UNIVERSITIES . . . WHY?

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As the twentieth century draws to a close, the situation in many institutions of higher education might be characterized as one of general frustration . . . frustration not only among faculty and students but also among administrators and the society that supports those institutions. Students seek to reduce frustration by refusing to take responsibility for their learning, by ignoring the advantages offered by the university, or, in short, by relegating education to the periphery of their lives. Faculties seek to reduce frustration by shifting their focus from "teaching" to "research" and by narrowing the definition of education; now, its meaning is largely confined to the transmission of knowledge sufficient for students to enter a profession. Administrators and state legislatures seek to reduce their frustration by imposing regulations and accountability on universities in the form of management models transferred from business. In previous generations, faculty were largely unhindered because, in the public's view, universities made only marginal contributions to society. But today, even the routine activities of faculty are presumed to be too important to remain unfettered.

The thesis of this essay is that the problems and frustrations now besetting institutions of higher education stem largely from a misunderstanding of what such institutions are supposed to be and misdirection relative to what they are able to accomplish. Such misunderstanding and misdirection promote short-term demoralization of students, faculty, and administrators and lead to long-term degeneracy of the entire enterprise.[1] So, what are universities supposed to be about?

HISTORICAL SKETCH

In Western cultures, formal schooling first appeared in the ancient civilizations that thrived along the Tigris, Euphrates, and Nile Rivers of mid-east Asia. Those schools trained a class of scribes, some of whom would later become religious leaders and advisors to the ruling class. The instruction centered on reading, writing, the arithmetic needed for accounting, and simple reasoning skills that applied to rules for conducting religious ceremonies and civil actions. In other words, from the beginning, a formal procedure was deemed necessary to help students learn to recognize and interpret abstract symbols and to develop the thought patterns required to manipulate those symbols. But ancient societies needed only a few symbol manipulators: the large bulk of humanity had no use for training in abstractions, for their needs were fixed on the concrete problem of sustaining life. Such needs could be met by informal instruction provided by family and by apprenticeship to craftsmen for learning specialized skills.

By the Age of Pericles in ancient Greece (*ca.* 430 BC), education had spread from the clerics to the youth of a leisured class. Naturally, this change brought with it a shift in focus; leisured youth has little patience with the intricacies of either clerical accounting or religious dogma. Instead, those ancient youths, like ours today, sought to understand their relations with the physical world and their relations with others. The first forms the basis for scientific inquiry; the second pertains to the proper structure and function of society.

The ancient Greeks had a genius for reducing matters to their essentials, and they used education as a vehicle for seeking such simplifications. Thus, they found that abstract reasoning simplifies when abstractions are placed in context. Context simplifies because it shifts our point of view from an inward one, in which the abstraction is a central issue, to an outward one, in which an abstraction is seen as part of a larger whole. In her book, *The Greek Way,* Edith Hamilton explained this by the following metaphor.[2]

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In medieval and Renaissance Europe, many communities undertook wondrous feats of architecture and engineering that culminated in great cathedrals—complex, vast, and intricate structures of wood, stone, iron, masonry, and glass woven into arcs, columns, domes, naves, towers, ribs, vaults, and flying buttresses. By the 14th century, the elaboration had extended to decoration of the interiors, including reliefs on walls, stained glass, richly detailed mouldings, surface patterning, networked vaultings, and highly ornamented interior columns. What remains incongruous about these impressive structures is that they were not placed within the context either of their physical surroundings or of the socioeconomic conditions of their societies. They did not blend into the environment, but rather dwarfed it—arising from the earth to intimidate their modest neighbors and the surrounding landscape. A cathedral can be beautiful, yet terrifying—internally consistent, yet elusive—but it always draws attention to itself, to its own logic and grandeur, and away from the world in which it sits.

