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iFoundry: Engineering Curriculum Reform Without Tears

Introduction

The National Academy of Engineering's (NAE's) 2020 reports[1,2] have identified the knowledge and skills needed by the engineer of the 21st century and the large-scale curriculum reform necessary to educate these new professionals. Blank-slate curriculum reform efforts,[3] innovations from the National Science Foundation's (NSF's) curriculum coalitions,[4,5] and even a brand new engineering college[6] have bootstrapped models for significant and effective curriculum innovation that offer a variety of plausible avenues for change. Yet, despite significant progress in outlining appropriate changes and widespread agreement that change is necessary, many engineering curricula appear to be locked in a cold war time warp with incremental, grudging modifications coming at the margins, if at all.[7]

This paper suggests that the organizational processes by which curriculum changes are vetted and made are key factors inhibiting effective change. In particular, the normal democratic processes of curriculum approval invoke a kind of educational NIMBY (not in my backyard) problem in which changes are fine with individual professor as long as they are not demanded in courses that particular professor teaches or cares about. The inevitable logrolling results in a coalition favoring the status quo to block changes that many know are needed.

The paper discusses efforts to overcome such *organizational resistance* through the creation of a grassroots interdepartmental collaborative pilot unit of students and faculty to test, implement, and assess needed changes. The pilot called *iFoundry,* short for the Illinois Foundry for Tech Vision and Leadership, was established in the summer of 2007. This paper discusses the origins of iFoundry, its progress to date, and the theory and practice of its implementation. A key notion is that the usual method of approving untested curriculum changes goes against the engineering grain, and that a pilot unit, especially one that combines the efforts of students and faculty from a number of different departments, is likely to test, implement, and then institutionalize changes more effectively than the traditional approach to curriculum change.

The paper starts by reviewing the context of curriculum change in 2008. It continues by discussing the lack of diffusion of tested curriculum reforms that resulted from the NSF coalitions and elsewhere and a number of organizational responses to the problems of change. The paper continues by examining two reasons why curriculum is so hard to change given the organizational processes of vetting and approving curriculum change. It then outlines the iFoundry idea of establishing a collaborative, interdepartmental pilot unit and six key elements of iFoundry's systems design. The paper continues with a brief report on progress to date and a call for open source curriculum development and the formation of a global xFoundry coalition of pilot units that subscribe to the iFoundry principles.

Flat Worlds and the 21st Century Engineering Curriculum

The current engineering curriculum was formed in the crucible of the cold war.[8] Since that time, radical changes in transportation, communication, and computer technology[9] leave us in a very

different world. Popular books such as *The World is Flat,*[10] *A Whole New Mind,*[11] and *The Rise of the Creative Class*[12] suggest that returns to innovation and creativity are especially important in a world where routine analysis and engineering tasks can be outsourced globally for dimes on the dollar. Scientific discovery and the integration of technology in everyday life are occurring at an increasing rate. These trends demand a more direct involvement of engineers in leadership roles in business and public service.

Against this backdrop, there has been growing recognition that the engineering curriculum must change as well. The National Academy of Engineering published two widely regarded reports[1,2] on the nature and education of the engineer of the year 2020, and new programs such as the one at Olin College[6] make significant curriculum changes, but much of the engineering education establishment remains resistant to reform.

The Coalitions, a Lack of "Diffusion," and Organizational Cures

Particular telling to the current situation are the millions of dollars NSF spent in the 1990s funding eight curriculum coalitions to pilot new innovations in engineering education. Despite local successes in many of the pilot programs, the innovations did not spread widely, and a recent report[13] explores the reasons for the failure of those efforts to take hold. The report suggested that a particularly important factor in the lack of diffusion is the culture of research dominant in many engineering schools. The report suggests a number of cultural changes to try to place more emphasis on undergraduate education, including tenure reform and changed incentive structures, but three types of *organizational response* to the need for increased undergraduate emphasis in practice are common: the standalone program, the engineering education department, and the interdisciplinary program or institute.

