Industry Fellows: A model for industry-academic collaboration in the engineering classroom[1]

Challenges of Basing Engineering Education in Professional Practice

A recent major study on Engineering Education calls for centering 21st century Engineering Education in professional practice[24]: "[I]f students are to be prepared to enter new-century engineering, the center of engineering education should be professional practice, integrating technical knowledge and skills of practice." Education policy bodies are increasingly cognizant that faculty and professional practitioners need to cooperate more closely in educating the next generation. Both the National Research Council, in their report *How People Learn*[3] and the Carnegie Foundation's report from their *Preparation for the Professions Program*[27] underscore the importance for educators to work with professional practitioners in practice-based fields such as engineering. Similar sentiments are expressed by the National Academy of Engineering in their recent report *Engineer of 2020: Visions of Engineering in the New Century*[17].

Yet there are three interrelated challenges in bringing professional practice more fully into the classroom. First, while college professors have expertise in teaching, they often lack the modern practices required in fields that are constantly changing. The workaday demands of the full-time academic make it difficult for college teachers to keep up with state-of-art practices, even for those with a strong background in industry. Second, while professional practitioners possess state-of-art technical skills, their professional demands prevent them from being able to devote time to "moonlight" as university instructors. Even for those who do, their effectiveness is limited by their lack of teaching knowledge and their isolation from the rest of the faculty. And third, simply introducing students to professional practices does not alleviate the challenge associated with relating and integrating these practices with students' academic knowledge. But such integration is necessary if they are to fully benefit from their educations over their professional careers.

This paper describes the *Industry Fellows* model[32], a novel attempt at addressing these interrelated challenges in an integrated manner. Industry Fellows involves a university faculty member and a practicing industry professional (the *industry fellow)* in the joint curriculum review, planning and teaching of a course related to the professional's domain of expertise. The balance of this paper is structured as follows. In the next section, I provide an overview of the Industry Fellows model. This is followed by a description of three instantiations of the model that define the range of kinds of participation by the industry fellow that this model supports. Following this, I discuss the key characteristics common to the model, with links to supporting research: viewing education as increasing participation in practice communities[20], division of labor along lines of expertise[8], using authentic artifacts of practice to mediate human interaction[29,30], and an emphasis on *intrinsic* motivation[9] to encourage participation by faculty, industry fellow, and students. I then present an evaluation of the model based on data collected from interviews with industry fellows, self-reflection by the instructor, and post-course surveys of students to argue that all three of the challenges mentioned earlier are addressed. Finally, I provide an argument for why Industry Fellows is novel as compared to other models for

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academic-industry collaboration, such as guest speakers and student internships. I conclude by summarizing the model and its key characteristics. In the balance of this paper, I use the term *Industry Fellows* (capitalized) to denote the model, and *industry fellows* (lowercase) to denote participating professional practitioners.

The Industry Fellows model

The Industry Fellows model pairs a university teacher and a professional practitioner to teach a course together. The faculty member has broad expertise in the discipline, deep expertise in teaching, and local knowledge about students and the university context. Practicing computing professionals, on the other hand, have up-to-date knowledge of specific technical areas of practice, expertise in making pragmatic trade-offs to meet workaday constraints, and skill in navigating organizational culture. By working together, the *Industry Fellows* program exploits what each does best. The faculty member retains full responsibility for all academic aspects of the course: planning and writing the syllabus, developing the assignments and examinations, and assigning grades. The practicing professional joins the faculty member in the classroom or remotely via electronic communication on a regular basis, interacts directly with the students, and provides feedback on a sample of the student work. Targeted courses are those tied closely to professional practice. In these courses, students produce tangible representations of authentic practice, which serve to mediate the interaction between students, the teacher, and the practicing professional.

Instantiating the model

I have instantiated Industry Fellows three times with three different industry fellows in courses that I have taught at my university, the University of Washington, Tacoma (UWT), once in an undergraduate Software Engineering course and twice in an undergraduate Interaction Design course. Classes had 25, 12, and 18 students enrolled, all but one of whom were Computer Science majors. Almost all students were between 20 and 30 years of age, approximately half attended university full time, and almost all students worked at least part time during the academic year. The Software Engineering course was 84% male, the Interaction Design courses were 70% male. Class sessions for each course met twice weekly for 2 hours, and class sessions were held in a classroom equipped with movable tables and a computer with Internet access and projector. UWT is a comprehensive university in a metropolitan region of the Pacific Northwest of the United States. The academic term is 10 weeks, and there are three terms during the academic year. A full-time course load for undergraduates is three courses per term.

