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An Integral Approach to Teaching History across the Engineering Curriculum

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The debate is as old as the profession and the sought after answer remains almost as elusive and ambiguous today as it did a century ago. What is the role of humanities courses in engineering education? How many liberal arts courses requirements should an engineering student take? What do these courses accomplish? Even in the brief history of the engineering profession and the subsequent accreditation movement in engineering education, a consensus has never been reached. Closer to consensus is the conclusion that engineers need some type of humanities based education; although the reasons for this conclusion may be varied, changing, and even conflicting. I suspect it is this perpetual lack of consensus that has entombed the majority of the dialogue in its broadest manifestation, that is, the "humanities courses" debated as an eclectic amalgam. Discussing details within a tenuous consensus is a recipe for trouble. Nonetheless, certain courses have always loitered around the tables of debate. History has been one of them.

In this paper, I am going to work from the commonly held view that the activities of technology and science never unfold independent from cultural beliefs and societal presuppositions. The implications of this understanding are that an engineer cannot engage in good engineering design without a coherent historical/cultural understanding. A thorough study of a social history of technology and science is not simply a nicety; it is a necessity in training engineers to design holistically. While engineers and engineering educators frequently recognize this, a common practice in engineering curriculum is either to relegate the teaching of history to the confines of a single "humanities" option, or to simply offer a regular sprinkling of historical anecdotes and snippets relating to heat transfer, digital signal processing, soil mechanics, etc. as a pedagogical aside. In terms of educating engineers with a propensity for designing holistically, both these approaches are counterproductive. Both approaches only solidify in the minds of engineering students the false notion that while engineering and history may be both good to study, these disciplines are independent from one another and not inseparably intertwined. The development of an integral historical component in the engineering curriculum requires more than just new course development or old course modification; it necessitates interdisciplinary communication and thematic continuity across the boundaries of every course taken by engineering students. Carefully crafting a history of technology "hub" course that enables integral historical reflection in all subsequent engineering courses is only a first step. As an example, I will briefly outline a recently developed engineering course at Dordt College that is designed to help construct a coherent philosophical and historical framework from which the entire engineering curriculum can build upon.

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ABET Criteria 2000 and Humanities Course Components

Recent revisions of the engineering education accreditation requirements (ABET Engineering Criteria 2000) have continued the tradition of requiring a substantial humanities component in the curriculum as indicated by four of the eleven essential program outcomes that must be adopted and assessed to receive accreditation. These state that "Engineering programs must demonstrate that their graduates have:…f) an understanding of professional and ethical responsibility g) an ability to communicate effectively h) the broad education necessary to understand the impact of engineering solutions in a global and societal context… j) a knowledge of contemporary issues"[1]. Clearly, the new criterion does not add definition to this issue of the role of the humanities in the engineering curriculum. Rather, it has increased the ambiguity. No longer is there a specified quota of humanities credits required for engineering accreditation. The implications of these changes have been interpreted a number of different ways. Lyman asserts that these changes represent a severe regression in engineering education[2]. Lyman claims that this is a clear signal that in the vacuity of non-consensus, ABET has caved in to the short-term industrial and corporate interests of mass producing rank-in-file engineers with standardized techno-skills. The humanities and social science (HSS) part of the curriculum is no longer a major concern for the leaders in engineering education. Others take a slightly less pessimistic view of the changes, claiming that what is certain about the new criteria is not that it will reduce the HSS course requirements, but that they will "throw the responsibility for non-technical education of engineering students squarely upon the shoulders of the engineering schools themselves"[3]. No longer will it be sufficient for engineering schools to simply outsource their quota of humanities courses to departments across campus and remain ambivalent as to what their engineering students are learning in those classes. This leaves engineering departments with two options. Either they can take a renewed interest in the courses they choose to outsource, assessing their value and building curricular bridges relating these HSS courses to the whole engineering curriculum or engineering departments can integrate curricular components into their own departmental offerings; curricular content specifically designed to meet ABET criterion relating to the humanities and social sciences. The end result is uncertain. Stephan concludes that the end result will be "a wider variety of non-technical education in undergraduate engineering schools that will range from very good to possibly very bad"[3]. However, as the face of HSS education in engineer changes, one thing is for sure, the teaching of these courses must have an integral character to them. It is not adequate to demonstrate to ABET that the engineering students take a history course. A department must demonstrate that this course helps students recognize the "impact of engineering solutions in a global and societal context". In terms of teaching history integrally across the curriculum, accreditation criteria may be forcing the issue.

