Globalization and Flexibility: Meanings, Challenges, and Opportunities for Engineering Education

Author:
Juan C. Lucena, Division of Liberal Arts and International Studies, Colorado School of Mines, Golden, 80401, Phone: (303) 273-3991, e-mail: jlucena@mines.edu

Abstract -- Globalization is a complex concept with a multiplicity of meanings, challenges, and consequences to engineering students, educators, and professionals from around the world. It is often assumed that globalization is an inevitable process of economic and political integration that people either accept or resist. Engineering educators often use "globalization" as a justification for curriculum change, internationalization of their programs, conference themes, or as a scapegoat to resist change. Some have successfully incorporated the concept in their courses in a variety of ways while others have resisted changes to this day. Yet a detailed analysis of the meanings of globalization, along with its challenges and opportunities for engineering education, remains to be done. In this paper I survey theories of globalization, analyze its connection with demands for flexibility in education and flexible engineers, outline existing and potential challenges associated to flexibility, and provide concrete examples of opportunities for engineering education.

Index Terms – Globalization, flexibility, flexible engineers, curriculum innovation

Introduction

Concerns about the relative inflexibility of engineering students have gained prominence among reformers in academia, industry, and government since the end of the Cold War. International organizations, national security think tanks, and academic and industry leaders argue that the global economy brings about the globalization of technological work, which in turn requires new ways to educate and train the future U.S. engineering workforce. [1-9] According to this vision of globalization, a transformation in economic activity may be changing, perhaps to an unprecedented extent, our values towards the way we work, create knowledge, and interact with others.

Proponents of educational reform argue that mapping the global terrain and instilling flexibility in how students solve problems are not only two of the most pressing educational needs but are the two skills that U.S. engineering students lack the most. Some studies, for example, document ways in which engineering education, research, and practice extend beyond national borders, taking a transnational character, and having significant consequences for the U.S. [10] Corporate reformers have begun to call for cross-cultural competency and flexibility in engineering education in light of the challenges of globalization. [11-14] ABET 2000 criteria call for the “ability to function in multi-disciplinary teams” and for “broad education necessary to understand the impact of engineering solutions in a global and societal context.” [15] NSF’s systemic reforms in engineering education through the Engineering Education Coalitions aim to create 21st-century flexible engineers for global competition. [16, 17] Human resource directors and professional engineers have joined the calls for flexibility. In the words of one engineer, “New engineers need to understand the nature of engineering—optimizing a huge variety of technical, practical, and political concerns to meet a business need. Engineering is not just sitting at a computer drawing all day. It is providing something that can be sold at a profit in a given amount of time, at a given investment cost, at a given price. The best solution to a business problem is not necessarily the ‘ideal’ design”. [18]

This paper explores the relationship between globalization and flexibility in engineering education, outline existing and potential challenges to the demands for flexibility, and provide concrete examples of alternative paths to educate flexible engineering graduates.

Brief history of the origins of flexibility in engineering education

To understand how the concept of flexibility became a paramount concern in US engineering education we need to look at the roots of US engineering knowledge. A short history of the changes in the engineering curriculum can shed light on what the current movement for flexibility is responding to.

A tension between theory and practice has come to define US engineering curriculum throughout the 19th and 20th centuries with the emphasis shifting to one side or the other depending on the historical circumstances of the time. In the
early 19th century the boundaries of engineering knowledge began to be set when the French model based on mathematical theory influenced the curriculum at West Point (1802) and the British model based on apprenticeship influenced the canal projects in the US northeast. [19] This tension was institutionalized at a larger scale when the Morrill Land Grant Act of 1862 provided federal land to states to build public universities to promote the mechanical arts. These universities became the vehicles through which engineering education, at that time defined as a combination of school education and practical training, became widely available to young students from farming communities throughout the US. [19]