I had taught each of these courses prior to working with an industry fellow, and thus had an existing conception of how to teach these courses, operationalized with the course materials I had developed in prior offerings. In all three cases, there were two distinct phases of interaction between myself and the industry fellow: *joint planning* in advance of the academic term, and *carrying out the co-teaching* during the term.

The Joint Planning Phase: identical across instantiations

The planning was carried out several months in advance, and involved three targeted, face-to-face meetings of approximately 1-1/2 hours each between the industry fellow and myself. Each meeting was centered around answering a key question.

Meeting 1: What will students be able to do on course exit?
Meeting 2: What specific work will we assign to students?
Meeting 3: How will we sequence the topics from week to week?

I kept extensive notes of these meetings, and shared these after each meeting with the industry fellow via email for commentary and clarification. There were several weeks between each meeting. At the end of the three meetings, I developed an updated set of course materials for the course: syllabus, course schedule (i.e. the weekly sequence of topics, assignments, and corresponding course readings), and assignments. In each case, we centered student work around developing a term-length, team-based project that would be developed incrementally throughout the term.

The Co-Teaching Phase: adaptive to the industry fellow's constraints

Although the planning phase was the same in each instantiation, differences between the instantiations arose in the pattern of interaction with the industry fellow during the academic term. In the heavy-weight versions (which I did twice), the industry fellow attended one of the two weekly class sessions. During this time, we structured interaction so as to maximize the interaction between students and industry fellow while at the same time making visible the industry fellow's expertise. The main activity was critique and discussion of student project work-in-progress that students would present for the full class. It also included presentation and discussion of authentic work from past projects by the industry fellow. I elaborate on these below along with a rationale. After each of these jointly-taught class sessions, the industry fellow and I would debrief the session (what worked, what didn't) and sketch a plan for the next week's class sessions.

In the light-weight version, the industry fellow attended only the first and last class sessions of the term in person. During the balance of the term, the industry fellow attended class for approximately 15 minutes each week via electronic mediation, using a video Skype call projected onto the classroom screen. Approximately once every two weeks the students would post their current project designs to a publicly-accessible Internet wiki, and I would ask the industry fellow to briefly look at these. The substance of the classroom interactions with the fellow was centered around his comments on the project work that he was viewing. In addition, the industry fellow prepared 3 screencasts of approximately 2 minutes each giving a brief tutorial on an area of his expertise (e.g. using Powerpoint to make prototypes), and a 3 minute screencast giving his professional biography. I interspersed these screencasts throughout the term to provide a sense of the industry fellow's involvement, particularly during the weeks when he had little time to spare from his professional responsibilities. Finally, the industry fellow and I would talk for 10 minutes at the end of each week by telephone. During that time, I would update him on student progress, and we would discuss what students needed based on the project increments that we were viewing. This allowed us to plan where to focus our efforts in the upcoming week.

The light-weight version arose for two reasons. First, the industry fellow was unable to commit the time to travel the 30 mile distance between his workplace and the university weekly, in addition to the two hours for attending class. That is, he could afford 30 minutes per week, not 4 hours. And second, I was curious to determine if the lightweight version had a similar impact on students; if so, then it extended the reach of the Industry Fellows model considerably, enabling instantiations in a wide variety of geographic locations and physical settings, even in those geographical areas with little high-tech industry and few skilled professional practitioners.

Key Characteristics of Industry Fellows

Pairing a practicing professional and an academic to co-teach is not sufficient for a successful collaboration. Industry Fellows was designed to have particular characteristics that are based on recent research in education, sociology, and social psychology. The most important of these are: viewing education as increasing participation in practice communities, division of labor along lines of expertise, using externalized artifacts to mediate interaction, and exploiting intrinsic motivation. Each of these is discussed in turn, with links to the research literature and how this impacted the design of Industry Fellows.