The Imperative of Historical Reflection for Engineers

Before addressing the "how", I feel it is necessary to answer the "why". Why is a solid historical understanding an absolute essential in engineering education? Some have argued that unless engineers study history they will be doomed to repeat the errors of the past[4]. While this argument may have some merit, each generation enters a changing world of the unknown in which the failures of the past may become the successes of the future. I believe there is a more fundamental reason that necessitates the study of history for engineers. Since this question alone could form the basis of an entire paper, let me argue from example. In my years of working as an engineer in industry, I found that less than half of my time could be categorized as solely "technical", the other half of my time was spent meeting with clients to better understand the problem, evaluating vendor presentations, defending ideas to management, arguing options with supervisors, exploring past experience with retired engineers, making long term predications on energy availability, presenting environmental consequences of implementation, etc. I was communicating, arguing, writing, and defending cases. What I found most lacking in the R & D team I worked with was a historical sense of technological development. I was appalled to find so many prominent business leaders and engineers working under the assumption that "technology happens". Therefore, the object of the game was to find a position behind what you thought to be the most recent cutting edge, with little regard for client or public need. This popularized notion has grown from a peculiarly technicistic and ahistorical generation, and not from any serious study of the history of technology. Unfortunately, their lack of historical knowledge resulted in some very poor decision-making. Technological determinism is not a viable working model for technological decision-making.

Technology is a human activity. This is evident as we study engineering and technology over the periods of recorded civilization. Consequently, all technological direction is shaped by human presuppositions, beliefs, and priorities. Since a large portion of our presuppositions, beliefs, and priorities are inherited from generations past, it is imperative that engineers recognize what they are, where they originate from, and why they have been embraced. Unless the engineer can effectively critique these ground motives, he or she cannot make an informed decision on the most fundamental design decisions, that is, in what general direction should I head? Engineering is a social profession. It ultimately is the task of teams involving engineers, business leaders, clients, teams, and the public. All social activity requires a person to have a sense of cultural development. Language itself necessitates an understanding of history for full comprehension. Historical study for engineers is not simply a nicety, it is a necessity. History is an essential for good design.

Approaches to Teaching History in the Engineering Curriculum

The teaching of history in the engineering curriculum is not new. Over the last fifty years there have been a variety of approaches used to introduce history in the engineering curriculum[5].

A common approach at many technical universities is simply to outsource their humanities courses. An engineering student is provided a block of optional courses offered on the other side of campus from which to choose from. In most cases history is at least on the menu, if not a general education requirement. Most engineering students perceive such courses as general requirements unrelated to their engineering education. Only occasionally does an engineering college concern themselves with what is taught in these courses, let alone how these courses can be woven throughout the engineering curriculum. This approach is clearly counterproductive in terms of providing engineers with an integral understanding of history and engineering.

Another approach is the historical snapshot. This approach is observed in many textbooks that claim to provide a historical context for heat transfer, material science, electronics, etc. In such texts, a side bar in a section introducing transistor theory might discuss the technical specifications of the first computer as it was developed at Iowa State University. A historical aside in a heat transfer text may provide a brief biographical sketch of Fourier, prior to in depth coverage of conduction heat transfer. Unfortunately, such an approach is also quite often counterproductive. Terse descriptions of the "old model" simply reinforce the erroneous notion that "new" is better and the "old" was just the way we used to do it when we did not know any better. End of reflection. While biographical sketches at least give the sense that technology has always been a human endeavor, many students will continue to dismiss such historical info-bytes as mildly interesting, rather than essential for engineering. In the end, whether packaged as an introductory chapter or sprinkled throughout a text, such an approach does very little in terms of integrating historical reflection throughout the engineering curriculum.

