Forward

Recently I had the experience of introducing myself to a colleague at a workshop and sharing the fact that I teach engineering at a Christian liberal arts college. As I explained the nature of our program I was met with the familiar question: What is Christian Engineering? Most of us who profess to be Christians and feel called to involvement in engineering realize that this is not an easy question to answer. It is not obvious how to integrate a technical discipline, usually considered to be based on scientific principles and logic, with the purposes and values of Christian faith. The Christian Engineering Education Conference (CEEC) provides an opportunity to reflect on this question in the company of fellow believers and engineers. By bringing together engineering educators from a variety of Christian and secular institutions, and providing them with a venue for presenting their perspectives on a variety of issues related to technology, engineering, and education, we are all presented with an opportunity to learn and grow, both in our faith and in our professional work.

We give thanks to God that CEEC has continued to flourish over the years. The 2008 conference includes 15 paper presentations (which are included in these proceedings) and two panel sessions. We expect over 40 attendees, including many who are attending for the first time. This year CEEC also celebrates its global reach by welcoming a delegation all the way from Handong University in Korea. Since 2002, the CEEC has met every other year in even years. We are considering moving the conference to odd years to avoid conflicts with other events, perhaps as soon as 2009 (in Austen, TX). Please consult the conference web-site (http://www.calvin.edu/academic/engineering/ces/ceec/) for more information. We would appreciate your input on this decision and always welcome volunteers!

I would like to extend my appreciation to general conference chair, Steve VanderLeest. His leadership has been indispensable to the success and growth of the conference. The quality of the conference has been greatly enhanced by those who served on the steering committee and all who thoughtfully reviewed abstracts and papers. The on-site coordinators at Geneva College, led by Murat Tanyel, also have our thanks. Finally, a special thank-you to Michelle Krul for her help in processing registrations and producing the proceedings.

We look forward to a time of blessing, at CEEC 2008 including worship, fellowship, refreshment, and intellectual stimulation. Please include in your prayers the need for safe travel and the desire for good fruits to be produced from the time spent together.

To God be the Glory!

Gayle Ermer

CEEC 2008 Program Chair
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Heating up the Engineering Curriculum to Include the Science Behind the Global Warming Debate

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A Christian Approach to Energy and the Environment at Baylor University

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Lessons from the Tower of Babel

Gayle E. Ermer
Calvin College

Abstract

The Old Testament story of the tower of Babel (Genesis 11) is sometimes interpreted as a warning against human technological and organization achievement and therefore could contribute to an anti-technology bias. This interpretation is not very affirming to engineers or supportive of their engineering design activity. The implication could be drawn from this interpretation that Christians should not be investing a great deal of time and effort in technological accomplishments on a grand scale. While it may be true that over-reliance on technological achievements can detract from trust in God, it is questionable whether this is the primary lesson of the Babel story. This paper will describe some current usages of the Babel reference in both Christian and secular sources, and summarize the conclusions these usages reinforce.

This paper will propose that the main lesson of the tower of Babel story is not to avoid generating new technology to collectively solve problems, enhance the quality of our lives, or achieve great things. Neither is it a justification for small-scale technologies. Rather, the point of the story is to ensure that the technology we design, whether small or large-scale, is pointed in the right direction. All technology must serve the right God, that is, reflect a correct understanding of who God is and how we are to relate to him and our fellow humans. This paper will examine several commentaries on Genesis in order to establish the meaning of the story for people living in the cultural context of the ancient Middle East. Other Biblical passages will be examined to provide additional guiding principles for interpretation of the Babel passage. The paper will then conclude by connecting the lessons of the story to engineering practice, both in the design process and in the engineering classroom.

Introduction

The Old Testament story of the tower of Babel (Genesis 11) is one of the few passages in the Bible that speaks directly about humanity’s technological development. As such, it is of interest to Christian engineers who seek the direction of scripture for their professional activities. We want to know what the Bible has to say to us about how we should do engineering that is pleasing to God. For those of us who teach at Christian colleges, looking to the Bible for inspiration and instruction for our work is something we are encouraged to do as part of developing a mature Christian perspective. This seems to be particularly important for our work as engineers, since technology is so interesting to us and since it has such a broad and significant impact on the way everyone lives.

But, there are always some dangers in trying to take specific Biblical passages or stories, which were produced in different cultural contexts, and apply them to modern day practices. I have heard the Babel story cited in discussions of technology, and wondered how appropriate it is to apply this story to our modern engineering efforts. It is not immediately clear what lessons can legitimately be drawn from this passage. The meaning of the Babel story does not seem easy to determine and a too literal reading may lend itself to interpretations that are not particularly affirming of engineering design work. This paper will discuss some of the messages that have been taken by Christians from the Babel story, presenting some of the ways the story has been used by Christians to guide technology and also how references to the story have filtered into the secular culture. The paper will then focus on better ways of interpreting the lessons
of the story based on context, literary style, and other Biblical principles. Some of the interpretations of contemporary commentators will be described, along with those of some figures important in church history. The paper will conclude with reflections on the applications of the lessons from the story to engineering practice and education.