Viewing learning as participation

A pervasive yet tacit belief among many academics is what Torff[28] calls the *transmission* model of learning. In this model, "education is the corpus of facts that has been collected about a particular subject. ... For learning to occur, knowledge has to enter learners' minds, which requires that it be transmitted from the outside world (e.g. from a teacher or book)[28]." The transmission model is what Bruner[4] calls "folk pedagogy", resting on intuition and cultural acquisition rather than scientific research. Such folk pedagogies can be difficult for teachers to recognize and change, even after undergoing considerable exposure to educational research[28].

In contrast to the transmission model, Industry Fellows is founded on principles from research in psychology and learning from the last two decades[7,12,16,19,20,22], often referred to as *sociocultural theory* or *situated learning theory*. A key perspective is that " 'to learn' means to participate more successfully in the collective practices that define particular ways of knowing as recognized by various communites[31]." This perspective does not view knowledge as unimportant, but sees it as arising from the goal-directed activity that people engage in within particular social and material settings. One cannot separate the individual and the social group; they are co-constitutive. Under this view of learning, "the mastery of knowledge and skill requires newcomers to move toward full participation in the sociocultural practices of a community[16]".

In Industry Fellows, there are two paired practice communities: university academics within a particular discipline, and professional practitioners of the discipline: lawyers and law professors, engineers and engineering professors, software developers and computer science professors, nurses and nursing professors. Within each pair, the two communities are distinguished by their goals (e.g. providing service to clients versus fostering student learning), and by the material resources and constraints of the work setting. What the two paired communities share are common language and tools associated with the field of practice.

In Industry Fellows each member of the teaching team is not so much transmitting content as they are *enculturating students into the practices of their respective communities*; thus, interaction among all three is focused on authentic practice, using the artifacts and representations typically used within professional settings. In addition, through their mutual interaction, the academic and the professional practitioner socialize one another into their respective practice communities.

Dividing labor along lines of expertise

Because of differences in context, materials, tools, and goals, practitioners in non-academic settings will develop considerably different expertise than academics. When paired in Industry Fellows, it is therefore important to divide labor along these lines of expertise.

Experts possess deep domain knowledge[5]. They additionally bring this knowledge to bear on problems in the field, self-monitor their work, and work with speed and dexterity[10]. Experts develop prodigious skill and sensitivity in choosing and working with materials and tools[13], and adapt these to changing contexts[21]. In a range of human endeavors, everything from photocopy repair[18] to bank telling[15], waitressing[21], and taxi driving[11], experts must develop a sophisticated repertoire of strategies for managing the complexities of human interaction within social settings. Practicing professionals thus have considerable expertise that they can bring to education. Yet much of this knowledge is tacit, embedded in the taken-for-granted practices that are enacted within the social and material context in which they work[26].

At the same time, it is easy for teachers (and others) to take for granted their own expertise. As important as domain knowledge is to teaching[3], teachers also rely upon their pedagogical knowledge that they learn through practice. In addition, teachers develop what Shulman[25] calls *pedagogical content knowledge*: "the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations-in a word, the ways of representing and formulating the subject that make it comprehensible to others[25]." Finally, teachers also develop considerable local knowledge about the context in which they teach, including such things as the resources available within their universities and classrooms, the frequency and duration of class sessions, the topics that must be covered in particular courses, the preparation of the students, the availability of labs, tutors, and peer mentors, to name just a few. Each of these acts as a constraint around which the teacher must adapt their practice. So although industry practitioners have considerable content knowledge and state-of-art practice, often far exceeding that of their faculty counterparts, they lack the local, pedagogical, and pedagogical content knowledge required for success were they to teach alone in the classroom.

What this means when adopting Industry Fellows is that the teacher should do all of the "teacherly" things, such as writing syllabi and homeworks, and assigning grades. In addition, the teacher has the pedagogical expertise so as to determine how to best structure the classroom interaction so that the industry fellow can connect their workplace expertise to student interests and needs. On the other hand, the industry fellow's role is to enact their practice in the classroom using familiar materials. One of the main ways is in responding to student work using authentic representations of practice, as discussed below. Other successful activities that I have asked industry fellows to do include: talking through a case study from past work projects; presenting their own design portfolio used in obtaining their current position; showing examples of the kinds of documents and artifacts from their own work (such as use cases, class designs, or test cases) similar to what I am asking students to do in their assigned project work. By having the industry fellow enact their practice using familiar materials, it 1) exploits what the industry fellow does well, 2) saves the industry fellow considerable time since they do not need to do preparation to talk about what is drawn from their familiar, everyday setting, and 3) it keeps the industry fellow in their comfort zone, thereby reducing any anxiety that they might feel about not have expertise in teaching in higher education.