WWII shifted the balance towards science in engineering education. Scientific knowledge gained status as it provided new solutions to the problems of war. [20] The struggles between ‘science-oriented’ engineers and ‘trial-and-error’ engineers of the time reflect the tensions within engineering education. [21] By the end of WWII this tension had shaped the engineering curriculum into two co-existing tracks: One scientific-technological and one humanistic-social. [22]

The existing model of building blocks of science, math, and engineering sciences lie in the scientization of engineering knowledge that began after WWII and reached its peak during the Cold War. Sputnik settled the struggle between science and practice in favor of the former. [23] For the first time, a body of knowledge known as engineering sciences was proposed as the core of the engineering curriculum. These would include six categories: mechanics of solids, fluid mechanics, thermodynamics, transfer and rate mechanisms, electrical theory, and property of materials. [24] According to the American Society of Engineering Education (ASEE), “all courses that displace engineering science should be scrutinized. The most important engineering background of the student lies in the basic sciences and engineering sciences”. [25] Math, basic science, and engineering science came to make more than 80% of the engineering curriculum with design and humanities/social sciences taking a distant second place. ABET accreditation criteria, which remained relatively unchanged until the end of the 1990s, shortly reflected this emphasis on science. Government agencies reinforced the scientization of engineering education and practice by establishing new criteria for funding curriculum development and research in engineering that emphasized science over everything else. According to the US National Science Foundation, “The NSF has adopted a policy which clarifies the engineering research supportable by the Foundation ...Such work must be of a true scientific nature and not routine engineering practice, and must meet the usual NSF standards of originality and excellence”. [26]

In 1980s American fears of Japanese technological competitiveness materialized in engineering education as a concern about the number of engineers produced in the US compared to those graduating in Japan. [27] However, the curriculum, with its emphasis on science, remained mostly untouched. Curriculum initiatives aimed at recruitment and retention (e.g., summer bridge programs, special intro sections for women and minorities, etc) and design education were introduced around the main blocks of math, basic science, and engineering science.

Policy analysts, who questioned the emphasis on numbers at expense of ignoring the kind of students that were coming out of the pipeline, made the first calls for flexibility in the late 1980s. According to an influential human-resources policy analyst, “...we need human resources that will be flexible enough in terms of their training so that if they don't quite match what is at that time the need for their skills, they can be retooled very quickly.” [28] These calls expressed concerns about how global competitiveness created a need for engineering graduates who could adjust to different cultural contexts and solve different problems. The NSF responded to this challenge in the early 1990s with the funding of the Engineering Education Coalitions: ECSEL (1990-94), Synthesis (1990-94), Gateway (1992-96), SUCCEED (1992-96), Foundation (1993-97), and Greenfield (1993-97).

The most coherent call for flexibility came from an NSF-sponsored conference aimed at systemic change in engineering education. Attended by the most influential figures in industry, government, and academic with strong interest in reforming engineering education to educate flexible engineers, the conference characterized the need for change as follows: “The shift from defense to international competition as a major driver for engineering employment; opportunities offered by intelligent technology to be more creative and "work smarter;" an expanding social infrastructure that demands a talent for complexity; an eclectic, constantly-changing work environment, calling for astute interpersonal skills; and massively integrated populations placing environment, health, and safety at the front end of design will require engineers whose intellectual skills include, but extend well beyond, the traditional science-focused preparation that has characterized engineering education since World War II.” [17] Although the champions of systemic reform opened a wider door to bring flexibility into engineering education, the tensions between science and practice are very much alive within the walls of engineering schools and systemic reform is far from being realized.

Globalization

The concept of globalization was not recognized to be academically significant until the mid-1980s and ever since it has become the “buzz word in the analysis of social change. According to Waters, “globalization is traced through three arenas of social life that have come to be recognized as fundamental in many theoretical analyses: the economy, the polity, and
culture.” Academics emphasizing the economic dimensions of globalizations have focused on the creation of institutions to regulate fiscal and development policies in non-industrialized nations; the rise of multi-national corporations; the separation of financial and manufacturing sectors and the deregulation of the former; the accelerated movement of manufacturing to developing countries and development of service and knowledge sectors in industrialized countries; and the changes in production, from a Fordist system of production to a flexible system of production.

