AC 2012-4961: REQUIRING A COURSE IN INFRASTRUCTURE FOR ALL GRADUATES

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Requiring a Course in Infrastructure for All Graduates

ABSTRACT

There is something universal about obtaining a degree from an accredited university; it is a license to call oneself educated. In recognizing this certification of erudition, society sets relatively simple standards that can be difficult to achieve. The graduate must be able to address difficult problems coherently, bringing to bear a mixture of knowledge, empathy, skills, and moral and ethical standards. Within this framework, society allows for specialization. Lawyers are not asked to design airplanes nor doctors to write complex opinions on the meaning of recent acts of Congress. There is, however, an underlying expectation of core knowledge which is inescapable. Any college graduate, for example, should be able to read or write a paper on a complex topic, illustrating or discerning both the obvious and implied elements. To provide the underpinnings for this task, essentially every university requires a course in composition, and usually more than one; science and mathematics are likewise added to the core to ensure a universal base of knowledge among the graduates. All of these core competencies help graduates understand and explain elements of their everyday life, and are broadly considered essential to their ability to lead society towards a better future, achieving what is often the stated goal of each university. But if universities are producing leaders for society, shouldn't those leaders have an understanding of infrastructure, of the basic foundational technologies of society? Flip a switch, turn a valve, flush a toilet or climb aboard and travel – can the typical college graduate explain the implications of that action? Do they know what makes it work and the systems enabling them? If one can appreciate art and thus build a deeper understanding of the world, couldn't Infrastructure Appreciation help build more complete citizens of the world, laying the groundwork for a broader view of the choices civilizations make?

This paper builds on previous work, which described only the *content* of a specific course. Here, the authors discuss the *need* for widely available, and perhaps required, courses in the area of infrastructure. By providing *all* students with an understanding of how the built environment forms an essential part of societies past and present, our universities would creat graduates ready to lead society's critically important discussions and decisions, creating a future that we can best imagine collaboratively, including all the disciplines brought together by a shared base of knowledge.

INTRODUCTION

Right and wrong, sometimes enlightened and too often foolish, societies are constantly making fateful choices. These choices are more or less deliberate, depending on how that society is organized, and more or less beneficial to that society, other societies, and the environment, depending largely on how well-informed the decision-makers are. In *Collapse*, Jared Diamond argues this point in detail (Diamond 2005). It is exactly this need for well-informed leaders and voters that justifies and underpins the educational system in the United States, indeed in most democracies, and the university system has done an admirable job of producing an educated citizenry by universally requiring general education courses rich in the liberal arts. That said, there is a sizable and increasingly unpardonable hole in the educational background of "typical" college graduates: their technical knowledge related to the nuts and bolts of our increasingly technological society is insufficient, limiting their ability to engage in a real way with decisions vital to our future. There is a need to fill this hole, and one bridge to that informed citizen of the future is a course in Infrastructure for all college graduates. Infrastructure should be taken here as a widely inclusive term, with many systems and meta-systems (the health care system, electrical power, information technology, transportation, etc.) providing the framework for such studies. The *how* of such a course, what such a course might consist of, possible course syllabi, models and the like, is presented by Hart et al. (2011), but this paper seeks to address a very different question; why require such a course, particularly for non-engineers. More directly put, this paper argues that if we are to address the broad and complex problems posed by our decaying existing infrastructure and our demand for future infrastructure, articulated well by the America 2050 plan (Regional Plan Association 2008), then our nation absolutely requires an educated populace, across all disciplines, who understand the realities of how the components, systems, and meta-systems that underlie our daily lives actually work.

BACKGROUND

The word infrastructure has come into vogue with the American body politic; in the most recent State of the Union address, President Obama lamented "Our infrastructure used to be the best, but our lead has slipped... Countries in Europe and Russia invest more in their roads and railways than we do. China is building faster trains and newer airports. Meanwhile, when our own engineers graded our Nation's infrastructure, they gave us a D." (Obama 2011) In his 2010 address, the President stressed the importance of keeping pace with China, Germany and India in providing infrastructure to support economic development. Across the spectrum of American politics, from local to federal, there is an emerging consensus about the need for greater focus on the renovation and creation of infrastructure (Rohatyn 2009). Further, the broad and urgent issues of energy, infrastructure (particularly for electricity and transportation) and climate change have become inextricably linked as societies around the world discuss, disagree, debate and make decisions about properly balancing the production and use of energy against quality of life, future climate risk and economic opportunity. A rough feel for the growing importance of this debate can be seen in a thumbnail analysis of the President's State of the Union speeches, which represent some of the most carefully planned words in a given political year. Figure 1 shows the results of this analysis from 1975 through 2011; only the years listed were analyzed.