Using artifacts to mediate interaction

Blumenfeld et al[2] define *artifact* in the sense in which I use it here: "We use the term artifacts to *denote* sharable and critiquable externalizations of students' cognitive work in classrooms ...

[that] proceed through intermediate phases and are continuously subject to revision and improvement." In the rest of this discussion, I will talk about *representations* and *tools*, and use these to mean kinds of artifact.

Research in the last two decades has thrown considerable light on the important role that artifacts play in thinking and social activity. Andy Clark, the philosopher of mind, summarizes much of this research in his discussion of what he calls *the extended mind*[19]. What Clark asserts is that *externalization* of thought, through various types of human-constructed artifacts gives rise to new perceptual and cognitive operations that allow for reflection, critique, and iteration. A useful metaphor he develops is of thought "looping" through mind and world[6]. That is, the act of bringing thoughts into material form, such as expressing software designs in words, symbols, and diagrams, is not merely a formal exercise, akin to taking mental dictation, but is itself constitutive of and essential to thinking and practical activity. Under this view, mind is not simply the sum total of representations and processes *within* the brain, but includes representations, tools and objects *outside* the brain as well. Sociocultural learning theorists[7,30] talk about how such externalizations *mediate* thinking.

This mediation, however, is not purely between an individual and externalized tools and representations. Rather, artifacts are *cultural*; communities of practitioners develop particular external forms in which their practices are enacted and made visible to one another for adoption and adaptation. As an example, consider the familiar graphical user interface (i.e. windows, icons, menus, pointer (WIMP)) that students imitate and adapt when learning interface design. Though students are often unaware of the history of its development, having grown up in a WIMP-saturated world, the WIMP interface represents the accumulation of decades of experimentation and negotiation among computer designers and users, sometimes explicitly in the design and usability lab and sometimes implicitly in the marketplace. When students construct such interfaces, they take part and become enculturated into the historical process of design that is an ongoing activity of interaction designers. Expert designers recognize and have expertise in designing this particular kind of artifact. These experts can therefore use both student- and expert-generated interfaces as objects of mutual reference around which to discuss, alter, experiment, and explore. These forms thus mediate both intramental and interpersonal interaction.

In Industry Fellows, interaction among students, practitioner, and teacher are mediated by the common artifacts appropriate to the domain of practice. A common activity when the industry fellow is present is for students to present the representations that they have developed (e.g. an interface, a class design, a unit test), followed by commentary, critique, and discussion among all participants in the class. Professional practitioners need no preparation in order to respond to student-generated externalized forms since such forms comprise the daily activity of the industry professional. And the public nature of critique provides other students within the "horizon of observation[14]" the opportunity to vicariously observe and learn at the same time.

But there is a difference between mediated activity in the classroom and mediated activity in the workplace. The demands of the workplace generally require high levels of performance, less than optimal for the novice learning his or her craft. The classroom, on the other hand, provides learning opportunities unavailable in the workplace setting. This includes *simulating* professional practices, thereby reducing the stakes and the risk, *slowing down and interrupting* activities to enable commentary and critique, and *reconstruction and replay* of student performance to allow cycles of reflection and practice. This is what Gee[12] calls a *supervised sandbox*—a place for exploration under the watchful eyes of those more experienced. With both the industry fellow and the teacher present, the classroom can combine the strengths of the university with those of the workplace. Using these mediating representations, the industry fellow can model and critique professional practice, while the teacher can narrate, alter the pattern of activity, and facilitate reflection. The representation and its associated activity thus stand at the boundary between the academic and the professional worlds of practice.

Choosing industry fellows and academics with intrinsic motivation to participate

Intrinsic motivation is a self-determined impetus for goal-directed activity. Extrinsic motivation, on the other hand, is a punishment or inducement to act that comes either from outside the individual or has been internalized by an individual. When people are intrinsically motivated, they engage in activity because of the pleasure and enjoyment that they receive from the activity itself—the doing is its own reward. There is little controversy in the scientific record: extrinsic motivators *reduce* intrinsic motivation[9]. "Despite our abiding faith in incentives as a way to influence behavior in a positive way, they consistently do the reverse[23]". Not only do extrinsic motivators reduce intrinsic motivation, they often reduce the quality of what is produced. "[P]eople will be most creative when they feel motivated primarily by the interest, satisfaction, and challenge of the work itself—and not by external pressures[1]".