Scholars analyzing the political dimensions of globalization have focused on the change from a Cold War bi-polar world to multi-polar world, the rise of liberal democracies all over the world, the demise of national sovereignty brought by multinational corporations and international organizations, the emergence of regional blocks such as the European Union, Mercosur, and NAFTA, and devolution of the nation-state into localized ethnic enclaves. Scholars analyzing the cultural dimensions of globalization focus on the flow of ideas, information, commitment, values, and tastes mediated through the symbols and the media and how these flows give a globalized culture a particular form, first, by forcing local cultural niches to relativize themselves to others and, second, by allowing the development of genuinely transnational cultures not linked to any particular nation-state society.

I use here a concept of globalization that emphasizes one of the main defining features of the global economy: the restructuring of system of production into a flexible system of production, accumulation, and consumption. Then I trace how this restructuring manifests in higher education institutions, engineering education programs, and, more specifically, in attempts to make flexible engineering graduates.

**Flexibility**

**Flexible system of production and accumulation**

Development, production, distribution, and consumption of goods and services, all of which employ large numbers of engineers, underwent significant transformations in the 20th century: from a linear system of assembly, distribution, inventory, and consumption (Fordism) to a ‘just-in-time’ flexible system (Post-fordism). According to David Harvey, in a system of flexible accumulation there are flexible workers that will work under subcontracts for multinational companies utilizing their knowledge and skills to develop and produce products and services tailored to specific market demands. Furthermore Harvey claim that global availability of goods and services depends on the availability of flexible workers to produce them ‘just-in-time’ according to shifting demands of consumers. See also

**Flexible organizations**

Some organizations, mainly private corporations, have responded to this shift to a flexible system of production and accumulation by adopting a matrix configuration in the way they organize and perform work. Organizations have gone from being divided along the main functions to be performed (functional) to becoming organized around both functions and products (matrix). “Following WWII, the US was in a dominant global manufacturing position, with industry intact and designed for mass consumption. But by the mid 1950s, global pressure was growing, along with military development pressure resulting from the Cold War. A cross-functional, or matrix, form of organization developed in conjunction with project management, drawing specialized talent from different organizations into one body to work on a project. The matrix form was thus an outgrowth of companies utilizing projects for work delivery, allowing them to retain functional grouping while meeting the needs of multiple projects.”

Matrix organizations are meant to improve lateral communication, and interdisciplinary/interfunctional collaboration in order to design, develop, or manufacture a product for a particular market and/or customer. During the participation in a project/product, employees end up with two lines of supervision: one from a project manager and one from a functional manager. After the project/product is fully realized, employees move to a new project/product and so on.

**Flexible organization in institutions of higher education**

Calls for higher education institutions to adopt matrix organizations have been made since the 1970s. However, knowledge organization along disciplines, reward systems aligned with a traditional value for publishing within the disciplines and organized around a functional organization, faculty fears of corporate-led takeovers of higher education, etc. probably prevented colleges and universities to consider matrix re-organization during the 1970s and 80s. Nowadays new competitive pressures from distance education providers, more accountability and yet less dependence on State funding, new student demographics, and the educational needs of non-traditional student populations, etc. are pressuring institutions of
higher education to re-consider one more time the adoption of matrix organization. Cross-disciplinary/functional arrangements (e.g., programs, certificates, courses, etc) are being developed and disseminated to respond to these challenges. 