Another approach is to teach an interjected historical narrative toward a moral. Bissell has shown that by selecting particular stories from the development of technology, the anecdote can be used to demonstrate a very important idea that students should understand as engineers[6]. For instance, examining information technology as it is manifest over the last century can demonstrate to students that continuity is as much a part of technological change as novelty. One might also tell the story of failed technological artifacts such as the gas refrigerator in order to disabuse engineering students of the notion that technology always progresses from best product to better product. The responsibility for technological direction lies firmly in the lap of society (including the engineers). This approach remains a promising method for engaging engineering in history and clearly illustrating its importance as they approach their engineering tasks. However, depending on how it is used in the bulk of the curriculum, students may be able to slide through the majority of their courses without a second thought about the inherent relation of technology and culture.

Finally, another approach emerged from the convergence of parallel movements in the 1950's. A group of historians began to recognize a significant absence of research and scholarship in the area of technology as a culture forming activity. At the same time, engineering educators were recognizing the importance of the study of the history of technology in the engineering curriculum. As Bruce Seely describes, it was this partial convergence of engineers and historians that spawned not only the Society for the History of Technology (SHOT) but also a number of university courses in the history of technology for engineers[5]. The benefit of dedicated courses in the history of technology for engineering students is that such courses typically provide opportunity for substantial reflection on technology and society that is relevant to all their technical courses, if individual students take the initiative to place these courses in their larger historical context. Here lies the perennial problem. Even with a formally established history of technology course, the majority of a student's coursework may still remain "purely technical", conveying a notion that an object or artifact can have a purely technical side or neutral core that can exist independent from socio-cultural norms.

Integral versus Interdisciplinary

Before I explain by example how a single course can be described as having an integral effect on the whole of an engineering curriculum, I must make a distinction between the terms interdisciplinary and integral. For a curricular component to play an integral role in an engineering curriculum means that it plays an essential part in the forming of a coherent idea or group of ideas that bind together the curriculum. A curricular component that is simply interdisciplinary does not necessarily work in the direction of a coherent theme, characteristic of the entire curriculum. For a component to be interdisciplinary, bridges are built between disciplines that may exist independent of overall curricular threads.

I believe that interdisciplinary approaches to introducing non-technical subjects in engineering curriculum are generally ineffective at generating substantial reflection and engagement in today's student. We must recognize that the typical North American students who enter our classes arrive as consumers. They have been immersed in a culture of choice since birth. Everything is seen in a large pot of options from which they can choose. Ideas are never universal or true. Ideas can only be modern, popular, out-of-date, useful, conservative, liberal, progressive, novel, cutting edge, hip, or vogue. To suggest a coherent framework of reality for them to consider, is to engage them in the exhaustive task of critique and analysis, beyond their comfortable position of picking a flavor for the day. Postman convincingly argues that overcoming such post-modern tendencies is one of the greatest challenges facing engineering education[7].

The challenge of education today is to move students beyond the level of ideological window shoppers capable of bagging numerous conflicting ideas simultaneously without concern for their consistency. For this reason an integral approach that develops a coherent philosophical framework will likely be the best way to engage today's engineering students in critical reflection. Simply being interdisciplinary is more of what our post-modern generation is shopping for - options without strings attached.

An Integral Approach Case Study

By blending what has already been done in established history of technology courses at institutions such as Iowa State University with a view of the entire engineering curriculum, a history of science and technology (HoST) course (EGR 310: History of Science and Technology) has been developed over the past three years within the Dordt College Engineering Department. The objective of this course is to be more than just an interdisciplinary excursion for engineers, but rather a course that plays a substantial role in weaving the entire engineering curriculum together (technical, humanities, and social sciences). The course has been taught for three years. Each year has seen substantial changes to the course. I do not intend to provide a picture of the entire course; rather my intent is to demonstrate, via example, how such a course is taught with the intention of integrating the subject matter throughout the entire curriculum.