It is therefore important that industry fellows and academics who teach together do so with a desire to participate, since they are more likely to follow-through on their commitment to co-teach and to gain from the experience. This is especially the case since it is unlikely for there to be sufficient funds to pay the industry fellow the market value of their time. Rather than provide money, industry fellows can be provided with feedback about the positive impact their work has on the students and the faculty member. In addition, some industry fellows may appreciate a formal appointment (e.g. I have used both "Visiting Scholar" and "Industry Fellow" for past fellows) that is formalized by a letter from the department head or Dean.

Industry Fellows is also designed to increase the intrinsic motivation of students to study, to learn, and to engage in the practices associated with the domain. Such motivation is stimulated by the legitimization of course content that the industry fellow can provide, from student gains in technical skill from industry fellow feedback, and from the visible connection between academic studies and future professional practice that is made visible in the classroom.

Evaluation of Industry Fellows

Industry Fellows has been evaluated with respect to impact on each of the main participants. The Office of Educational Assessment (OEA) at the University of Washington carried out semi-structured interviews with each of the three industry fellows to date, students were surveyed at the end of the academic term, and as the instructor, I kept detailed notes on the experience with each fellow. I report on each of these in turn.

Impact on industry fellows

A researcher from the OEA carried out a single 30-45 minute telephone interview with each industry fellow focused on reasons for participating and the characteristics of the experience, with a follow-up exchange via email. The discussion here quotes from the OEA evaluation report.

> Industry fellows were highly motivated to take part in the program. Given their experience in the field they felt that they were in a unique position to inform the nature of computer science education at the curriculum level. It is their hope that these changes would better prepare incoming computer science professionals for the

rigors of “real” work. Moreover, fellows reported that they enjoyed teaching and the program gave them the opportunity to do so without a significant time commitment.

In general, fellows reported that they found the industry fellows experience to be enjoyable and rewarding. Fellows were most impressed with students’ level of engagement, the improvement in students’ work, and students’ appreciation of fellows’ efforts.

Fellows indicated that the experience was less work than they had originally anticipated for two main reasons. First, fellows reported that the Project Leader went out of his way to provide the support needed to make the project doable for them. Second, fellows reported that there was considerable overlap between their professional work and their classroom contributions.

Fellows felt that having an industry fellow in the classroom benefitted all parties involved including students, professors and industry fellows. First, students were more engaged because they were able to see practical applications. Second, the professor was able to supplement her/his knowledge base with up-to-date developments in industry. Third, industry fellows gained general classroom experience, a greater appreciation of why things are taught the way they are in academia and had the opportunity to impact future computer scientists.

Impact on students

Students were given an end-of-term survey administered electronically on the final class session for each of the three courses in which an industry fellow participated. 23, 10, and 18 students completed the survey of the 25, 12, and 18 students enrolled. Students were asked to indicate on a 5-level Likert scale (strongly positive, positive, neutral, negative, strongly negative) how the participation of the industry fellow impacted several aspects of the course: motivation to do coursework, motivation to attend class sessions, engagement in course activities, and learning the course material.

The survey results are summarized in the table below. “ID” stands for the Interaction Design course, and SE stands for the Software Engineering course. The designators “heavy” and “light” refer to the industry fellow’s involvement as either heavyweight or lightweight as detailed above. The numbers in the cells of each of the last 4 rows indicate the number of students who indicated positive or strongly positive for the corresponding question.

	ID 1 (heavy)	SE (heavy)	ID 2 (light)
Number of students completing survey/enrolled	10/12	23/25	18/18
Indicate how participation of the industry fellow impacted your:			
motivation to do coursework	9 (90%)	18 (78%)	17 (94%)
motivation to attend class sessions	8 (80%)	21 (91%)	17 (94%)

engagement in the course activities inside and out of class	7 (70%)	19 (83%)	17 (94%)
learning of the material in this course	10 (100%)	20 (87%)	17 (94%)

Not only were students overwhelmingly positive about the impact of the industry fellow, no student indicated negative or strongly negative impact for any question. From these responses, it is clear that involvement of the industry fellows significantly impacts student motivation.