Flexible engineers

Multinational corporations like Boeing, engineering accreditation organizations like ABET, federal sponsoring agencies like NSF, and many engineering educators assume that “flexibility” is something that can be taught in the engineering curriculum. [11, 15, 17] The underlying assumption of these calls and initiatives is that students can learn the ability to quickly adapt to new situations, such as a new cultural context, demand for a new product, new manufacturing techniques, etc. As new flexible technologies of production are set in place new demands for flexible skills emerge. New technologies (computer and telecommunications) and new organization practices significantly increase the need for computer, interpersonal, and problem-solving skills of engineers. [50] Examples of work arrangements that have significantly increased the need for flexible engineers include Boeing’s design-build team concept where design engineers, technicians, shop floor mechanics, etc. were organized around a part of the aircraft (product) during the design and manufacturing of the Boeing 777.[51]

Flexibility in engineering education

Here I outline a diversity of educational initiatives that have been developed to answer to the need for flexible engineers.

Flexibility through systemic reform

A number of engineering programs and initiatives have been developed to respond to the challenge of flexibility. As we have seen, the most prominent of these initiatives is the NSF’s Engineering Education Coalitions. The main contributions from the Coalitions came in the form of individual curriculum developments aimed at creating flexible engineers, e.g., students working in teams rather than independently and including cooperative learning; increased use of contemporary educational technologies, with computer-based methods of delivery taking the place of traditional lectures; and integration of engineering with other disciplines. However, the Coalitions’ goal of systemic reform through wide “dissemination of new structures and approaches affecting all aspects of undergraduate engineering education” was not successful. Most courses and initiatives were idiosyncratic in nature and difficult to implement elsewhere, even within the participating institutions.”[52] In short, the goal of creating an engineering education system to educate flexible engineers has not been realized. (See below, Challenges to flexibility)

Flexibility through design engineering education

A cursory review of 554 publications listed at the websites of the Engineering Coalitions indicates that over half (or 284) reported innovations in design education revealing that design education is perceived as one of the most prevalent vehicles to educate flexible engineers.[53] Some design initiatives expand design experiences in the first year, with the hope of introducing students to what engineering is all about as early as possible. [54-57] Other initiatives integrate design throughout the curriculum with the goal of helping students in "making the transition from the 'seat-of-the-pants' freshman design approach to the engineering design approach required for the capstone experience and engineering practice.” [58] Finally, senior design capstone courses aim at exposing engineering students to the key elements of design --design methods, project management, teaming, engineering economics, ethics, risks, and professional issues-- before graduation.[59]

As we have argued elsewhere, “the manner and extent to which engineering students resist and devalue education in design might provide some insights not only into design pedagogy but also into the pedagogy of the engineering sciences. Their experiences suggest that reform in engineering education may have to move beyond expanding and enhancing design education to address the very distinction between science and design, as this distinction has been taught and lived.” [53]

Flexibility through new products and delivery modes

One of the most comprehensive summaries of a flexible program comes from Palmer [60] who lists the following characteristics of a ‘flexible learning’ programme: 1) a modular curriculum where units are organized into discrete separable sections of content; 2) policies for recognition of both formal and experiential prior learning where faculty and students work together to identify approaches and methodologies used by their organization in addressing issues/problems covered in
course; 3) learning resources and tools to support the learning needs and styles of all students (e.g., lectures, printed materials, video and audio tapes, home experimental kits, CD Roms, computer programs and simulations, teleconferencing, email and Internet); 4) a means of facilitating two-way communication, especially through the use of computer-mediated communication.

It is ironic that a move towards flexible education creates a rigid production of educational products. Delivery of a course changes from service to a product “that must be manufactured in a factory and delivered to remote customers. The analogy to industrial production is very close; the production of flexible learning materials involves the design of the product, the planning of production, the assembly of the required human, material and financial resources, the development and evaluation of product prototypes, the freezing of design changes, the commitments to mass production, the control of production, the storage of product inventories, the delivery of products to customers, after sales service to ensure customers received the correct product and are operating it correctly, and a quality improvement process to ensure the product market share is retained and developed.” [60]

