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Teaching Technical Engineering Courses from a Christian Perspective: Two Examples

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by Charles C. Adams

Abstract
Engineering professors, like those of the natural sciences, usually teach by breaking the subject matter into parts, that is, courses and activities that are logically abstract from each other. While together comprising a coherent whole, those individual parts too easily foster abstractionism, the view that such subjects as calculus, fluid mechanics, engineering design, and engineering ethics "really are" separable from one another. Such a view militates against a Christian perspective of engineering, technology, and reality in general by replacing the organic wholeness of life before the face of God with the compartmentalization that is characteristic of modern science and naturalism.

This paper makes the claim that engineering education—and certainly Christian engineering education—ought to be characterized by wholeness, a quality of integrality whereby the individual courses and activities are organically connected to each other and to the central mission of the educational institution. That claim is first grounded in a number of basic philosophical and theological principles and then fleshed out by the description of two examples. The first example describes a design project included in a sophomore/junior level course in fluid mechanics in which groups of three to five students design a water supply system for a village within a developing country. The second example describes a design problem—the seasonal storage of thermal energy—that may be used in a number of different ways in a senior level course in heat transfer.

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Introduction
Early on a sleepy summer morning—in a different century and in a community far, far away—a young Christian engineering professor awoke to continue the task of learning fluid mechanics. As a chemical engineering undergraduate, he had never taken a formal course in that particular subject. But in the coming fall, he was scheduled to teach one to students in the mechanical engineering emphasis

of the engineering program at the Christian college where he had been teaching for the past three years. He had learned enough from his undergraduate physics and unit operations courses to make reading through the fluid mechanics text an enjoyable experience. But this particular summer morning, he was confronted by more than just book learning. As he stumbled into the kitchen to prepare a pot of coffee, his nose detected a damp and musty smell that tickled his memory, but not enough to create any specific recognition. An hour later, after two cups of coffee and halfway through the chapter on closed conduit flow, his oldest son ran up the stairs from his basement bedroom, and cried out, "Hey Dad, what's going on? We're sinking! Come on down and look!" As the young engineering professor followed his son downstairs, sight enhanced smell to merge memory with perception and bring the vexatious knowledge of a flooded basement to his consciousness. He had been told by the builder that this would never happen because the foundation of the house, a raised ranch, was buried only four feet into the ground. But the house was a "spec house," and the builder was actually a real estate agent—whose knowledge of soils, foundations, and fluid mechanics was woefully inadequate to predict whether or not a house would suffer water in its basement, four-foot foundation or not. So the engineering professor spent the better part of that day wet-vacuuming the lower level of his home so that his three sons would have a dry place to sleep that night. He also hired a plumber to dig a hole in the foundation floor and install a sump pump to keep the water out of the house.

That evening, he sat down with his fluid mechanics text and designed a piping system that would transport the water, underground, from the discharging pump at the back of the house to the front of the house, where it would flow into the street. Three months later, he was telling this story to the students in his fluid mechanics class as they learned about friction factors, the Moody Chart, and application of the energy equation to systems for closed conduit flow.

The Problem

The flooded-basement story illustrates two important points regarding engineering and engineering education. First, engineering problems are real-life problems with dimensions beyond the numeric and economic. Second, an effective method for teaching engineering is telling stories. Not only do stories usually interest engineering students, but they also merge content with context and confront those students with the holistic nature of engineering problems.

The task of the engineer is to solve practical problems by making use of modern scientific knowledge. Immediately, however, as the story above illustrates, there arises a difficulty with this task. Practical problems are "real world" problems. They confront us with the pre-theoretical and existential wholeness that characterizes our everyday living in God's creation and before God's face (*coram deo*). Modern science, on the other hand, depends upon abstraction. Scientific methodology provides us knowledge of creation by separating—in our minds—our whole, pre-theoretical experience of creation into parts.

In pre-modern technology, the approach to solving a problem, like the problem itself, was characterized by a kind of wholeness and contextuality. Even today, there remains a strong tendency to resort to non-analytical, trial-and-error solution methodologies for technical problems. In small companies, this pre-modern approach is all too common. And every senior design instructor knows well the task of coercing a group of students away from "seat-of-the-pants" engineering toward a methodology that employs careful analysis and informs design with the results of that analysis.