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In contrast, with the temples of the ancient Greeks we have beauty of a very different kind—a beauty based on simple and restrained proportion. (The ancient Greeks did not even have the arch; rather, they had to rely on the post and lintel.) Those proportions extend beyond the geometry of the building to include the context into which the temple was placed. The Parthenon was beautiful not merely because of the precise proportions and optical illusions that were built into its structure, but also because it was designed to occupy the Acropolis—the highest point in ancient Athens. The Greek temple had no need of elaborate ostentation, for its beauty was reinforced by its environment. These same qualities—simplicity, proportion, and context—characterize sound engineering practice; thus, Petroski has observed that[3]

> *Good engineering blends into the environment,*
> *becomes a part of society and culture so naturally*
> *that a special effort is required to notice it.*

But the development of minds that can recognize simplicity, proportion, and context, as well as manipulate the abstractions that pertain to them, is no small task; a process of formal education is required, as the ancient Greeks realized. How can this be done? Perhaps etymology can offer a hint. Although the fundamental ideas about education are Greek, our word *education* comes from Latin: the sources are the Latin verbs *educare,* meaning to raise or bring up, and *educere,* meaning to lead or draw out. Thus, an appealing metaphor is to liken education to drawing water from a well (students might prefer to liken it to extracting a tooth).

Such an interpretation serves as the basis for the Socratic method of teaching, exemplified by any of Plato's dialogs, but most explicitly in the *Meno.*[4] Thus, education is more than transmitting information to students; rather, to educate means to draw students out so their minds surround knowledge, embrace it, and make it a part of themselves. For the instructor, this means that simply telling ideas to students is not enough;[5] for students, it means that merely adding to their store of knowledge is not nearly enough. To paraphrase Alfred North Whitehead, the merely well-informed person is the most useless bore on earth.[6]

From ancient times and languages, let us now shift to the mid-nineteenth century. In 1852, the Church established the Catholic University in Dublin so that Catholic youth might have access to the same advantages of education as their Protestant neighbors. But although the University was new, the educational challenges it faced were neither new nor parochial. Indeed, certain of those challenges are with us still. On the occasion of assuming the position as the first Rector of the University, John Henry (Cardinal) Newman observed, with dismay, that[7]

> *All things now are to be learned at once,*
> *not first one thing, then another,*
> *not one well, but many badly.*
> *Learning is to be without exertion,*
> *without attention, without toil;*
> *without grounding, without advance, without finishing.*
> *There is to be nothing individual in it;*
> *and this, forsooth, is the wonder of the age.*

"Nothing individual in it"—fearsome words that are indicative of *our* age.

By the mid-twentieth century, the scenes and the players had changed again, but the challenges remained. In addressing the deplorable state of Spanish society between the World Wars, José Ortega y Gasset asserted that a principal purpose of the university is to teach the *vital ideas of the society.*[1] Vital ideas include those of science and engineering, which interpret the physical world; those of politics and law, which formulate how society is regulated; those of economics and business, which try to explain the trade for goods and services; those of the humanities, which try to help us understand ourselves and our relations to one another; and those of the arts, which foster self-expression. Note that this purpose is concerned solely with ideas, for the mind can grapple only with ideas, and it is only the mind that can be the recipient of the teaching. (For a readable introduction to the connections among objective facts, concepts, and society, see Bronowski.[8])

The sum total of the vital ideas of a society comprises that society's culture, so even more important than training professionals, universities are to transmit the culture of a society to succeeding generations. This has become an exceedingly difficult task, for many reasons. One is the sophisticated abstract thought that is required to describe and understand modern societies. E. O. Wilson has pointed out that cultures evolve in tandem with advances in scientific understanding and with increased facility at manipulating abstract symbols that represent those understandings.[9] This means that, relative to earlier generations, we have more to do to bring students to an appreciation of the culture in which they live. *More* here refers not only to the number of abstractions, but also to the complexities inherent in the network of those many abstractions by which we represent and manipulate our environment. Thus, in 1999 a committee of the National Research Council asserted that U.S. students have a poor understanding of basic scientific principles and their relation to everyday life;[10] further, that

> *Institutions of higher education should provide diverse opportunities for all undergraduates to study science, mathematics, engineering, and technology.*

Note this plea applies to *all* undergraduates.