Standalone undergraduate programs ensure that undergraduate education is a primary focus of the institution. At a research institution, however, a standalone program risks the segregation of the faculty into less prestigious undergraduate teachers and more prestigious graduate faculty who conduct research. College-wide interdisciplinary programs or institutes on undergraduate education provide a locus for education-oriented faculty in different departments. Separate departments of engineering education take this one-step further by permitting full unit status and a dedicated faculty for education research and innovation.

Despite the differences in these three approaches, each of these arrangements assumes that *modification of organizational structure* is part of the answer to the question of how to reform engineering education. We agree with that assessment and go further. We believe that there is now fairly widespread agreement as to *what* should be done and even *how* engineering should be taught, but that insufficient attention has been paid to the manner in which curriculum reform is tried, vetted, voted, and then implemented. The next section discusses two key organizational obstacles to curriculum reform.

Two Reasons Why Curriculum Change is Hard

Despite widespread agreement that significant curriculum reform is necessary, curriculum change comes slowly if at all. Current organizational structures and processes in universities are *structured* to be conservative and resist change. To understand this kind of *organizational*

resistance, consider the usual *processes* of curriculum change and general lack of *data* that accompanies proposed changes.

First, at many institutions curriculum change is generally a democratic political process centered in a department or unit in which the status quo is the easiest course of action. Faculty members may generally agree that certain items are ripe for change, but they resist changes in the particular courses they are responsible for, and they resist changes that might deemphasize particular areas or specialties of interest to them. Thus, curriculum reform becomes something of an academic NIMBY (not in my backyard) problem: "It is fine to change someone else's course, but if you threaten to change my course, or courses or requirements that will affect my interests, I will form a coalition with others to oppose any or all but the most modest changes." Many readers will recognize this dynamic in their own previous curriculum encounters, and it is the key dynamic that must be overcome in significant curriculum reform efforts.

A secondary difficulty comes from a kind of *catch-22* type of problem surrounding curriculum change. Engineers are empirical beasts, and they like to see data confirming the efficacy of any design, but the nature of most curriculum change is that *it has not yet been implemented* in the curriculum. As a result, curriculum proposals generally face a dearth of data, making it difficult to move ahead with the kind of certainty one would hope for changes of such lasting importance. In short, there is no easy way in most curriculum processes to *pilot* changes to the curriculum prior to their actual trial as part of the curriculum. Of course, this fact exacerbates the NIMBY problem of the previous paragraph. If the politics of change resists change as it is, empirically minded engineers will resist untested changes even the more.

With these two difficulties in mind, it is possible to think systemically in a way to construct organizational modifications that will enable changes to be tried, data to be collected, and proposals to go forward with a greater chance for successful outcomes.

iFoundry: Overcoming Organizational Resistance with Systems Thinking

Understanding the dynamics of resistance to curriculum reform discussed above gives us the necessary clues to help overcome these difficulties. Without data, it is difficult for good engineers to feel comfortable with change, but without an arena to *experiment* and actually make changes, it is impossible to collect the data necessary to move ahead. With this in mind, in the summer of 2007,[14] an interdepartmental collaborative pilot unit was proposed at the University of Illinois at Urbana-Champaign to make it possible to collect data on proposed curriculum changes. The pilot unit was called *iFoundry* or the *Illinois Foundry for Technology Vision and Leadership*, and the proposal contained a number of key elements:

1. Create a collaborative interdepartmental pilot unit among key undergraduate curricula to promote curriculum reform.
2. Solicit volunteer faculty members and students to pilot proposed experimental curriculum changes.
3. Permit iFoundry volunteer students to get degrees in home departments using Dean's signatory authority to authorize limited curriculum variances on an experimental basis.
4. Respect faculty governance by requiring that experimental changes be vetted through ordinary curriculum channels following pilot study.

5. Consider scalability of pilot efforts in the design and testing of iFoundry courses.
6. Develop principles, processes, course materials, and curricula in the open, shared across campus and to other campuses.

In the remainder of this section, each of these elements is discussed in turn.