The reality is that scientific analysis has been a powerful tool in the arsenal of the modern engineer. The problem is that the method of scientific analysis is predicated upon an abstract and highly artificial picture of reality. This method of scientific analysis—abstraction—requires one to isolate aspects of a problem in one's mind, then to perform logical and numerical operations upon those aspects in order to deduce new knowledge of the reality under examination. But that new knowledge is an abstract, scientific kind of knowledge that differs essentially from the pre-theoretical, holistic knowledge from which the situation under study originated. This abstract kind of knowledge works remarkably well for science—the search for understanding—because scientific understanding is, by its very nature, an abstract kind of understanding, a theoretical way of knowing reality that is clearly distinguishable from the way one knows reality in one's pre-theoretical experience. But—and here is the heart of the issue—engineering design seeks ultimately to solve "real" problems, not abstract problems. The abstractions that result from the scientific method of analysis are highly stylized pictures of reality. Just as an abstract painting allusively refers to unique characteristics of life in its fullness, so scientific abstractions portray with lucidity several aspects of the natural world while ignoring all other aspects. We see the dimension under study but ignore the context.

To the extent that an abstract educational methodology contributes to narrowness in design, that methodology needs to be questioned and, ultimately, reformed.

Consider the case of the engineering professor with water in his basement. The engineering design in the story was the classic textbook problem of designing a piping system based on pump head, gravity head, and friction losses in a given length and diameter pipe. But the actual problem was far broader than that. It involved the presence of water where water was not wanted, a musty odor, dirty and near-ruined carpet, soggy sheetrock walls, and the communicated discomfort of three young boys. And those were only the immediate manifestations of the problem.

The point is that an engineering design problem is very different from a scientific problem:[1] It is existentially whole as opposed to being abstract. And that difference brings us to the central point of this paper. Science and engineering education have been structured on the basis of science and the scientific method: abstractly. Thus, "courses" are distinct from one another in the curricula of the natural sciences and engineering. Those courses are further abstracted into "subjects," which are dealt with in "course units" represented by chapters in textbooks. The overall abstract character of this kind of education tends to foster abstract thinking. That kind of thinking is most appropriate for science, and it is often useful in engineering. But engineering problems are not abstract; they are whole, and they are context-laden. Thus, engineering design ought to be characterized by a concern for existential wholeness and context-laden-ness. To the extent that an abstract educational methodology contributes to narrowness in design, that methodology needs to be questioned and, ultimately, reformed.

A Christian Perspective on Engineering Design

A Christian perspective on engineering design and engineering education must necessarily be consistent with a Christian perspective on all of reality. Basic to any Christian perspective on reality is the biblical claim that "In the beginning God created the heavens and the earth,"[2] a claim re-articulated in the Apostles' Creed as "I believe in God the Father almighty, Maker of heaven and earth."[3] All creatures owe their origin, their continued sustenance, and their final redemption to the Word of God[4]. All share a common non-self-sufficiency and finitude.[5] Thus "reality"—or "creation," or "the universe"—is of one piece. It is unified, whole, and finite by virtue of its status as "creature" as distinct from its "Creator." Thus a Christian perspective—and certainly an evangelical Christian perspective—will reject any view that absolutizes a part of reality and separates it from those parts viewed as less than absolute. It will reject, for example, the Greek dualistic view that separated what it believed were the eternal "forms" from the perishable matter that was given temporary existence by those forms. It will also reject the Enlightenment dualistic view that separated mind from matter and held that both, in very different ways, are absolute. And it will reject the modern, monist view of naturalism that considers matter and energy to be all there is—everything else being an explainable manifestation of that basic, eternal stuff that constitutes the universe.