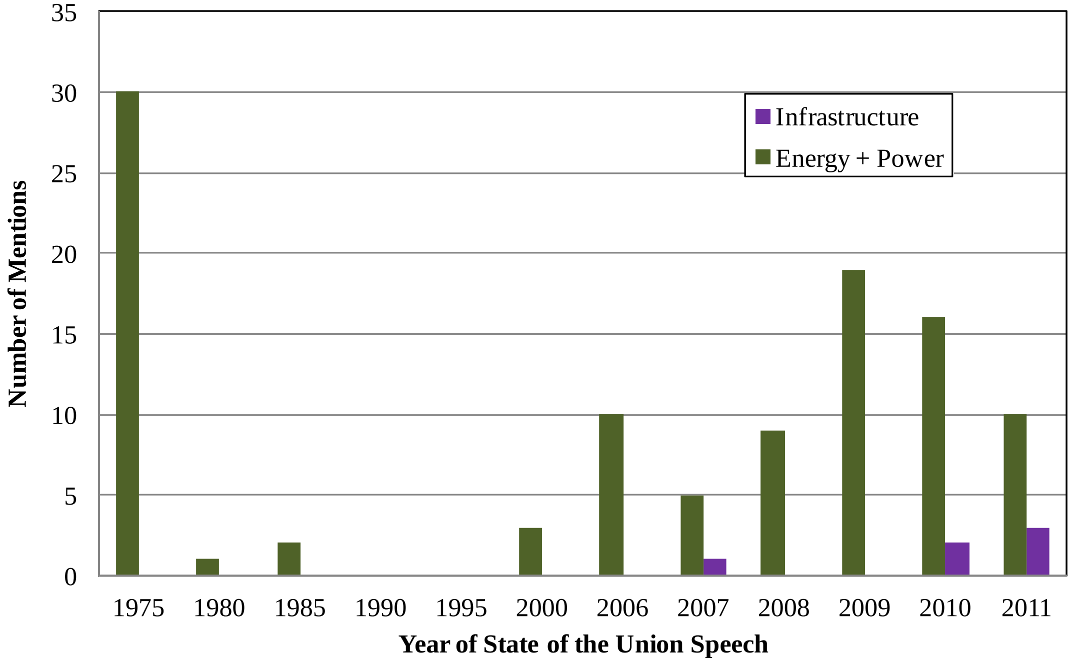

Figure 1: Number of uses of certain words in the selected State of the Union addresses

The clear implication is that complex and intertwined combinations of economics, culture, politics and engineering find their expression as choices societies make about their built environment – their infrastructure. In a democracy, these choices are shared, and technological literacy (TL) forms a critical foundation for both the individual and society. This necessary linkage between TL and citizenry has been emphasized and described well by others (Devon and Ollis 2007) (George 2006) and especially by the National Academy of Engineers (Pearson and A.T.Young 2002) and the National Science Foundation (National Science Foundation 1996). Krupczak and Ollis (Krupczak and Ollis, Technology Courses for Undergraduates: Developing Standard Models 2008) also concluded that "to achieve widespread impact, standard classes must be taught at many institutions round the country". Mary Kasarda's 2004 *Prism* piece (Kasarda 2004) directly explores this, stating "it is the social responsibility of everyone in higher education…to educate students in technological issues and change cultural perception of technology for the betterment – and survival – of society."

Despite this focus, the details surrounding the construction and maintenance of infrastructure has largely been left in the hands of engineers. A faculty member tasked with escorting an important politician related how, while crossing a major suspension bridge, the politician expressed amazement at the number of strands of wire making up the main cable: "My goodness! Who would have thought there was so much need for telephone around here?". Initially, one might be tempted to deride the leader for making such a statement; how could one not know the main cables hold the bridge up, and how can we possibly trust such a person with important decisions surrounding the bridge and the many others like it? Upon reflection, it is less clear where the blame lies; society selected that person to lead, and the politician holds a degree in law from a very well-respected institution. The politician learned what we (those charged with providing an advanced education) had deemed important: an introduction to science, likely very little on engineering as a discipline, and almost certainly little or nothing about infrastructure.