Pilot unit. The notion of a pilot unit is a commonplace in industry, but it is seldom observed in academic life. Curriculum reform cries out for *in situ* experimentation, but without a locus for such experimentation we are faced with (1) accepting changes before they are tried or (2) trying them outside the usual boundaries of the curriculum Even those changes that have been tested elsewhere are likely to require experimentation at the adopting institution to ensure they interact well with the faculty, students, and other coursework there. To overcome these difficulties, iFoundry has established a grassroots, collaborative team to move ahead with pilot changes to the curriculum. This group has been meeting since September 2007, and plans for the first iFoundry class are being set for September 2008.

Voluntary participation. It is best to staff such a pilot program with faculty who are truly interested in undergraduate education and students who are amenable to change. Even the most research-oriented institution has a cadre of dedicated undergraduate teachers, and many students today are interested in many of the modifications to the curriculum that have been proposed in the 2020 reports and elsewhere. iFoundry began with faculty and chief advisors from five departments, and student leaders joined the discussion in September 2007.

Signatory authority and variances. It might be possible to create a new department or new curriculum in a brand new unit, but the idea here was to create an experimental facility that would allow the existing curricula to change on a continuing basis. As a result, iFoundry is "wired" to have students in the program obtain degrees back in their home departments, using the Dean's signatory authority to override the current standing curriculum requirements. Thus, experiments can take place in iFoundry, and students get accredited degrees back in their home departments, thereby permitting the experiments to take place in the context of current degrees and accreditation. This usage of signatory authority stretches the way such authority is often used at many institutions, but the flexibility it presents is essential to the spirit of data collection necessary to overcome the current difficulties in curriculum change.

Faculty governance. Although iFoundry-like arrangements allow for greater flexibility in experimentation and data collection, they do not change the usual process for regular curriculum approval. Faculty votes through normal channels are still required to make piloted curriculum changes permanent; however, it is believed that the dynamics of that approval process will be significantly altered by the iFoundry trial. First, proposed curriculum modifications will have been piloted experimentally and assessed, and only successful modifications will be put forward for approval.. Second, for identical or similar changes faced by multiple departments, changes will have been piloted in iFoundry across those curricula, and the results will be sent back simultaneously to all departments concerned; it is believed that passage of difficult changes will be more probable if multiple departments examine those changes simultaneously. Third, students and industrial stakeholders will have become involved in the changes and may form a significant advocacy group for change. Taken together, before iFoundry, untested changes were

put forward in isolation and could be easily defeated by small coalitions of resisting faculty for reasons unrelated to the main rationale for making the changes. After iFoundry, well tested changes will be put forward by coalitions of faculty within a department and across a school or college, supported by enthusiastic students and stakeholders. In this way, it is expected that curriculum change will face a more balanced discussion on the merits of the changes rather than the limited, individual interests of a small minority of resistant faculty members.

Scalability. The NSF coalitions piloted many interesting variations on undergraduate content, pedagogy, sequence, and degree of integration. New curricula such as the much remarked program at Olin[6] have demonstrated effective models, but it is one thing to pilot a small test program with a large injection of funding and attention, and it is another to implement a *scalable* program at a large institution with a more ordinary allocation of resources and attention. Those of us who work in research-oriented institutions will continue to spend a significant portion of our time devoted to research and graduate education. Pressure toward research funding will continue at high levels, and it is unrealistic to think that dramatic shifts in resource allocation are likely to take place. As a result, iFoundry is dedicated to finding *scalable* means of implementing effective curriculum reform without ongoing faculty heroics or extraordinary exogenous funding.

Open-source curriculum development. Another key idea of iFoundry is to make the process be as open and transparent as possible. An iFoundry website was created at an early date, and reading materials, whitepapers, plans, and principles were posted from a very early time. iFoundry intends to make available all plans, curricula proposals, course materials, video, audio, PowerPoint, curricula, and assessment results on the web as a way of sharing our efforts across the college, across campus, and with our colleagues elsewhere.

These six elements form the basis of the iFoundry idea, and the next section considers some of the specific progress made to date in the implementation and testing of these ideas.