Instead, a Christian perspective will appreciate that the creation is diverse and multifaceted. There are innumerable individual creatures that have existed, presently exist, and will exist before Christ returns. Moreover, there are mind-boggling numbers of "kinds" of creatures. The command given to Adam to name the living creatures[6] suggests both the ordered diversity within creation and humankind's task in recognizing, respecting, and bringing to verbal expression that diversity. As a result, Christians involved in science and technology will embrace a multifaceted approach to creation, such that not only are the numerical, spatial, and physical dimensions real (that which naturalism accepts), but so are the dimensions such as the biotic, sensitive, lingual, aesthetic, economic, ethical, and pistic, or faith.[7] Only God is eternal and absolute. But the various dimensions of creation that transcend the "natural" (the numerical, spatial, and physical), though they share the creatureliness and temporality of those dimensions, are just as real as those dimensions and are irreducible to them. In short, a Christian view of reality is multi-dimensional, sees all of creation as composed of God's creatures, called into being in order to serve him,[8] and sees all human activity as a service to God, neighbor, and the rest of creation.

Engineering design deals, then, with the world in its fullness and not merely our abstract imaginings of the world (i.e., engineering design is distinguishable from scientific theorizing). As such, engineering design must take seriously those aspects of reality beyond the numerical, spatial, and physical. It won't surprise most engineering educators to hear that their teaching ought to take the economic dimension into careful consideration. The point being made here is that engineering education ought to take into careful consideration all aspects of reality. Engineering problems are "concrete" rather than "theoretical" in nature. And since engineering problems are "concrete, engineering design ought to be characterized by holism rather than abstraction. Therefore, our teaching of engineering design—and engineering education in general—ought to be characterized by holism.

Demonstrating Wholeness in Engineering Education

How do we demonstrate wholeness, the quality of integrality whereby the individual courses and activities bear an organic connectedness to each other and to the central mission of the educational institution? How do we engage our engineering students so that not only in the senior design course are they confronted with the integral and multi-dimensional character of reality and with engineering problems, but in the math, natural science, and engineering science courses as well?

The Subject Matter Approach

One thing we ought not to do is abandon the "subject matter" approach to the curriculum, an approach that is natural to the thinking process with which we have been created. Since modern engineering builds upon the foundation of natural science, modern-engineering education needs to respect that foundation. The current structure of the curriculum—broken into courses that deal individually with the mathematical, the kinematical, and various expressions of the physical—is a pattern that respects the diversity and irreducibility of the created order. But because good pedagogy goes beyond respecting creational diversity, those courses should somehow be tied together. For the sake of pedagogical integrity, they should exhibit the unity and wholeness of the creation, even as their separate existence exhibits the multi-dimensionality of creation. One way of exhibiting that unity and wholeness is to use a "tapestry" model for the engineering curriculum.

The Tapestry Model of the Curriculum

In the tapestry model of the curriculum,[9] different kinds of courses are "threads" woven together to create the whole. When the various kinds of courses are viewed as threads, the individual integrity of the various kinds of courses is respected. Yet the thread metaphor suggests strongly both structure and interwovenness. Just as a thread starts in one place in a tapestry and terminates in another, so a thread of courses in the curriculum has a beginning and an end, often demonstrating a careful prerequisite structure. And most critical to our present considerations, the interwovenness of the threads exhibits the relatedness of kinds of courses to other, different kinds of courses.

Consider the traditional introductory course in differential calculus: Calculus I. In most engineering curricula, it is the first course in the mathematical thread. It serves as a necessary prerequisite to later mathematical courses. Equally important, it prepares the student for work in engineering courses like fluid mechanics, a course within the thermal-fluids thread of most mechanical and civil engineering curricula. The positioning of courses along their respective mathematics and thermal-fluids threads is therefore significant, but mere sequence of positioning is not enough. Too often students who have earned good grades in calculus seemingly lack the ability to apply that knowledge of calculus when the appropriate moment arises in fluid mechanics. It is important, then, for courses to produce an interpenetration of the subject matter, just as it is important for faculty to produce a tight weaving of threads together in a tapestry. Ideally, the mathematics courses ought to consciously anticipate the engineering courses for which they supply preparation. This anticipation most often occurs in a good differential equations course (especially if it is taught by a member of the Engineering Department). But faculty should consciously design that anticipation into the mathematics course so that the student awaits with eager anticipation the opportunity to use that mathematical knowledge in later engineering situations. In a similar manner, a course in fluid mechanics should consciously recall mathematical knowledge. By this time, several kinds of mathematical knowledge (algebra and geometry) can be taken for granted. However, a good fluid mechanics course will require students, in a conscious and planned manner, to recall and use their knowledge of calculus and differential equations. In a limited but very real sense, calculus should be re-taught in fluid mechanics.