The first and maybe most obvious way HoST provides an avenue for curricular integration is that it intentionally builds on prerequisite knowledge from other courses required in the engineering curriculum. For example, HoST relies heavily on a prior western civilization course to provide a chronological picture that HoST cannot adequately provide to students. Communication and writing courses are essential for the argumentation and research paper writing skills needed for this course. But more that just providing skills and background to students, prerequisite courses begin themes that are revisited in HoST and explored further. For this type of integration, an instructor must be very familiar with the out-of-department courses taught at his or her institution. EGR 310 specifically builds on the framework introduced in philosophy class, in addition to building on the students understanding of classical philosophy, scholasticism, rationalism, positivism, etc. Additionally, HoST builds on what has been taught in EGR 103: Introduction to Engineering to freshman, and lays a foundation for what will be taught in EGR 390: Technology and Society to seniors. All courses in the curriculum from the HSS to the technical courses are shaped by a "reformational perspective"; a perspective that makes no false classifications of sacred and secular, but sees all of life as religion. This "reformational philosophy" begins with the recognition that reality is best understood within an overarching historical narrative of creation (What does it mean to be human? a creature?), fall (What is the root of the problems in our world as we know it?), and redemption (Where do our hopes, dreams, and expectations lie?). An excellent overview of the "reformational perspective" can be found in Kalsbeek[8].

To encourage cross-departmental integration, instructors occasionally sit in on the courses of their colleagues. Doing this generates a healthy interdepartmental dialogue. Another approach used to add coherence and continuity to courses taught by different instructors within the department, is a monthly departmental "discussion meeting" in which a book or essay relating to philosophical or perspectival thread in our curriculum. Ultimately, any means of increasing departmental and interdepartmental dialogue on campus is a potential means of improving the integral character of courses taught in the engineering curriculum.

The course objectives for HoST are as follows:

- Students will be able to identify events that characterize the historical landscape of western science and technology, and be able to articulate the ways of thinking about the world that gave rise to and derived from these events. Students will recognize that the history of technology cannot be understood apart from an understanding of cultural history (i.e. political, social, aesthetic, pistic, economic…)
- Students will understand that doing history from a "reformational" perspective, is rooted in the understanding of our human calling as culture formers and image-bearers. History is the human activity in which we write the narrative of culture as it unfolds in the broader narrative of creation-fall-redemption. Technology is the human activity of responsibly shaping and forming the natural creation. Students will recognize both activities as human activities, avoiding the error of either historicism or technological determinism.
- Students will be able to critically evaluate past and present notions of progress. Seeking answers to the questions: Progress for whom? Progress for what end?
- By establishing that the direction of technology has been shaped by a society's worldview and religious presuppositions, and that this predominant worldview is in turn influenced by technological activity, the course will equip students to engage in obedient and responsible redirecting of technology.
- The students will come to acknowledge through study of history, that technology is neither good nor evil. Technology is a human activity that, like any human activity, will be directed obediently or disobediently. It can be an avenue for destruction, but it also can open a path to shalom and healing.
- Students will be able to articulate how technological artifacts, which are neither good nor evil, are not neutral. Such artifacts carry with them the idolatries, biases, and intentions

of the designers and builders, and can shape the obedient or disobedient direction of human culture forming.

It is evident in the objectives of the course that no particular events or time periods are noted or listed. The content of the course can be quite fluid and variable. More important however is the observation that all the objectives comprise thematic threads that are not unique to a course in history. This is intentional. All themes are designed to be explored further in numerous other courses in the engineering curriculum from fluid mechanics to material science to philosophy of the environment to technology and society. It is a means of integrating the course throughout the curriculum via the course objectives. As for the course itself, such thematic objectives provide at least three distinct advantages. First, it gives students flexibility to pursue a wide rage of topics in science and technology while still working within the course objectives. Secondly, it removes the burden of having to try to provide an exhaustive course in the history of science and technology in one semester. Finally, while western civilization is the focus of much of the course, these universal themes can easily be explored in the context of non-western cultures. The liberty afforded by this approach is valuable for students and instructor.

