departments. *J. Eng. Educ.* **99,** 185–207 (2010).
9. Henderson, C., Beach, A. & Finkelstein, N. Facilitating change in undergraduate STEM instructional practices: An analytic review of the literature. *J. Res. Sci. Teach.* **48,** 952–984 (2011).
10. Foote, K. T., Neumeyer, X., Henderson, C., Dancy, M. H. & Beichner, R. J. Diffusion of research-based

instructional strategies: the case of SCALE-UP. *Int. J. STEM Educ.* **1,** (2014).
11. Daly, S. R., Mosyjowski, E. a. & Seifert, C. M. Teaching creativity in engineering courses. *J. Eng. Educ.* **103,** 417–449 (2014).
12. Zappe, S., Mena, I. & Litzinger, T. Creativity is Not a Purple Dragon. *Natl. Coll. Invent. Innov. Alliance* (2013). at <http://www.nciia.org/sites/default/files/features/conference/2013/papers/zappe.pdf>
13. Schön, D. A. *The Reflective Practitioner: How Professionals Think in Action*. (Basic Books, 1983). at <http://deepblue.lib.umich.edu/bitstream/handle/2027.42/24973/0000400.pdf?sequence=1&isAllowed=y>
14. Dym, C. L., Agogino, A. M., Eris, O., Frey, D. D. & Leifer, L. J. Engineering Design Thinking, Teaching, and Learning. *J. Eng. Educ.* **94,** 103–120 (2005).
15. Wing, J. M. Viewpoint: Computational Thinking. *Commun. ACM* **49,** 33–35 (2006).
16. Rosen, J. The Right to be Forgotten. *Stanford Law Review Online* **64,** (2012).
17. Christiansen, C. *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail*. (Harvard Business Review Press, 1997).
18. Papert, S. & Harel, I. in *Constructionism* (eds. Papert, S. & Harel, I.) **36,** 1–11 (Ablex Publishing, 1991).
19. Knowles, M. S. *The Modern Practice of Adult Education: From Pedagogy to Andragogy*. **41,** (New York Association Press, 1970).
20. Prensky, M. Digital Natives, Digital Immigrants. *Horiz.* **9,** (2001).
21. National Academy of Engineering. *Infusing Real World Experiences into Engineering Education*. (2012). at <http://www.nae.edu/65099.aspx>
22. Oblong Industries. *Mezzanine Infopresence: Multi-Location Collaboration*. (2015).