Perhaps more of a challenge (and therefore even more important) is the integration of a course like engineering ethics into the curriculum. One might argue that engineering ethics is a component course in the "Humanities and Social Sciences" (HSS) or "perspectives" thread. A quality course in engineering ethics would require, as a prerequisite, a more general, introductory course in philosophy, or perhaps theology, if the course is taught with sufficient breadth. Similarly, an engineering ethics course ought to prepare students for their senior design-project experience. These courses ought not to be the only points of contact between ethics-related threads and courses. Even the fluid-mechanics course ought to include points where the thermal-fluids and HSS threads are intertwined. An example of such intertwinement is discussed at the conclusion of this paper[10.] For now, we can summarize this point by saying that a clearly defined perspectives (or HSS) thread ought to exist in the engineering curriculum at Christian colleges. In addition to the existence of such a thread—containing courses or parts of courses dealing with engineering ethics—there ought to be points of contact between that thread and other threads in the curriculum. Effort should be made to design, into the technical-engineering courses, reflections upon or anticipations of the ethical issues dealt with more substantively in the perspectives (or HSS) thread of courses.

Teleological Sensitivity

One simple way of demonstrating the curriculum's wholeness and organic unity is by ensuring that every course takes the time to reflect upon its central purpose: equipping students to one day deal with and solve real-world engineering problems. We might describe this character of a course as its "teleological sensitivity." This sensitivity is relatively easy to achieve in design courses, more difficult in engineering- science courses, and extremely challenging in the naturally more abstract courses in the areas of mathematics and natural science. In part, this difficulty can be attributed to the fact that students' teleological sensitivity will not be achieved by our simply telling the student to "remember, this very abstract concept will be important when you become an engineer." Rather, every quality engineering course will pay attention to context and incorporate at least some narrative methodology in order to call attention to context.

> *In the tapestry model of the curriculum, different kinds of courses are "threads" woven together to create the whole.*

Context

Every engineering example, assignment, or assessment problem includes a context, whether that context is stated or not. Too often, "back-of-the-chapter" problems ignore context and thereby encourage the kind of "plug-and-chug" assignment problem-solving methodology familiar to all engineering students. These days, when actually reading the text is done by only the most dedicated students—usually those who are not working 20 hours per week or who have been raised in homes that encouraged reading and discouraged television—one finds that students use their textbooks like handbooks. They first turn to the back of the chapter problems. Identifying the minimal information given in the problem, they then turn to the chapter where the concept central to the problem might be found. Of course they then search for an equation into which they might plug the information given in the problem. But this methodology treats the engineering student like a computer—as little more than a calculator—and does almost nothing to develop the kinds of holistic problem-solving skills that enable future engineers to solve real-world problems.

Real-world engineering problems occur in context. It is therefore imperative that conscientious, Christian engineering educators provide context for engineering students when they assign homework or test problems. For example, a problem in fluid mechanics—let's say, in closed-conduit flow—might depend only on the pipe dimensions, the pipe material, and the flow rate desired. A pedagogically well-stated problem, however, ought to include extraneous information like the temperature of the air (assuming no significant heat transfer exists between the environment and the system), the elevation of the system (assuming everything occurs at one elevation), and possibly even some obviously extraneous information, like the day of the week or the current state of affairs in the Middle East—just for fun or to remind students of the need to select relevant information from the whole of the context. But including contextual information need not be accomplished by a crudely artificial listing of facts. Contextual information is best supplied by means of narrative.

Narrative

Narrative, or story-telling, is one very effective way of communicating. It is, perhaps, the most effective way of communicating context while engaging the interest of the person to whom one is communicating. The use of narrative in technical courses can be especially effective for providing context, for creating links with courses in other curricular threads, for thwarting abstractionism, and for promoting a holistic understanding of subject matter that helps Christian engineering students develop comprehensive problem-solving abilities. The following four brief narrative examples were used in fluid-mechanics and heat-transfer courses, at first to elicit student interest. They have since proved even more valuable in helping students contextualize problems for a more holistic understanding of the subject matter:

Water in the basement: The story with which this paper began is not a fabrication. The events occurred in the summer of 1981, and the fluid mechanics course was taught for the first that same fall. That narrative remains an effective way, on the first day of class, to convince students of the practicality of studying fluid mechanics. It also provides a connection between what can be a fairly abstract engineering science course and the much more concrete course in senior design, taken by the students two years later. As will be seen at the end of this paper, the story ends with a final interesting twist, reinforcing the admonition that engineering students consider the broader context of any technical problem.