To explore this further, the authors searched for infrastructure courses offered to undergraduates not taking a technical degree and came up largely empty-handed. Though the engineering community is clearly moving to provide infrastructure programs related to civil engineering, sustainability and systems management, the courses in these programs are primarily at the graduate level and are not suitable for non-technical students. An extensive list of technological literacy courses are listed by Krupczak and Ollis (Krupczak and Ollis, Technology Courses for Undergraduates: Developing Standard Models 2008), but only one of these carries the word "Infrastructure" in the title, and that course no longer appears in the course catalog for that university, at least not with infrastructure in the title. Two programs, at West Point (Hart, et al. 2011) and the University of Wisconsin–Platteville (M. Roberts, et al. 2007) (Roberts, Parker and Thompson 2010), offer relatively new introductory courses specifically focused on infrastructure and available to any major at the university. Further, though not specifically focused on infrastructure, the work of David P. Billington and Michael Littman at Princeton must be acknowledged: for instance, the recent book, *Power, Speed, and Form: Engineers and the Making of the Twentieth Century* (Billington and Billington 2007), and cross-cutting education efforts to teach design to both engineers and non-majors (D. P. Billington 1993); courses in the history of engineering and the development of infrastructure have also been offered to a wide cross-section of students at Princeton and a number of institutions. Others, notably the Engineering Education Innovation Center at Ohio State, have been offering survey-style general education courses in engineering or engineering history to all undergraduates, imposing limited prerequisites to ensure broad-based enrollment (Gustafson 2008) (EEIC 2012). An excellent bibliography entitled "Engineering for Non-Engineers and Technological Literacy" has been compiled by the ASEE's Technological Literacy Constituent Committee and can be found online (Technological Literacy Constituent Committee 2011). Lastly, Krupczak (Krupczak and Disney 2011) has been writing, with others, extensively about this topic for some time, providing invaluable resources for implementing engineering courses within the general education curriculum. Although not infrastructure courses per se, the thrust of the thesis advanced is similar: "All Americans need to better understand the wide variety of technology used every day. The need for technological literacy has never been greater at both an individual and national level." (Krupczak, Simpson, et al. 2008)

A LIBERAL ARTS DEGREE

It is a generally accepted statement that a liberal arts education is focused on those subjects essential for study by a free person to produce well-rounded individuals suitable for citizenship (Connor 1998) (Becker 2003) (Kanter 2010). The history of liberal arts education shows that the "subjects essential for study by a free person" have evolved over time to meet the changing needs of society. In Ancient Athens, a liberal arts education consisted of grammar, logic, and rhetoric, which came to be called the Trivium. The emergence of these skills and the training of youth in their use proved essential to the functioning of the Athenian democracy (Connor, 1998). Later, in medieval times, the Quadrivium of arithmetic, geometry, music, and astronomy was added to form the seven liberal arts of a medieval university curriculum. These evolved into the contemporary liberal arts of literature, languages, philosophy, history, mathematics, psychology, and science (Colish 1999). These are manifested both as the basis for curriculum in liberal arts colleges" and in the general education curriculum found in most colleges and universities.

As one would expect, the process of discussion and debate on what constitutes a modern liberal arts education is alive and well within the liberal arts community. In a 1998 speech, W.R. Connor, President of the National Humanities Center, posed the questions "What does it take to create a truly open, free society in this strange new world we have entered in recent years? What are the skills of freedom today?" (Connor 1998). In 2003, Jonathan Becker, Dean of International Studies at Bard College addressed "What a Liberal Arts Education is…and is Not" in terms of goals, curriculum, pedagogy, and process (Becker 2003); furthermore, Harvard President Drew Gilpin Faust, in a 2009 address launching Harvard's revised general education program, traced the evolution of Harvard's program through the restructurings of the 1940s and 1970s to the most recent changes. In this speech, she re-validated an idea introduced at Harvard after World War II:

> Knowledge should be for citizens, not just scholars in their disciplines; knowledge should be for responsible human beings and citizens in a democratic society. This meant the development of special courses that would accomplish these goals using the knowledge of disciplines, the knowledge of research, to be translated into an education for the citizens the world so desperately needed. (Faust 2009)

Further, the website for the Association of American Colleges and Universities defines liberal learning in a way that envisions active citizenship supported by knowledge and practiced analysis:

> A truly liberal education is one that prepares us to live responsible, productive, and creative lives in a dramatically changing world. It is an education that fosters … an acceptance of responsibility for the ethical consequences of our ideas and actions. Liberal education requires … that we explore connections among formal learning, citizenship, and service to our communities.
>
> The ability to think, to learn, and to express oneself both rigorously and creatively, the capacity to understand ideas and issues in context, the commitment to live in society, and the yearning for truth are fundamental features of our humanity. In centering education

> upon these qualities, liberal learning is society's best investment in our shared future. (Statement on Liberal Learning 1998)

Strongly held and well-evolved views about the importance of liberal arts have led to a long-standing debate between engineers and the humanities at nearly every university where engineering is taught. This healthy exchange tends to center on the need for engineers to have a firm grounding in the humanities and to encompass in some way the aspirations of their universities for informed *citizens* and *leaders*, common nouns when universities speak broadly about their intended long-term goals for their graduates. Though there remain vast differences between liberal arts and the technical degrees, the days when engineering degrees could be called strictly vocational are long over. Engineers, to their credit, have steadily embraced the need for increased focus on the humanities, and essentially every graduate from an ABET-accredited program must demonstrate knowledge, and in some cases mastery, of important aspects of the humanities, usually as part of the general education requirement for the university.

For instance, the work of civil engineers is largely to and for society (Evans and Lynch 2008). As such, it is important for engineers to receive an education that is broadly based, enabling the understanding of the myriad social issues that underlie well-thought-out solutions. The American Society of Civil Engineers (ASCE) recognizes this, and has consequently worked to "raise the bar" with regards to civil engineering education by publishing a Body of Knowledge (BOK). The 2nd edition of the BOK (BOK2) establishes 24 outcomes that define the knowledge, skills, and attitudes that civil engineers must achieve prior to entering professional practice. The first four outcomes are Mathematics, Natural Sciences, Humanities, and Social Sciences. These foundational outcomes reflect the concept of a liberal education that liberates, or frees, the learner "from the constraints of ignorance, sectarianism, and myopia." (Statement on Liberal Learning 1998)

But a broader view is needed beyond giving engineers a foundation in the liberal arts. To educate the citizen needed in a modern technologically-based society, where issues like water, energy and communications are prominent in the national conversation, a common base of knowledge is needed so that historians, political scientists, philosophers, scientists and engineers can meet to begin the multi-disciplinary, visionary conversations that are essential to answering the most perplexing questions of our times. These conversations will be difficult and time-consuming, but creating sustained programs that can provide robust, efficient and sustainable infrastructure will require persistent focus across many disciplines. For instance, it is not likely to be particularly productive to have an in-depth conversation about electrical power production with someone who does not understand that there is a need for both baseline and peak electrical generation capacity, and that excessive demand, insufficient distribution capacity, or undersupply all lead to the same result. That said, the production of electrical power is an exceptionally important topic, and key questions like "Nuke or not?" need to be discussed if there is to be a rational decision process leading to infrastructure creation that is forwardlooking, holistic and technically sound. This is not to say that political science or economics majors need to be ready to design a power plant, but they should absolutely be informed actors within the decision process. Conversely, engineers acting alone are equally unlikely to make well-informed decisions about system-level concerns like climate change. Sadly, engineers in the past have too often made decisions that were good for the project or purpose within their purview only to find that the solution had broader societal harms that far outweighed the project gains. It will take an intellectually diverse team to meet the Triple Bottom Line of Economic Prosperity, Health Environment and Social Equity (Regional Plan Association 2008).