Flexibility through flexible appointment of faculty across disciplines

A faculty of engineering began at the U of Georgia in 2001 without creating a rigid organizational structure like a school of engineering. [61] At the University of Georgia, engineering faculty get faculty appointments in non-engineering disciplines and teach in engineering programs that have no home in traditional engineering departments. Along with affiliated faculty from other disciplines, engineering faculty create undergraduate and graduate programs from clusters of courses. These programs come in and out of existence according to demand and need. Other schools of engineering have followed suit by creating similar flexible programs with faculty and students coming from established disciplines, such as the Colorado School of Mines’ upcoming bioengineering and life sciences (BELS) program.

Flexibility through cohorts of students

Recognizing the differences between academic and industrial workplace behaviors and reward systems, Vickers created cohorts of graduate engineering students that can be socialized inside of academia to perform according to the values of industry. At the University of Arkansas, cohorts build communication, develop commitment to goals, inspire peers to accomplishments according to timelines, and model team building, as they move through the years and problems. [62]. In sum, this is a model of a flexible engineering team within an academic program. The expectation is that socialization into flexible teams will counteract the effects of a rigid academic culture.

Flexibility through multiple entry and exit points

For Krasniewski “flexibility means that each student has a lot of freedom in design of his/her education path.” The faculty of Electronics and Information Technology at Warsaw University of Technology created a “flexible system of studies” that has: 1) multiple exit and entry points so, for example, students can finish elsewhere or leave at third year with a certificate to seek employment or after fourth year move into master’s degree; 2) several areas of concentration within one or more fields of study; 3) large and diversified offer of courses; 4) freedom in design of an individual program of study (course selection); and 5) a possibility to adjust the course load in each term to individual background and pace of learning. [63]

Programs of this nature have been established to counteract the limitations of the educational engineering pipeline which dictates linear career paths from K to employment. The pipeline metaphor requires us to focus on recruitment and retention, to recognize "leaks" or "drop-outs" as people who have little, if any, chance to come back into the pipeline, and even to ignore non-engineers who might want to come into the pipeline at later stages. Proponents of diversity and flexibility in engineering education have begun to question the usefulness of the pipeline metaphor [64, 65] and to propose alternatives like that of "a river with feeders, streams, tributaries, oxbows, deep pools and shallow riffles, etc." which better reflects the complexity of pathways in and out of engineering education and employment. [66] The engineering education community has barely begun to respond to this new challenge.

Flexibility through case-studies in existing courses

Wood proposes to build flexibility in existing engineering courses by developing and incorporating industry-based modules into existing courses like math, physics, circuits, and instrumentation. At the Tri-Country Technical College in South Carolina, Wood developed and incorporated modules in industrial settings that reflect real industrial problems, and cover
basic concepts in math, science, and communication. This might be the most realistic approach, but also the most conservative, since it does not call into question the rigidity of the existing block curriculum model or academic structure.

**Challenges to flexibility**

Much has been written to advice corporate management on the challenges to achieve flexibility in organizations and people. However, a detailed analysis of the meanings of flexibility and its challenges and opportunities for engineering education remains to be done. My commitment here is to provide an outline of the challenges to flexibility to engineering educators and students with the hopes of highlighting dimensions of flexibility that might not be readily apparent.

**Cultural differences**

Cultural differences play an important role in the manner in which people easily adopt or resist flexible organization of work. For example, people from Anglo-Saxon cultures easily accommodate to the fluidity of flexible teams—with their changing membership and leadership—while people from collectivist, high power distance culture like Taiwanese, have a more difficult time accepting the constant change in membership and leadership. Yet this combination of Anglo-Saxon and collectivist cultures might become the most common in engineering practice and education, for example, as Chinese and Taiwanese engineers move in high numbers into engineering education and practice of Anglo-Saxon countries.