Water hammer on early TV: In the section dealing with the momentum equation in a fluid mechanics course, most textbooks discuss briefly the phenomenon of water hammer. Some students have experienced the noise of water hammer when a faucet has been closed quickly in an older home or building. A more interesting story was originally told during the mid-1950s on the CBS television drama *West Point*. In that drama, a group of cadets come from a class—in fluid mechanics, of course—in which they have just learned about water hammer. They decide to run an experiment to test the potential magnitude of the water-hammer effect by synchronizing the time at which they shut off the water supply in a number of bathroom sinks in their residence hall. They succeed all too well. West Point was the first engineering school in the United States, and the piping system that supplies water to the residences halls was already quite old in the 1950s. The result of the synchronized water shut-off was to send a powerful pressure wave back from the faucets in the residence hall, through the piping system under the campus, to the source of the water. The pressure wave was so intense, however, that it ruptured a water main under the sidewalk outside the resident hall. The image of a gusher of water shattering the sidewalk and rising two stories into the air is fixed in the mind of the fluid-mechanics professor, who was ten years old when he saw the TV episode. Depending on the vigor with which the story is told, that image is transferred to the minds of the students and accomplishes far more of pedagogical value than the memorizing (and eventual forgetting) of the equations for water hammer.

Designing the first set of ME lab experiment: During the summer of 1982, members of the first graduating class of engineers at Dordt College, the class of 1983, were hired on a part-time basis to design and build the experiments for the future Mechanical Engineering Design Lab course. Those experiments included a pipe-flow apparatus, a fluid-jet-impact apparatus, a convective-heat-transfer experiment, a beam-deflection experiment, and a torsional-stress apparatus. Students were broken up into teams, with one student from each team having "foreman" responsibilities. The teams met once per week with their engineering professor to develop objectives, refine designs, and discuss problems that arose in the construction and testing of the equipment. Telling the story of how those students dealt with each of the assigned lab experiments, encountering and solving various problems, has been very effective in eliciting student interest in the current fluid mechanics and heat transfer courses. For example, in the design of the pipe flow apparatus, the first design simply used lab tap water as a source which, after exiting the piping, was simply sent to the drain. An immediate problem arose, however, since the source water in the lab was not independent of the water in the rest of the building. Any time a toilet was flushed somewhere in the building, a pressure variation would occur and be transmitted to the sensitive U-tube manometers that measured pressure differences throughout the experimental piping apparatus. Eventually, the apparatus was re-designed with a dedicated pump and reservoir so that extraneous flow perturbations did not affect the experiment.

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Designing a home for thermal energy efficiency: The author of this paper has taught heat-transfer and solar-energy engineering for many years at Dordt College. In both courses, stewardship of thermal energy has been an important theme. In the solar energy course, one significant unit is spent on heating-load analysis. In connection with that unit, and as a project, teams of two students go into the community and perform energy audits on select local residences. In a report, students are required to make recommendations to the homeowner for energy-stewardship improvements. After years of reading such reports, the instructor was able to put the knowledge gained to good use. In the summer of 2000, he designed a new home, with a particular emphasis on energy stewardship. The house was built during the 2000-2001 academic year; and in July of 2001, the instructor and his wife moved in. Serving as designer and contractor for one's own home and working with builders, plumbers, electricians, and city officials will give a person stories to tell. With respect to thermal-energy stewardship, stories dealing with placement of the house on the lot, selection and placement of windows, choice and amount of insulating materials, and selection of HVAC equipment provide the students with a holistic picture of thermal-engineering design. Issues of economics and aesthetics are not easily overlooked, but neither are the psychological, sociological, and ethical issues that arise when one must work with persons holding a different perspective on energy stewardship. Even such an abstract subject as radiation heat transfer can find its way into a story that provides a multi-faceted design context. Narratives achieve a more holistic (and durable) understanding of the Stefan-Boltzmann Law.