The Story

The story of the Tower of Babel is found in the Old Testament of the Bible in Genesis 11: 1-9. The relatively short passage is included here in its entirety (taken from the New International Version).

Now the whole world had one language and a common speech. As men moved eastward, they found a plain in Shinar and settled there. They said to each other, “Come, let’s make bricks and bake them thoroughly.” They used brick instead of stone, and tar for mortar. Then they said, “Come, let us build ourselves a city, with a tower that reaches to the heavens, so that we may make a name for ourselves and not be scattered over the face of the whole earth.” But the Lord came down to see the city and the tower that the men were building. The Lord said, “If as one people speaking the same language they have begun to do this, then nothing they plan will be impossible for them. Come, let us go down and confuse their language so they will not understand each other.” So the Lord scattered them from there over all the earth, and they stopped building the city. That is why it was called Babel – because there the Lord confused the language of the whole world. From there the Lord scattered them over the face of the whole earth.

Genesis 11: 1 – 9 (NIV)

I have to admit that my initial reaction to the story is not particularly positive. The story makes me a bit defensive. On the face of it, it seems to present a tale of God’s judgment on a people for planning and building something, the same kinds of tasks pursued and enjoyed in engineering work. Does it imply that God disapproves of large towers? By analogy, is my activity in analyzing and designing large scale systems displeasing to God? Should we conclude that God disapproves of the coordinated effort necessary to implement large technological projects?

Many of our engineering projects today dwarf the scale of the sort of primitive tower described here. We have designed skyscrapers, dams, bridges, and computer networks that span the globe. We live in an era in which television shows like “Modern Marvels” and “Mega-Structures” celebrate large-scale engineering endeavors. The most interesting engineering work is often on large-scale projects. These projects are sometimes the ones that require the most creativity, analytical skill, and organized management on the part of engineers. These complex systems also have the possibility to greatly influence the world for good or evil. Having a better idea of what this story is saying to us as engineers could help us to better understand the place of technology in the world and help us to make it most effective in promoting God’s kingdom here on earth.

Different Interpretations

The applications of this passage for contemporary society are not immediately obvious. Christians have struggled over time to identify the universal themes that might be taken from the story and translated into advice for modern living. It is tempting to look to this story in particular for guidance on technology development, because it is one of the few Biblical stories that deals directly with something that shares some key characteristics with modern technology, namely the collective effort necessary to build the
tower and the apparent planning that went into the preparation of materials and the tower design. While an earlier passage (Genesis 6) refers to the building of another practical object, Noah’s ark, the effort in constructing the ship was primarily individual, what we might identify as craftwork rather than engineering work.

Some Christians associate the story primarily with warnings against modern technology. For example, in the book *Choices At the Heart of Technology: A Christian Perspective* by Ruth Conway, the Genesis 11 passage is quoted at the beginning of a chapter titled “Dreams and Delusions of Development”. The author suggests that technology has been transformed into an end in itself, as opposed to a means to achieve good ends associated with eliminating suffering and encouraging justice and plenty. The emphasis on efficiency and rationality became the goal of industrial society and thus a modern tower of Babel was built. The author goes on to describe the calamitous results brought on by this dream of progress, including environmental pollution and reduction in cultural diversity. “The story of the builders in the plain of Shinar is sharply relevant: the Lord condemned their arrogant efforts, using a “single language” to “make a name” for themselves through their own technological prowess. The city was doomed to be left unfinished and the people scattered into mutual incomprehension and broken relationships.” The chapter goes on to suggest that a radical change in the emphasis of technology toward local economies and sustainability is needed. While her conclusions about the characteristics and direction of modern technology may have some merit, I am not sure that the tower of Babel story contributes to those conclusions.

Often, the Babel story is read primarily as an effort by humans to achieve transcendence by reaching the heavens. Stephen Garner, in a presentation on technology and spirituality, notes some references to technology in the Bible “from the Tower of Babel where humankind’s quest for transcendence is seen as rebellion against God through to Revelation where the Heavenly City, a technological artifact, that is redeemed by God and seen as a good place for humanity to dwell.” Many of the sermons in the internet database sermons.com that reference the Babel passage also emphasize the building of the tower as the people’s attempt to reach the gods and/or the pride evidenced by the people in determining to make a name for themselves. As such, they do not directly reflect on the technology named in the story or make any conclusions about the story’s implications for modern-day technology.