**National systems of industrial relations**

National differences in industrial relations seem to play a significant role on whether flexible organizations are adopted or not. In spite of the challenges of globalization, not all industrialized nations have embraced matrix organizations in the same way. For example, “in some countries, such as Japan and Germany, these flexible and team-oriented work systems were relatively common already, while in others, they represent such fundamental changes in culture and practice that they tend to be adopted slowly and meet with strong resistance from supervisors, managers, and in some cases union leaders. For example, in the UK, no more than 2 percent of all establishments with more than twenty-five workers have quality circles or problem-solving groups. Teamwork and major alterations in job content are even more rare. In the United States recent survey research suggests that no more than one-third of American workplaces have introduced more flexible work systems covering a majority of their employees…Canada appears to have experienced only a handful of cases where large scale innovations in work organizations have taken place…In contrast, quality circles, team-based work, job rotation, and flexible jobs appear to be extensive and diffuse throughout Japanese industry…These observed differences in patterns of work reorganization suggest that those countries that come from a tradition of job control—the US, Australia, Britain, and Canada—in which work was traditionally organized along more rigid Taylorist lines, have experienced the greatest pressures to transform their work organization arrangements. In contrast, those national systems of industrial relations that were never completely Taylorist and/or where they already had workplace practices that promote flexibility and communication such as Japan, Germany, and to some degree Italy, seem to have been able to accommodate more easily the need for these new workplace practices through incremental adaptations of their existing arrangements.”

**Nationalism**

Nationalism has also played a role in the way engineers accept or resist to be integrated in flexible teams with engineers from foreign countries. Historically, the engineering profession has been deeply connected to the emergence of that nation-state, its infrastructure and organization. In some countries like France, this connection has been and remains explicit and visible. In Mexico, presidential calls to serve the Mexican nation since 1929 have materialized in larger number of engineering students in those fields of engineering that contributed to the building of Mexican public infrastructure. According to Cleaves, “the expropriation [of foreign-owned companies] asserted national sovereignty and self-respect. The measure was immensely popular inside Mexico, and inspired young petroleum engineers. A spirit of nationalism characterized the engineering profession from its conception.” In other countries like the US and UK, the connection between the engineering profession and a sense of national greatness is not as explicit as in France and Mexico but it takes place through the private sector. In either case, many engineers have accepted a view of engineering as an activity deeply rooted in and connected to the technological greatness of their nation, have embraced a great sense of nationalism, and have resisted working in multi-national teams. For example, US engineers at Boeing resisted working with their Japanese counterparts during the development of the Boeing 777 due to nationalistic fears of giving up high tech knowledge and practices to the
In a survey distributed among engineers in Germany, Spain, France and England in one division of TRW, Grandin and Dehmel found out that the majority of engineers surveyed felt being judged by their peers on the basis of national stereotypes.

Functional engineers

Engineers who have defined their professional identity and build their authority in functional structures might resist flexible organization of work. Decision-making power and budgets reside on functional managers who are reluctant to give up or share it with program managers in matrix organizations. As I have documented elsewhere, functional managers feel threatened by flexible organization of work, like Boeing’s Integrated Project Teams (IPTs), under which they might become program managers and lose control of budgets.

Losing budgets and power might not be the only reason why functional engineers resist flexible organization of work. Traditionally engineers have come to define their professional identity along functional divisions, in some cases to the point that they mistrust engineers from other functional divisions, for example, when the interests of design and manufacturing engineers collided in the development of GM’s copper-cooled engine. As engineering students find themselves working as interns or new hires in functional organizations they might inherit or find themselves embedded in these functional tensions. At first functional organization could feel comfortable because it resembles the disciplinary organizational arrangement of school. Yet soon young hires will be required to work in flexible teams or projects. As I have documented elsewhere, engineering students do not receive the education to prepare them for these organizational changes and hence resist these changes without an organized strategy or conceptual framework to guide them. Very likely their resistance will not be good for them or the organization for which they work.