GEN ED 231: INFRASTRUCTURE APPRECIATION

Unfortunately, the truth is that very few universities offer, much less require, even a single general education course covering the composition and function of infrastructure; call it Infrastructure Appreciation. This is a puzzle, since the built environment surrounds us in our daily life, simultaneously shaping and expressing our choices large and small. Understanding infrastructure, viewed in this way, is not specialized knowledge but an essential element in building a whole understanding of the way a society functions and the choices it makes. Infrastructure is not just concrete, steel and asphalt, but also the facilitator for producing the goods and services necessary that enable an economy and a people to function. Without knowledge of power production and distribution, for instance, how can one discern the changes wrought by the coming of electrification to our cities in the latter part of the 1800s, much less employ history to guide decisions about creating sustainable power for the future? Sustainability, transportation, communications and waste management present similarly daunting, and technically complex, challenges for our university graduates. The current generation of graduates will have to think, decide, act and lead during difficult times absent a basic knowledge of infrastructure, with the result that the decisions of future leaders will be ill-informed, or the leader will be forced to abdicate responsibility to experts, staffers and lobbyists, making tough choices based on trust rather than knowledge. Further, and perhaps more importantly, without an understanding of the infrastructure, decisions that emphasize short-term gain will continue to be the norm, ignoring the long-term risks which accompany deferring or underfunding infrastructure.

A SOLUTION

To bridge this knowledge gap, new paradigms are needed which integrate infrastructure as one of the essential elements in the modern graduate's intellectual development, on par with basic mathematics, writing, and the physical and social sciences. Certainly, if an engineer needs to be able to parse Shakespeare to call herself educated, then a humanities major must possess a basic understanding of where electricity and fresh water come from and where waste goes in order to call himself educated. Though it represents only one possible solution, a course intended to fill that need for a multi-disciplinary approach to building the infrastructure of our future was described in detail by Hart et al. (2011). This course has drawn a surprisingly passionate response from its students, particularly the humanities majors. For instance, when asked late in the semester whether they should have been obligated to take a course on infrastructure, students were nearly universally supportive of the requirement and broad in their reasoning. Student statements like “It is imperative that (infrastructure) be taught to all students majoring in American Politics, Comparative Politics and Economics” and “Regardless of the degree, a working knowledge of infrastructure is vital to being a member of society” were common, though these statements were arguably influenced by the focus of the course on a combination of engineering, culture, politics and economics in the context of citizenship. No better summary statement can be made than the following offered by a student: “A course on infrastructure should be required for all college graduates in order to produce a sustainable society. If we wish to sustain and improve our society… we must understand the systems that underpin it.”

Finally, one question on the final exam asked students, “What is the most pressing infrastructure need in the United States today?” One student, a kinesiology major, answered, “Education—people need to be better educated on what it takes to keep them living the way in which they are accustomed.” She then went on to explain how understanding the important concepts of infrastructure engineering could lead to changes in societal behavior.

Anecdotal evidence aside, further work is needed to assess the impacts of individual courses, and plans are in-place for the authors to undertake such assessments at multiple institutions in the near future. Concept inventories to track growth in infrastructure knowledge would be very useful in this task. More broadly, others, like the Institute of Education Sciences, have or are developing formal Technology and Engineering Literacy assessment tools (National Center for Education Statistics 2012) to measure the overall technological literacy of a broad cross-section of students and teachers. Further data are also needed to measure student advancement in knowledge on multiple levels from Describe to Analyze as well as longitudinal studies tracking post-graduation motivation to get involved in leading teams in technologically complex problem solving.

CONCLUSION

The authors firmly believe that educated persons must have a clear understanding of the basic underpinnings of modern life. This means a grounding in what modern infrastructure consists of, the impacts associated with its use, and insight into how the seemingly disparate infrastructure systems interact to support civilization. The specific technological pieces of the infrastructure examined could vary widely – health care systems, water supply, information technology and its networks, and on and on, all represent viable areas of student inquiry, as long as they are set in the context of their role within the wider technological world. By looking at infrastructure not just in the context of technological issues, but also in terms of political, social, environmental and cultural impacts, the student gains a sense of the interconnectedness of politics, money, culture and the built environment.

For better or worse, ill-defined problems are the norm in the modern world, and through a foundational understanding of infrastructure we can learn what the built environment tells us about our past, our future and the choices we make as a people. By creating a shared understanding through expanded university course offerings, it is hoped that technical and non-technical graduates can come together, contributing their diverse knowledge and perspectives to provide sustainable solutions for our collective future.

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