CHALLENGE TO ENGINEERING EDUCATION

We now want to extend the general comments from the previous section to the education of engineers. To prevent the discussion from becoming too abstract, we present it within the context of a hierarchical cognitive model for learning. In recent years, several such models have been proposed; at least three are similar and closely related, although they were proposed independently and are based on different kinds of evidence. Thus, the cognitive hierarchy proposed by Egan[11] is based on studies in educational psychology; the hierarchy proposed by Donald[12] is based on studies of cultural evolution, and that by Haile[13-15] is based on studies of brain function. These hierarchical models are all integrative; that is, the progression to a higher level requires the individual to master skills and to reorganize knowledge gained at lower levels.

THE PHILOSOPHIC LEVEL OF UNDERSTANDING

Egan's version of the cognitive hierarchy contains five levels:[11] somatic, mythic, romantic, philosophic, and ironic. Each level corresponds to a specific mode for getting thoughts out of the mind and into forms by which they can be dissected, analyzed, and reassembled. Thus, to oversimplify considerably, the somatic level includes tactile learning,[16] mythic corresponds to oral learning, romantic involves graphics and written learning, philosophic refers to learning by formal reasoning, and the ironic level encompasses exceptions, limitations, and learning by modeling.

In this hierarchical model, it is the *philosophic* level that contains the basic skills required of engineers. At the philosophic level, knowledge and skills mastered at lower levels may promote development of higher-order thinking skills: inductive and deductive logic, inferential reasoning, mathematical reasoning, analysis and synthesis, critical thinking, creation of theoretical constructs, and generalizations. These operations relate, simplify, and extend knowledge gained at lower levels. To maintain control over the material, we seek simplifications via patterns, theories, and schema that organize knowledge into useful structures; that is, in the words of Mach,[17] we seek *economy of thought.* The reorganization of knowledge into abstract and economical structures is the characteristic activity of learning at the philosophic level.

Note that philosophic understandings *may* develop, but they do not necessarily do so. Of the numerous human cultures that have appeared throughout history, only one—the ancient Greek—developed to the level of philosophic understanding. Over the years there has been endless speculation as to why this is so: What was unique to Greek society? Donald offers the persuasive answer that the breakthrough came when the Greeks combined writing with formal logic.[12] Making logic visible through writing clarifies analysis and communication, and it stimulates further mental growth to levels that, apparently, cannot be reached in any other way.

The consequences of these observations are profound: individuals cannot complete the transition to the philosophic level by themselves. To do so, people must live in a community of philosophic and ironic thinkers and learn from them.[11] This is the *sine qua non* of the university.

IMPLICATIONS FOR ENGINEERING EDUCATION

The traditional view has been that engineers are problem solvers; hence, engineering was traditionally taught by having students solve many, many problems. In recent years, this view has broadened to encompass a variety of reasoning skills that are captured under the general rubric of "critical thinking." But, based on their experience, many engineering educators have come to believe that today's students are generally weak problem solvers and poor critical thinkers. To cite just one example, Wankat[18] has noted that

> *My personal observation is that the average engineering student of 20 years ago was a better problem solver but not as skilled at calculating as the average engineering student now.*

This observation has provoked educators to subject students to more problem solving and more thinking exercises. Thus, we find recitation sections, student workshops, and specialized courses devoted explicitly to problem solving, and we find problem-based learning, discovery-based learning, and web-based learning intended to develop and exercise critical thinking.

It is my contention that "more of the same" will not prove to be the most effective way to overcome these educational difficulties. Instead, before we can expect students to function properly at the philosophic level, we must address their deficiencies at the somatic, mythic, and romantic levels. For example, the use of equations in derivations, proofs, and problem solving are logical exercises and, hence, are philosophic activities; however, equations themselves are collections of abstract written symbols and, hence, are romantic devices. Further, individual terms and symbols in an equation are usually interpreted at cognitive levels other than the philosophic; thus, the interpretation might be in relation to equipment (somatic), or in terms of a narrative that describes a process or procedure (mythic), or it might invoke schematic diagrams and plots (romantic). If we ignore these lower levels of understanding or if we tacitly assume that students can invoke these levels on their own initiative, then their success in such philosophic exercises as performing derivations and solving problems will be fragmentary.