The degrees of freedom inherent in this thematic approach provide an appropriate venue from which to engage students in a wealth of topics exploring how the technological artifact, the engineering profession, and the institutions of technological education are all shaped by predominant cultural norms. For example, tracing the changing ideas of what the engineering needs to know, and the common assumptions as to "how" the engineer comes to know flows quite naturally from an in depth coverage of technological utopianism and the progressive movements in the late 19th and early 20th centuries. Within this broader cultural discussion, the multifaceted details associated with the evolution of the engineering profession begin to solidify for many students. This thematic approach also provides an avenue for the reverse to be explored. How do technological institutions and innovations shape culture? For example, how does the computer change how we perceive "knowledge" or "language"? Since I cannot possibly explore all the avenues of discourse opened up by this approach, I will try to illustrate how one of these integral threads is woven through the HoST course such that it becomes applicable beyond the HoST classroom.

HoST Thread: Technology and science are human activities whose shape and direction are defined by religious presupposition, that is, by what a culture maintains as divine and by how that culture is to exist in relation to the divine. This notion of religious belief and the divine is taken from Roy Clouser's book on the non-neutrality of all theories[9]. The "divine" is not to be understood as a specific deity or god, but rather as anything that achieves the status in a culture of unconditional non-dependent reality; that which simply exists.

- Ancient: While it may seem a stretch to talk about science and technology in sun-worshiping, mountain-worshiping cultures, all cultures have had an understanding of the natural creation and their relation to it. For the ancients, non-dependent reality was the deity (or deities) in nature itself. Deity-acts remained unpredictable and arbitrary. A human's relation to the divine was as a slave, there was little one could do to alter the moods of the nature gods. The only option was to attempt to appease such gods with sacrifice, offering, or architectural flattery. As you review agricultural technology or structural technology in the ancient era it is important to recognize how superstition and technical methodology were blended as one would expect from a culture with this understanding of the divinity. It is important to emphasize to students that seeing the natural creation as ordered, structured, and consistent requires a very different conception of the divine from that of the arbitrary gods of the ancients.

- Classical Greek: For the classical Greeks a rational symmetry (a logical or mathematical order) assumed the role of divinity and changed the way they perceived the world around them. The implications this had for science can be observed in their cosmological theories that necessitated geometrical symmetry regardless of what was observed in the heavens. Their symmetrically dualistic anthropology and epistemology, led to a disdain not only for the technician/artisan, but also a disdain for any empirical approach to knowing. Once again, it must be stressed to students that this is not simply "short-sighted" or "primitive" thinking but a way of thinking about the world that is entirely consistent with the Greek conception of "rational symmetry" as divine.
- Europe in the Middle Ages: Christianity brought an entirely new understanding of the divine and the human relation to that divine to the culture of Europe. The divine was now a creator God who not only created all that is, but orders and sustains all that exists. In addition, humanity was called to be the God-ordained caretakers of the natural creation. What transpires is a period of increased technological innovation and interest in the workings of the natural world. Klemm provides some excellent texts for student review regarding the teachings of church fathers on science and technology during this period[10]. Students should see that in contrast to the notion of the "Dark Ages" as seen through the eyes of the enlightenment, the middle ages began building a foundation from which the scientific and technological revolutions could emerge. It demythologized nature and further promoted an ordered natural world that could not only be understood rationally, but also could be shaped and formed for human purposes (with positive and negative consequences). Once again, the direction of science and technology begins with the cultural understanding of the divine.
- The European "Enlightened" Revolutions: Out of the enlightenment and scientific revolutions emerge two conflicting conceptions of the divine that characterize science and technology into the 21st century[11]. Both conceptions reject any notion of an almighty god as divine in the sense that such a god is unconditionally non-dependent and that the natural creation can only be understood with reference to that creator god. The first working definition of the divine was that matter itself was unconditionally non-dependent. This was the starting point for most rationalists who promoted a machine motif to explain everything in the natural world. Physical determination was not only how the world worked but also how we were to relate to the divine. The enlightenment also brought a conception of the autonomous human as that which was unconditionally non-dependent (to some degree). This was the freedom motif, the notion of self-determination. Students quickly recognize that these two conceptions of the divine are polar opposites. What follows in the development of technology and science is a continual tension or oscillation between these two conceptions. While those who seek to rationalize all of life seem to get there way, consistently the voices of romanticism, anti-technology, and individuality rear their heads in opposition. Numerous textbooks such as Technology in America: A Brief History, by Marcus and Segal provide an excellent narrative that reveals these tensions very effectively[12].