Example-1: Design of a water supply system for a village within a developing country

In the Dordt College course EGR 302, Fluid Mechanics, students are assigned a group project (see Appendix 1 for the actual 2005 fall semester project) near the mid-term of the course. In the narrowest technical sense, the objective is to have students gain the experience of designing a pipe flow system. However, the overall objectives of the project assignment are more broad. As with most group projects that require a final report from the group, this project includes important social, communication, and economic objectives. Students gain experience working in teams, communicating with members of the team, appropriating team resources, and dealing with strengths and limitations of team members. Students also gain experience in writing a report and making an oral presentation to the class. In this particular project, students gain experience budgeting for the project—at least in terms of the material costs.

Beyond the usual social, communication, and economic dimensions of an engineering problem, students encounter issues unique to meeting people's needs in a developing country. In the 2000-2001 academic year, the class project was more than merely academic. The problem was to design an irrigation system for the Tolpan Indians in the mountains of Honduras. With support from a number of organizations, the design provided by the fall fluid mechanics class was picked up by a senior design team in the spring. During the winter break, a small team traveled to Honduras to collect data; then, during spring break, a larger team returned to Honduras to construct the irrigation system. Because this project dealt with the basic needs of real people in an actual developing country, students were confronted with unique social, political, and ethical issues. The knowledge required to understand and deal with those issues forced students to draw insights from other sources, including other courses that they had taken or were taking.

Although each fluids mechanics class does not offer students opportunities to work on an actual real-world problem, plenty of available resources provide those necessary real-world connections. For example, ECHO, the Educational Concerns for Hunger Organization, provides a website, http://www.echonet.org/about_echo.htm, where many practical issues are discussed. The evaluation of the final report submitted by students is based not only on how effectively they designed the actual water- supply piping system but on how well they identified and dealt with economic, social, justice, political, and ethical issues. The experience is certainly one that counteracts the abstractionism too often characteristic of standard fluid-mechanics textbooks.

Example-2: Seasonal storage of thermal energy

Sunnyside Manor House, the historic home of Washington Irving,[11] overlooks the Hudson River in Tarrytown, New York. Not a castle or a mansion, it is in many ways quite modest. Yet for anyone interested in the history of technology, a visit there will be rewarded with not a few surprises. For in addition to the beautiful landscaping, walking paths, pastures, and gardens, the house, in its day, had running water and a closed-fire cooking stove in the kitchen—advanced technology for the early nineteenth century. But perhaps the most intriguing example of 19th-century technology is found outside the house and just beyond the kitchen yard. At first glance it looks like a tool shed of sorts, except that it is fairly large and built very sturdily. Opening the heavy wooden door and looking inside, one notices that the floor is well below grade level and filled with straw. The walls of the structure seem thicker than the walls in the house. It quickly becomes apparent that this structure was designed to resist heat transfer. Looking at the small map of the Sunnyside Manor property provided each visitor, one discovers that the structure is an ice house, a piece of technology that the modern refrigerator displaced long ago.

The basic principle by which the ice house functions is called *seasonal thermal storage*: making use of the earth's orderly rhythms for the purpose of ordering our lives—in the case of the ice house, gathering low-thermal-energy material in the winter, when it is plentiful, so as to meet our need for it in the summer, when it does not naturally exist. We don't consider this principle much today because we are impatient; we want instant gratification of our desires. And, at least for the past century, we've had the technological resources to provide that instant gratification when it comes to thermal-energy storage. The electric refrigerator is a prime example. But our impatience is catching up with us. As traditional petrochemical sources of thermal energy become more in demand, they become more expensive. There were dire predictions of escalating prices for heating fuels for the winter of 2005-2006. Due largely to the mild weather, these price escalations were relatively minor. But space heating in cold climates will become an increasingly difficult problem in the years ahead.

That's just the kind of problem that can present engineering students with an example of interdisciplinary design—design that goes beyond the abstract concepts of any standard-heat-transfer text and requires students to recognize the social, economic, legal, ethical, and even aesthetic dimensions of a real-world engineering problem.