Traditional curricular model

One of the most under-analyzed challenges to flexibility of engineers is the organization of engineering knowledge in higher education: engineering curricula. As we have seen, during the Cold War, engineering curricula became organized in blocks of knowledge: math, basic sciences, engineering sciences, applied engineering, design, and humanities and social sciences. Students are supposed to build on the fundamentals of science and math and apply these fundamentals as they progress through the engineering science blocks. There are very specific passages between blocks, often in the form of pre- or co-requisites. Requisites and sequences are very rigid and the technical and non-technical blocks remain, for the most part, disconnected from each other. There have been some attempts to create lateral connections with other disciplines that are often similar in content but true interdisciplinary engineering programs remain to be realized.

One of most problematic assumptions of this model is that students will be able to make interdisciplinary relationships between these blocks. The disconnect between blocks, particularly between the engineering sciences, on the one side, and design, humanities, and social sciences, on the other, makes it difficult for students to integrate economics, politics, or culture into a statics problem. In addition, when students try to transfer credits across institutions, either as transfer students or upon return from study abroad, engineering faculty resist credit transfers, even when the course have same name, for they believe that the blocks have more value at home institutions. Furthermore, students have a difficult time committing to the flexibility required by open-ended design problems after passing through a rigid block-curriculum.

The unintended consequences for engineering education of continuing to commit to this rigid block model could be a continued decline in engineering enrollments since 1983, a lack of diversity in engineering student population, and attrition of students unwilling to commit to a curriculum that does not foster integration of knowledge areas. As more students begin to understand the importance of being flexible, they begin to search for majors with more flexibility in their curricula.

Engineering problem solving method

Another under-analyzed challenge to flexibility of engineers is the method at the core of engineering knowledge: the engineering problem solving method (EPS). Throughout their entire curriculum, but primarily in engineering science courses, students learn to solve problems as follows. First, they are GIVEN a problem, usually from a textbook, and they are told what to FIND. These problems are usually void of any socio-cultural- political context. They learn to extract only the relevant information to solve the problem. Second, students learn to create a free-body diagram (FBD) which is an idealized visual abstraction of the problem at hand further isolated from its political, economic, and cultural context. Third, students learn to identify and apply scientific principles to the problem at hand. These principles, in the form of equations, come exclusively from the engineering sciences. Fourth, once the equations are in place, students learn to deploy mathematical strategies, from
calculus and differential equations, to solve these equations. Fifth, students produce one solution, which needs to be accompanied with units to have any meaning at all, for which they receive reward or punishment. In spite of significant historical and cultural differences in engineering education systems, this method is being exported throughout the world through engineering textbooks from major publishers. I have found EPS in popular textbooks widely available in college bookstores in places like Denmark, India, and Mexico.

Where does the inflexibility of EPS come from? First, problems are always given to students and removed from their political, cultural, economic context. As long as they solve problems using EPS, they are not learning how to define problems in their proper context. Second, as students are told what to find, and not be given a choice to decide on other important variables to find, they do not learn that a problem might lead to the discovery of more than one important variable. Third, FBD further isolates the problem from its context. So if one of the characteristics of flexible engineers is to identify and solve problems in different contexts, FBDs are not helping students develop this important skill. Fourth, as equations from engineering science become the only acceptable means to the solution, students will not seek knowledge into other disciplines (e.g., architecture, economics, urban studies) or other experiences (e.g., trial and error, graphical methods, industrial experience) that might have significant contributions. Fifth, students learn to see problems as having only one solution when they are repeatedly rewarded by only one solution.

Conclusions

There are, at least, three positions that engineering faculty and students can take with respect to the challenges of flexibility: acting blindly, resisting blindly, or intervening responsibly.