Using a thematic template to view science and technology across the ages can be a very effective means of drawing together events and theories that seem at first glance to be quite unrelated. This thematic template provides an inherent extension into other courses. What we embrace as divine shapes our physical understanding of the universe and its order (i.e. our science). How we relate to the divine determines the very motivations and choices we make when doing our technology and engineering, from our evaluating the merits of a heat exchanger design to the ethical issues associated with biotechnology. In fact, all aspects (juridical, economic, ethical, aesthetic,…) of our living as human creatures is impacted by our religious presuppositions, therefore it is evident that this thematic thread can be easily woven through every course that engineers take. The impact of such a thread should not be underestimated. Students might disagree and argue with the framework proposed (that's good), but they will come away with a sense of connection. It is this integral character that should pervade all courses in the engineering curriculum

Teaching Integral History in Engineering Beyond Dordt College

Dordt College is a small Christian liberal arts college located in Sioux Center, Iowa. The college has an ABET accredited general engineering program that typically enrolls approximately 80 to 90 students. Five engineering faculty teach in the engineering program. The faculty members share a common vision to train responsible engineers; engineers who recognize a creating, sustaining, and redeeming God who claims the totality of their lives. While this distinctive character of the Dordt engineering program coupled with its small size provide an excellent environment to adopt an integral approach to teaching history across the curriculum, I believe a move toward integral historical contextualization can take place to some degree in the majority of engineering institutions. While it may be impossible at some institutions (due to size or lack of a shared vision) to weave a coherent thread through all engineering courses, the following characteristics of the proposed curricular approach make it applicable beyond the walls of Dordt College.

- This approach does not necessitate the embrace of a particular worldview. To integrate history in this way requires only a recognition of the non-neutrality of all theory making. Students should be led to recognize that it is impossible to posit any theory apart from religious presupposition. Students must be encouraged to recognize that all assertions, judgments, and theories (technical and non-technical) begin with a concept of the divine (i.e. that which is held to be unconditionally non-dependently real). This essential recognition is the fabric that can weave itself across all components of the curriculum. All courses posit theories and elicit judgments.
- A required history of science and technology course in which the primary objective of the course is to have students identify the "ground motives" for scientific and technological direction can play a pivotal role in integrating historical reflection across the curriculum. All universities have the potential to develop such a course in their curriculum. Many institutions already have one. This course will likely be most effective in the second or third year of the engineering program.
- Engineering faculty at all institutions should be encouraged to audit this HoST course and all HSS courses required for the engineering program. Clearly, faculty members who are

not aware of the content and objectives of this course (or any HSS course) cannot effectively make the necessary thematic connections introduced in these courses.

- Finally, with an understanding of the framework used in the history of science and technology course, the objective of the individual instructor in heat transfer, or fluid mechanics, or electronics is not to introduce additional historical narrative but rather to explore how the establishment of theories and engineering decision making presuppose a worldview (a concept of the divine). Neither science nor technology is neutral. This thread, firmly argued in the context of heat transfer, fluid mechanics, or electronics will move students toward a recognition of the importance of historical contextualization on their design work.

Conclusion

There are a number of reasons that departments should reassess the teaching of history across the engineering curriculum. The first is driven by changes in ABET criterion that move toward a more integral approach to teaching the humanities in the engineering curriculum. The second is that the tendency of today's student is to compartmentalize courses in the engineering curriculum as "engineering" and "other" rather than recognizing the humanities courses as essential to their task as engineers. Departments must seek innovative ways of thematically weaving such humanities courses into the engineering courses. Finally, engineering students that leave with a coherent historical foundation simply make better engineers. Teaching history across the engineering curriculum does not necessitate the coverage of historical narrative in every course. Rather, by introducing and exploring important historical threads in a dedicated history of technology course, these threads can be woven through all the courses in the engineering curriculum. The threads re-evaluated in subsequent courses will draw students back to the historical narratives in which this thread was introduced. The end result is an education that is interconnected and coherent rather than an amalgam of only loosely related subjects.

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