Some themes derived from the story have found their way into popular culture – perhaps not all in helpful ways. The phrase “Tower of Babel” has become part of North American culture. It is used frequently to suggest cacophony and miscommunication, even in technical circles. These references occur especially among computer software developers. Some computer firms claim that their goal is to “tame the tower of Babel,” that is to develop a common language that will allow the multitude of computer codes to interface successfully with each other. In our current global age many of the communication barriers explained in the Geneses 11 passage are being reduced. Does an accurate interpretation of the passage suggest that this is a bad thing?

**Interpreting Correctly**

When we read Biblical stories, especially those from the Old Testament, it is not always easy to determine what universal principles we should take away that apply for us today. It can be tempting to begin with a bias toward interpreting a story in a given way in order to support pre-conceived ideas. I may be susceptible to this myself, which is why I decided to take the time to consult commentators on this story. The first step in trying to determine the lessons of a narrative such as the Babel story must be to
attempt to hear the story as its first listeners did. As Daniel Harlow suggests in his article in Christian Scholar’s Review entitled “Creation According to Genesis: Literary Genre, Cultural Context, Theological Truth”:

“The book of Genesis must be allowed its own integrity. It must be permitted to reveal its own truth in its own way and not be forced to speak directly to all our modern questions or concerns. Before becoming God’s word to us, it was first of all God’s word to them – the ancient Israelites.”

Cultural Context. It is important when interpreting any Biblical passage to take into account the cultural context in which the passage was generated and the literary style in which it is presented. Harlow notes that Genesis was “written in a non-scientific age by a non-scientific author for a non-scientific audience.” It seems clear that the ancient cultures of the Middle East had no conception of our view of scientific activity. They did not use a structured approach to determine universal laws or apply scientific method to understand the world around them. Certainly the cosmology of the world was understood very differently from the way we understand it today. For example, ancient peoples viewed the sky as a solid vault separating the waters above from the earth below. Therefore it might have been reasonable for them to think that they actually could build a tower that would reach the gods, who lived above the vault.

But if we can conclude that Geneses 11 was written from and for a non-scientific culture, can we also conclude that it was written for a non-technological culture as well? This depends on how we understand the concept of technology. The definition of technology included in Christian reflections on technology, for example the book Responsible Technology, are often very broad. According to the authors of this book, technology is “a distinct cultural activity in which human beings exercise freedom and responsibility in response to God by forming and transforming the natural creation, with the aid of tools and procedures, for practical ends of purposes.” Based on this definition, every society is a “technological” society. From the very beginning humans have been constructing tools and designing implements for practical purposes – for shelter, for clothing, and for food production. Although the level of technological skill and the complexity of the technological products of the ancient Middle East were considerably lower than those of current North American society, the peoples of these societies still had engagement with the fundamentals of technological development: creativity and usefulness. It is reasonable to assume that particular individuals in those societies performed some of the functions of engineers. Someone had to conceive a structure for the tower, select the materials of which it should be built, and specify and oversee the process for constructing the tower. The Babel tower is clearly an example of human cultural activity, and because it had a practical end or purpose, it is an example of technological activity.

Literary Style and Place in the Genesis Story. It is helpful to remember that the stories of Genesis are not intended for the purpose of providing a complete and precise history of events. Genesis does not attempt to provide a detailed chronological account in the way that we would expect a history textbook to provide today. Rather, the Babel story and others like it are included in the Christian canon to make a point about God’s relationship to his people. The primary purpose of this form of literature is explanatory. The stories of Genesis were aimed at answering the Israelites’ fundamental questions about who they were and how they were to relate to their Creator. The Babel story in particular reflects a carefully crafted structure, reinforcing the poetic nature of this literary style. Notice the parallelism of man’s plans in verse 4 “Come, let us build ourselves…” versus God’s plans in verse 7 “Come, let us go down and confuse…”.

This suggests that we need to look beyond the face value of the words to understand the meaning of the
story. According to Leon Kass in his commentary *The Beginning of Wisdom*, the tower of Babel “completes the account of the universal human story, with human beings living largely on their own and without divine instruction.”

The immediate context of the story suggests that the tower may have been constructed for safety and security reasons, to provide high ground in the case of another flood and as a defensive watchtower over the plains. The place of the Babel story within the book of Genesis suggests that it represents a transition. It follows the Noah story and the list of Noah’s descendents. Before moving to Shinar, the descendents of Noah had participated in the covenant established with God after the flood, in which they had been instructed to “be fruitful and increase in number and fill the earth” (Genesis 9:1). This was God’s attempt to make his will known to all of humanity. But the people did not keep their side of the covenant, as shown in the Babel account. Immediately after the Babel story is found the genealogy of Abraham. Following the dispersal of peoples due to the confusion of languages resulting from the Babel incident, God selects Abraham as the father of the particular people with whom he will work out his covenant plan of salvation for the future.