Progress to Date

Many curriculum reform efforts start as top down efforts to impose change on a resistant faculty, but iFoundry started as a grassroots network of faculty and administrators interested in promoting effective change. The following list of iFoundry and related activities points out a number of the key building blocks in the progress to this point:

Engineering and Technology Studies (ETSI) network formed (Summer 2006). A network of engineering, humanities, social science, and arts faculty started to meet and hold lectures and seminars at the intersections of engineering, technology, the humanities, and the arts. URL: http://www-illigal.ge.uiuc.edu/ETSI.

iFoundry concept paper written and initial meetings held (Summer 2007). The idea for iFoundry grew out of revulsion for the appointment of yet another curriculum study committee in the summer of 2007. The concept paper for an active pilot unit was written that summer, five core departments were approached, and support was solicited among key faculty and departmental chief advisors. URL: http://www-illigal.ge.uiuc.edu/ifoundry

Engineer of the Future workshop held (September 2007). A workshop on *The Engineer of the Future* was held in September 2007 featuring keynote talks by Bill Wulf, outgoing president of the National Academy of Engineering and Sherra Kerns, VP of Innovation for Olin College. URL: http://www.illigal.uiuc.edu/web/etsi/engineer-of-the-future/

Collective learning exercise held (Fall 2007). As a follow-up activity to the Engineer of the Future workshop, a team of faculty and students met to go through relevant literature, exemplary practices elsewhere, and exemplary practices at Illinois. URL: http://www.illigal.uiuc.edu/web/ifoundry/collective-learning/

Formal approval sought (Fall 2007)**.** The Dean of the College of Engineering charged a subcommittee of the College Executive Committee with making recommendations for the reform of engineering education. A report of this committee was presented to the Dean in February 2008 and the report recommended the establishment of an "incubator" along the lines of the iFoundry model.

By the time this paper is presented at the ASEE Conference, the fate of the approval process should be known. Regardless whether the proposal lives on, the thinking, principles, and plans discussed may be useful to other programs as they consider ways to make curriculum reform speedier and more effective

iFoundry, xFoundry, and Global Open-Source Curriculum Reform

The iFoundry concept paper articulated an organizational vision that removes key elements of organizational resistance to curriculum change. In particular, overcoming the academic NIMBY problem and the catch-22 problem of curriculum experimentation through the formation of a collaborative interdepartmental pilot unit promises to provide a means of continuing curriculum innovation and reform that is scalable, respects faculty governance, yet works within existing departmental structures and accreditation dictates. Important progress has been made toward the realization of this vision, and efforts are ongoing at the time of this writing. A key element in the iFoundry solution is devising an effective interdepartmental unit that permits shared creativity and problem solving, and in this way iFoundry is animated by a spirit of overcoming the stovepipe-like lack of cooperation between departmental units that exists in many engineering schools and colleges.

In that same spirit, we believe it is possible to create a nationwide or even global movement of engineering curriculum reform animated with a similar can-do spirit and shared creativity and problem solving. When NSF put big money on the table for the engineering coalitions, this money was sufficient incentive for partners to join together in the coalitions in an honest effort at reform, but when NSF funds were exhausted, much of the driving force for change was withdrawn. Of course, some of the changes stuck, especially those on coalition campuses, but the aforementioned difficulties in getting these changes to diffuse combined with enormously successful examples of open-source software development make us wonder whether it is possible to drive curriculum reform with a grassroots open-source collaborative effort across many campuses around the globe.

The organizational principles articulated in this paper address a form of resistance that is universal; all of us recognize the NIMBY and catch-22 problems of curriculum reform at our institutions. As such, we believe that the widespread adoption of the six iFoundry elements can help overcome organizational resistance at all engineering schools. As such, we envision the formation of a global coalition, call it the *xFoundry coalition* (where "x" can be substituted with initials or a prefix appropriate to your institution), in which principles, processes, and practices can be freely shared from engineering school to engineering school. We close by inviting our colleagues at engineering schools around the country or around the world to join in an effort to promote curriculum change appropriate to the 21st century.

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