In order to gain additional insight into the impact of the industry fellow, two short-response questions were also asked: ``Compared to other courses in the Institute of Technology at the University of Washington, Tacoma, what difference did it make having the industry fellow as part of the teaching team?" and ``How has interaction with the industry fellow affected the design and execution of your final project?" All students who completed the survey answered both of these questions.

In analyzing the responses, two themes were prominent.

1. **Connecting the classroom to the world of professional practice**

Most students mentioned how the industry fellow helped them to see the relevancy of their school work, and how they might use their classroom experiences in their future work.

> "I found that having an 'Industry Fellow' in the class gave me a better representation of how this course applies to a real job"
>
> "It gave the course a greater sense that this was something we could put to use in our professional career."
>
> "I was able to see what I learn in the class can be used in real life settings."
>
> "Hearing stories from someone 'in the trenches' made the value of the subject matter we were learning in the course much more obvious."
>
> "... it helped me gain a more realistic view of my class material, seeing that it's more than just theory ... that it is used in practice."
>
> "It really helped tie the course to a real life situation. I felt that I got a lot more out of it, and paid more attention just knowing that she had a career doing this."
>
> "A lot of the time in courses, I find myself asking 'how much of this stuff am I actually going to use,' and come with an answer myself. Having and [sic] industry fellow present to clear up any ambiguity to this question helps a lot."
>
> "It helped tie in some of the key concepts that we would need to learn and be conscious of for work outside of an academic setting."

2. **Developing specific technical skills through the industry fellow's critical evaluation of student work**

Many students pointed out the importance of the feedback that they received from the industry fellow on their work in progress. Several mentioned specific skills and practices that they improved as a result. They also emphasized both the salience of the feedback and the degree of legitimacy that they accorded to it because of the industry fellow's expertise in professional practice.

> "... her critiques of the classes [sic] deliverables pointed out ways to improve the design and incorporate features in the design that would have not been considered otherwise."
>
> "Our code was much cleaner than it would have been thanks to her feedback."
>
> " ... it helped me realize the various flaws in my designs."
>
> "It was the honest critics [sic] that were most valuable."
>
> "The most important thing I have learned from [the industry fellow] is to be able to tell a story behind my design."
>
> "We even tried to take his advice on presentations for our final presentations."
>
> "[the industry fellow] influenced the way that we conducted our interviews, how we set-up the content on the website, and even gave us hints on how to better present our ideas."
>
> "[the industry fellow's] feedback helped me realize that simple was beautiful, and more importantly, clarity and simplicity would ensure more users would experience our project, and be able to get something positive out of it."
>
> "Her advice was used by every group in the class."
>
> "[the industry fellow] gave us many pointers about good coding practice, requirements gathering, and designing."

One of the surprises from this evaluation data is the amount of impact that resulted from the lightweight instantiation, averaging only 30 minutes of electronically-mediated involvement by the industry professional per week. It suggests that frequency of interaction and feedback on student work are more important than length of interaction. It is likely that the payoff curve for industry fellow involvement graphed against time is initially steeply upward, then dropping quickly. Thus, even with little involvement industry fellows can have significant impact, as long as the fellows understand the course and teaching context, and have ongoing interactions—however brief—with students and the teacher.

Impact on the teacher

Prior to and during the academic terms in which I worked with an industry fellow, I took notes during and after each meeting and telephone conversation. I also spent time between conversations and after the term reflecting on the experience and the lessons learned. My comments on the experience, like the students', can be grouped into the same two categories: increased relevancy of course material, and the learning of specific technical skills. The increase in relevancy resulted from interactions both during the planning phase and as the course was running. For example, in the Interaction Design course, I obtained a better sense of the importance of different kinds of prototyping methods and artifacts during planning discussions with the industry fellow, as well as when and how they are used in different phases of the product lifecycle in industry. I was thus able to better mirror some of their uses in more realistic ways in the classroom. Simply having my industry fellow say "I never use that, and almost nobody that I know does either" was quite helpful in eliminating the obsolete practices (still enshrined in academic texts) that I was having my students learn.

My technical skills in Interaction Design and Software Engineering also improved. For example, in the Software Engineering course, the critiques of the industry fellow on student designs helped me to see some of my own misconceptions (and lack of skill) in object-oriented design, which I was able to improve with her help. These technical skill improvements will benefit students in future offerings of these courses. And in the Interaction Design course, I was able to see the importance of narrative in envisioning the uses of designed artifacts.