Consider the possible ways in which seasonal storage of thermal energy might be used to provide space heating for fairly traditional homes in fairly traditional suburban developments in the future. Unlike new houses that are being built now, each with its individual heating system, future homes may be arranged in clusters, and each cluster may have a centralized heating system that serves all the homes in that cluster—and that heating system would likely combine seasonal storage with solar-energy collection, using petrochemical combustion only as an emergency backup. Consider a typical new housing development of houses on parallel streets, each with about a 100-foot frontage. Each house has one house on either side and another house behind it. A cluster of six houses would have 300 feet of back yard in common. Imagine that where those back yards meet, there might be, submerged beneath the ground, a well-insulated reservoir, filled with water. There might also be a system of solar collectors on the roofs of those six houses and possibly above the reservoir area where the back yards intersect. All year round, but particularly during the summer, solar energy will be collected and stored in that reservoir as hot water. Because the reservoir is large, submerged well beneath grade level, and extremely well insulated, it will not lose much heat, even during the winter. Rather, heat from that reservoir will be pumped into the six homes. At first it will be used to increase greatly the efficiency of heat pumps, devices that use a modest amount of electrical energy to move much greater amounts of thermal energy from one place to another. But as electrical energy gets more and more expensive, the thermal energy from the reservoirs will be used—supplemented by real-time solar energy—to directly heat the six homes in the cluster.

A "back of the envelope" computation will show that such a heating system is technically feasible.[12] Obviously, it would add additional cost to new houses—but not an unreasonable amount. The biggest problem is the sociopolitical problem of getting neighbors to yield a little of their independence, to accept a semi-centralized heating system, probably managed by the local utilities provider. Another issue, of course, is the aesthetics of a solar-energy collector system. But that is nothing new. These are precisely the kinds of issues that make for a meaningful engineering design project—the kind that fosters holistic thinking on the part of students. With the introduction of the historical dimension (Washington Irving's ice house), the economic dimension (the trade-off between the immediate cost for the system and the future savings of petrochemical costs), the sociopolitical dimension (creating public policy and public consciousness to work together for community wellbeing), and the stewardship dimension (harmonizing the functioning of houses with seasonal cycles, not to mention the environmental benefits of reduced use of petrochemical resources), one has created a rich, interdisciplinary context for solving engineering problems. And, it may be argued, one is well on the road toward developing a Christian perspective on engineering design.

Conclusion

This paper began with a story about water in the basement. A fitting conclusion will be to tell the rest of the story. The engineering professor did indeed design the piping system based on his newly acquired knowledge of fluid mechanics. It was installed by the plumbing contractor who had dug the sump pump hole in the basement and installed the sump pump. The system worked beautifully all summer long. When autumn and the new school year arrived, the water table had receded, and the pump became silent. Still, the professor told the story when teaching fluid mechanics for what was the first of many semesters.

The use of narrative in technical courses can be especially effective for providing context, for creating links with courses in other curricular threads, for thwarting abstractionism, and for promoting a holistic understanding of subject matter. . . .

But the story isn't over. The following spring brought rain and a rising water table. Soon the sump pump's gentle hum was heard as it pumped water from the sump pump hole to the outside of the house. Unfortunately, the engineer only noticed the level in the sump pump hole quickly lowering as the pump did its work; he did not notice that the end of the pipe, at the front curb of the house, was only trickling a small amount of water into the street. Then one morning, not all that different from the previous year, the engineer's morning reading was interrupted by the splashing clamor of his three sons as they informed him that, once again, "the house is sinking."

There were a few hours of befuddlement as the young engineer tried to figure out what was going on. In the end he came to the realization that the PVC pipe had not been buried deep enough in the ground. As it passed around the back of the house and turned toward the front, the last water from the previous season had frozen during the cold winter—frozen, and as freezing water always does, expanded. The expansion had burst the pipe underground on the opposite side of the house from where it was being pumped. So for a time, the sump pump was pumping the water out of west side of the house's lower level, only to have it come back in on the east side—the side where his sons' bedrooms were to be found.