Similarly, manipulations of data—the inferences and deductions that attach meaning to data—are logical exercises and, hence, invoke philosophic understanding. However, the steps used to acquire and organize data combine lower levels in the cognitive hierarchy. Collecting the data involves somatic activities using instruments attached to an apparatus or processing equipment; narrative descriptions of the process and the experimental protocol are mythic activities; organizing the data into tabular and graphic forms is a romantic activity. Many sophomores and juniors fail to find meaning in data because they cannot organize the data into tables or plots that reveal patterns or trends.

With the activity we call problem solving, success requires a much more complex array of cognitive skills than is usually required to manipulate equations and analyze data. Problem solving is obviously philosophic: we use abstract symbols to represent quantities and processes, and we manipulate those symbols according to logical rules to extract unknowns from knowns. But to find an algorithm for solving a problem, we appeal to more cognitive levels than just the philosophic. Thus, Wankat[18] notes

> *The expert problem solver writes things down, draws sketches, constructs a variety of different representations of the problem . . . expects the problem to eventually make sense and is looking for this sense . . .*

The expert expects that finding a sensible interpretation of a problem will also indicate a direction toward a solution; in pursuing that search, the expert appeals to many levels in the cognitive hierarchy. For example, sketches, schematics, and plots are romantic devices; connecting the problem to hardware and equipment appeals to somatic understandings; narrative descriptions of processes and responses to changes in variables are mythic activities; models introduced to achieve appropriate simplifications are ironic devices. In contrast to the expert, many sophomores flounder at solving problems because they fail to sketch the situation, or to articulate a story about the situation, or to connect the situation to hardware, or to recognize what equations might apply—their low-level cognitive skills are insufficient for the task.

These examples suggest that success at the philosophic level requires facility with understandings at other levels. If we accept that the fundamental purpose of the university is to develop and exercise philosophic understandings, then our responsibility to today's students seem clear: we must pay more attention to developing lower-level cognitive skills rather than simply intensifying our emphasis at the philosophic level.

CONCLUSION

The purposes of a university are to develop in students the ability to interpret and manipulate abstract symbols that pertain to the vital ideas of modern society. The manipulation of such symbols involves a suite of high-level, critical thinking skills; however, critical thinking apparently develops only when the student lives among, and learns from, those who not only have mastered critical thinking but who also can shift effortlessly among cognitive levels; these are attributes of ironic thinkers. Thus, a university faculty is a community of ironic thinkers intent on elevating students to high cognitive levels. To become adept at such high-level skills, students must develop a foundation of low-level cognitive skills; but compared to previous generations, today's students need more help from university instructors in developing that necessary foundation.

From Plato to Bacon to Jefferson to Ortega y Gasset to the present, informed thinkers in Western cultures have argued that the life of the mind is not merely worth living, but that it is indispensable for society to flourish: every society needs philosophic and ironic thinkers who understand how the world works, how society functions, and how abstract reasoning can be deployed to improve society. Today, universities are the only institutions that can possibly develop the necessary understandings: church, government, and industry have all abandoned attempts to develop human potential in favor of feel-good policies, special interests, and the bottom line. Universities are under attack to do the same. But if we succumb to these pressures, if we teach skills that expand pocketbooks but not minds, if we are satisfied to help students feel good rather than challenge them intellectually,

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then not only do we hinder student growth, but we also undermine the university and, ultimately, corrupt society.

If this seems farfetched, consider the catastrophic consequences of the Soviet experiment in which a society attempted to provide economic security while suppressing intellectual growth and development. Consider further the grave difficulties now being faced by countries of the former Soviet Union—difficulties engendered because too many of their people fail to understand how modern societies function.

In our society, the difficulties of educating are exacerbated by an astonishing degree of self-satisfaction. It is possible to operate cars, computers, and microwave ovens without knowing anything about how they work; possible to vote and pay taxes without understanding the rudiments of government; possible to work at a job without comprehending the larger workings of the economy; possible to be courteous and well-meaning while ignoring the deeper implications of human psychology. In other words, it is possible for many to live only at the surface of the culture and to be unconcerned about the underpinnings by which the society functions.

The operative question is this: For a society to survive and its culture to continue to evolve, what is the smallest fraction of the population that must comprehend how the society functions? In modern societies, it is the unique responsibility of universities to keep that fraction above the minimum.

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