One other point to note is that the changes that I made to my courses are lasting. That is, I have not reverted to teaching in the way that I did prior to working with the industry fellows. And even without the presence of the industry fellow, I use considerably more public critiques of student work using mediating representations.

Industry Fellows is novel

The *Industry Fellows* model is novel, drawing inspiration but also distinct from past attempts to link practitioners and academics. I briefly compare Industry Fellows to the use of industry advisory boards, guest speakers from industry, professional practitioners moonlighting as teachers, and student internships to argue for the novelty of Industry Fellows.

Industry advisory boards can provide important input into curricula, thus having a positive impact on the development of degree programs. But acting at the program level divorces many of the board concerns from the day-to-day realities of the classroom. In addition, many of the members of the board are no longer practitioners but rather in higher levels of management.

Guest speakers from industry provide students a window into the world of work. But inherent in this type of student-practitioner interaction is the fact that guest speakers have no opportunity to provide feedback to students on their work, and they rarely understand the context of the courses or the specifics of the college settings in which students are working. In addition, there is no ongoing relationship between guest speakers and students, no opportunity for these speakers to contribute to further student development. Considering that learning involves enculturation into a practice community rather than the transmission of packets of knowledge, there is little opportunity for guest speakers to enact authentic practice, or critique students' attempts at imitating and adopting expert practice.

When professionals moonlight as part-time teachers, there is the opportunity for this ongoing interaction. These moonlighting practitioners have deep content knowledge and a keen awareness of one or more specific work settings that they can bring to the classroom. Yet, as discussed above, they do not have the pedagogical or pedagogical content knowledge that only comes from experience in teaching. And, because part-time teaching faculty have little interaction with skilled teaching faculty, they improve as teachers only very slowly through their own trial and error in the classroom.

Industry Fellows also differs from student internships, where individual students spend time working in specific industries. These kinds of experiences can be invaluable to students, and can provide increased motivation for students to continue with their academic studies. Yet the experience also varies widely from student to student. In addition, there is often little opportunity for participating students to reflect on their internship experience and to explicitly integrate their academic knowledge with what they are learning about practice.

Because of the ongoing interaction of the industry fellow, and the pairing of practitioner with educator, Industry Fellows is a novel model with the potential to be extended to other practice-based disciplines and diverse settings. In addition, none of the existing models above provide the opportunity for teaching faculty to increase their practice knowledge. And with the exception of professionals moonlighting as part-time teachers, none provide industry practitioners the opportunity to develop a practice-based understanding of the academic enterprise or to improve as teachers and mentors.

Industry Fellows is a novel model for bridging the academic-industry gap

There is general agreement by blue ribbon task forces and engineering researchers that 21st century engineering education must be centered on the professional practice of engineering[17,24]. As such "faculty need to make clear what expert practice looks like, modeling or otherwise making visible both thinking and doing[24]". One important avenue for doing so is for "engineering educators [to] engage practitioners from business, industry, and government. Practitioners can … also work with faculty to help bring approximations of professional practice into the classroom[24]."

But the reality of higher education and professional practice present challenges to realizing industry-academia collaboration. Teachers need further education in state-of-art skills, while professional practitioners need experience and guidance in working with students. Meanwhile, students struggle with bridging their academic knowledge with the world of practice that they will be joining.

Industry Fellows was designed with an explicit recognition of these challenges for teachers, industry practitioners, and students. Viewing these three challenges as interrelated allows industry fellows to impact all three participants. The evaluation data indicates that the Industry Fellows model does have this impact. Industry fellows report that they learn about the educational enterprise, and are able to link their professional skills with those required in the university setting. They find satisfaction in being able to positively affect undergraduate education. University teachers benefit from practitioner expertise in updating course materials and in increases in technical skills. And students gain from increases in motivation to study, learn, and engage in the course because they are assured it links to professional practice, while at the same time learning state-of-art practices.

Industry Fellows is based on research in sociocultural learning theory, expertise, the use of mediating representations, and the importance of intrinsic motivation. With its direct interaction between students, faculty, and practicing professionals over an extended period of time, Industry Fellows offers a novel model for helping to bring engineering education into the 21st century.

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