The following fall, the engineering professor told a more complete story to his fluid-mechanics class. Not only could he tell them about a practical application of closed conduit flow, but he could warn them about the perils of abstractionism. By focusing on only one aspect of a problem—in this case the fluid flow aspect—one leaves oneself open to failure in other aspects of a problem—in this case the aspect having to do with strength of materials, specifically that of the PVC pipe. And, of course, those are only two of the most obvious technical aspects to that particular engineering problem. Good engineering design requires that we give consideration to all aspects, technical and non-technical as well.

Endnotes

1. For good general discussions of this difference, see Monsma (1986), and Schuurman (2003). For an in-depth, philosophical analysis of the issue, see Schuurman (2003).
2. Genesis 1:1 (NIV).
3. *Psalter Hymnal*, 813.
4. Proverbs 8, John 1, Colossians 1, Hebrews 1.
5. See Walsh and Middleton, Chapter 3; Wolters, Chapter 2; Clouser, pp. 43-48.
6. Genesis 2:19-20.
7. See L. Kalsbeek.
8. Psalm 119:91.
9. See Adams, p. 333.
10. See Appendix I.
11. Washington Irving (1783-1859) was the author of *Rip Van Winkle* and *The Legend of Sleepy Hollow*.
12. In April of 1991 the American Public Power Association (APPA) awarded a $3,000 scholarship to Curtis Smit and Scott Hulstein, two Dordt College engineering seniors, who worked under the supervision of the author on a project (their senior design project) that investigated the feasibility of a four-home seasonal storage scheme in Northwest Iowa.

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Appendix I

ENGR 302 FLUID MECHANICS: DESIGN TAKE-HOME TEST, Fall 2005

Group: 1 (Student #1, Student #2)

You are to design a fresh water supply system for a village in Nicaragua. The source of energy for pumping the water will be solar, so it will be important to utilize a water tower both to stabilize the source pressure and to provide for flow when the sun is not shining. The village is rectangular in shape, approximately 0.5 miles wide (E-W) by 1.0 miles long (N-S). At this stage in their history, the people in the village have not constructed permanent housing. Therefore your water supply system should be designed to provide a single supply valve with the capacity of 3.0 gpm at 20 relatively evenly spaced locations within the village. The supply for the water is a lake which is fed by streams from the mountains. The surface of the lake is at an elevation 20 feet above the village and 2 miles to the west (of the village border). The village is in a valley, however, and an excellent site for the tower exists on a natural plateau on a mountain 3 miles to the north (of the village border) at an elevation 35 ft above that of the village.

Your supplies can be purchased at the Farmers Co-op here in Sioux Center, or you may find a vendor by searching the *Web* for the lowest prices. In any case, the supplies will be transported free of charge by a PLIA group during spring break. The PLIA group will also construct the water system during a summer vacation.

You are to design the least expensive, functional system possible. Determine all pipe sizes and lengths as well as their layout. Determine all fittings necessary. What size pump is needed? You do not need to design the solar energy system, but you do need to specify the power that will be required of it.

Your completed project must include a parts list complete with prices, total price, and specifications; a carefully labeled drawing of the system; and a page or so in which you discuss the characteristics of the system and any peculiarities that you think should be known. In a separate section you should discuss the social and political situation. E.g., what social, political, or economic problems (other than simply raising enough money for the project) might you encounter?

Providing fresh water to small communities in developing countries is not something novel. Various groups have done it before. Therefore you should do some preliminary research (consider using the *Web*) to find out *what* has been done and what kind of difficulties (technical, social, political, etc.) have been encountered.

You are to work in groups of three students each (actually there will be five groups of three students and one group of two students). Thus the work can be shared. This means, however, that a solid, comprehensive, final report is expected of you. In addition, every member of the group must understand every aspect of the project. In other words, the final report is not to be a collection of individual parts, but rather a representation of the knowledge of all members in the group. During the "Group project work" day (December 6) class time will be spent by having each group make an informal (10 minute) presentation to the class regarding the project. The presentation will involve presenting the results to date and fielding questions. The time between the presentation and the deadline for submittal of the project should be spent, if at all, only polishing the project (putting it in final form). The bulk of the work should be completed before exam week.

(Final note: At the end of the semester you will be asked to evaluate this group effort. That evaluation will include evaluating the effort of each member of the group. I will take seriously those evaluations and apportion the project grade accordingly.)