Acting blindly

Many faculty and students have acted without giving much consideration to the unintended consequences of flexibility, e.g., economic and political cost to higher education of flexible organization of knowledge, the undermining of the disciplines, the meaning of emphasizing flexible skills over core values and knowledge in the education of students who after all we expect to become whole persons and citizens. For example, at the institutional level, one can blindly promote flexible programs that come from appointing faculty from different departments without considering the conflicts that might arise in decision-making and control of budgets, e.g., between department chairs who control budgets and evaluations vs. program chairs who control course scheduling and staffing. At the pedagogical level, one can promote flexible learning formats without asking whether students come to college to get more than flexible problem-solving skills wanting a deeper understanding of how to become whole human beings and longing to forge long-lasting relationships with faculty and students. Some have begun to question the hidden assumptions of flexible learning formats: “For some the notion of a deterritorialised lifelong learner, consuming learning opportunities, where and where they desire, might have a certain attraction. We argue for a more cautious and analytical approach.”[80]

Resisting blindly

Some faculty and students have resisted blindly to the educational demands of flexible accumulation because they find these demands to be serving the interest of corporate capital in manufacturing, distribution, and consumption around the world. In some cases corporate globalization becomes a convenient scapegoat to resist institutional, programmatic and curricular reform and to maintain the status quo in higher education. Indirectly, this resistance serves the purposes of those trying to protect the status quo of the block curricular model and EPS. But what if the theory of flexible accumulation gives us an accurate picture of the organization of work today? Then, whether we like it or not, as educators, we owe it to our students to prepare them to think critically, cope with the complexities of this world, and acquire lifelong appreciation for learning so they can adjust to ever changing circumstances. As educators and students, how can we do this without serving only the narrow interests of global capital?

Intervening responsibly

If flexibility is defined as the ability to solve different kinds of problems under different constraints and circumstances then engineering educators and students can redefine the existing dominant definition, which only considers narrow interests of global capital, to incorporate social justice, community development, cross-cultural understanding, and environmental preservation. Significant steps are being taken in engineering education in this direction.
Flexibility redefined as serving community. Flexibility could be redefined as the ability to solve different kinds of problems facing developing communities (e.g., water shortage or contamination, lack of basic infrastructure, etc.) under different constraints (e.g., lack of funding, political insecurity, environmental vulnerability, etc.) and circumstances (e.g., varying national and cultural context). Engineers Without Borders USA (EWB), a new grassroots organization aimed at providing engineering assistance for communities in need, have already inspired more than 20 student chapters across US engineering schools. Students are challenging faculty in design courses and labs to redefine engineering problems around the needs of poor communities around the world. This movement has already inspired faculty at the Colorado School of Mines to redefine a significant portion of the existing engineering curriculum along these lines. Similarly, Engineers Without Frontiers has inspired 14 student chapters and curriculum development along these lines at Penn State and Cornell University. Similar organizations, like Ingenieurs Sans Frontieres in France and Global Village Engineers in Massachusetts, exist elsewhere.

Flexibility redefined as serving the nation. Flexibility could also be redefined as the ability to solve different kinds of problems facing nation-states (e.g., terrorism, food supply contamination, air pollution, lack of alternative transportation systems) under different constraints (e.g., budget crises, shifting political environment, etc) and circumstances (e.g., global armed conflict making oil process volatile, etc). If engineers cannot expect long-term employment and job security from their corporate employers anywhere any longer (high tech companies are actually quite explicit about this) then engineers need to rethink the long-term interests that they serve when they engage in problem-solving. Hence, engineering problem solving could transcend, but yet be relevant to, corporate needs to incorporate those of the nation-state. Some schools have begun to address US national security needs.

Flexibility redefined as serving human diversity. Flexibility could also be redefined as the ability to solve different kinds of problems facing diverse groups of humans (e.g., multi-cultural engineering teams working on any type of engineering project) operating under different constraints (e.g., lack of funding, narrow stereotypic images of each other, etc) and circumstances (e.g., varying national and cultural context). We have developed a course, Engineering Cultures, which is aimed at helping students understand, analyze, and even value engineering perspectives of others who might solve problems different than they do.

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