**Larger Biblical Context.** It is important to interpret any text within the context of the whole of scripture. An appropriate interpretation should also be consistent with broader theological principles. Use of other texts that deal with the same topic and Christian principles that arise from a holistic reading of the Bible along with the interpretations of churches and believers over time will help to arrive at a correct interpretation.

Brueggemann, in his often recommended book *Genesis: A Bible Commentary for Preaching and Teaching*, notes that the early passages of Genesis reflect the back-and-forth relationship between God and his creatures. “These theological affirmations, then, set the main issues and the dramatic tensions of the text: the faithful, anguished, respectful purpose of the creator and creation’s mixed response of obedience and recalcitrance.”

One of the key passages from the beginning of Genesis that may help in understanding the events of Babel is referred to as the cultural mandate. In Gen. 1:29, humanity is instructed to fulfill God’s plans for his creation by going out to “be fruitful and increase in number; fill the earth and subdue it.” This mandate is emphasized once again as God covenants with Noah after the flood in Gen. 9:1. Within the context of the cultural mandate, one of the problems with the Babel citizens was that by staying together and building a fortress on the plain of Shinar they were resisting God’s purpose for creation. There is a dialectic involved in the early writings of Genesis between God’s desire for his people to go out and be scattered in order to cultivate the earth and God’s desire for his people to be unified in their covenant relationship with him. The Babel-ites were trying to structure their unity in themselves. Because of their fear of being scattered, they determined to make their own name and provide for their own security rather than trusting in God to provide their unity as they dispersed to do his work in the world.

Other passages in the Bible that describe technological objects or activities do not appear to do so in a way that expresses God’s disapproval. In Exodus 1, the Israelites in Egypt are forced to participate in the building of Egyptian cities by making bricks. The injustice of this situation was not related to the technology, but to the method the Egyptians used in their construction, namely the ruthlessness with which they ran the project and the difficulty of the work. Later, in Exodus 25, the structure and adornments of the tabernacle are described in ways that seem to honor the craftsmanship of the builders. Of course, this example of technology development is an example of technological skills being employed
for God’s glory in a very direct way, in constructing a house of worship. In the New Testament, Paul is referred to as participating in tent-making, another technological activity. The activity is spoken of approvingly, at least as far as it is able to provide an income and respectable work.

**Babel Commentaries**

Various commentaries were consulted to emphasize and expand on the themes and meanings of the story. All of them reinforce the idea that the story is not meant to condemn technology *per se*.

**Idolatrous Purpose of the Tower.** Some commentators suggest that the tower of Babel was meant to be a ziggurat, a common structure in Babylonia at this time. A ziggurat was meant as a symbol of worship for the Babylonian gods, serving as a temple and perhaps in the case of the citizens of Babel, even as a means for reaching the gods in their vault above the heavens. If this were the case, it would be clear that God acted in judgment against the people for idolatry, and perhaps also against their blasphemous pride in thinking they could make themselves equal to the gods with their technological prowess. This would support the interpretation in which God is angry not because they were building something large and impressive, but because their engineering plans were put to an improper end: the worship of false gods.

**Improper Motivations.** In Volume 1 of the *Commentary from the New Interpreter’s Bible*, the author suggests that it was not what the people actually did that was sinful, but the motivations behind their activities. “The text offers no reason to suppose that the building efforts as such are pernicious; we might in fact think of human creativity and imagination in developing such materials and projects. The author focuses on their motivations, not that they built or what they built. The precise nature of their failure remains elusive, however, resulting in various scholarly formulations.

John Calvin, in his commentary on Genesis, focuses on pride as the improper motivation for building the tower, and the scattering that followed as divine retribution for that pride. He suggests that their wish to make a name for themselves was evidence that their desire “to raise an eternal monument to themselves, which might endure throughout all ages, was proof of headstrong pride, joined with contempt of God.” Calvin regards the fact that all the people conspired to participate in the project (rather than a single individual or small group) as another reason that the punishment was so severe. He describes the lesson to be learned from the story in this way: “Difficulty often deters us from necessary works; but these men, when they had neither stones nor mortar, yet do not scruple to attempt the raising of an edifice which may transcend the clouds. We are taught, therefore, by this example, to what length the lust of men will hurry them, when they indulge their ambition” He concludes that the lesson of the Babel example is that we all must live humbly.

**Not the Tower, but the City.** Jacques Ellul comments on the Babel story in his book, *The Meaning of the City*. He suggests that “the tower is not the central element in the narrative. The two facts around which this myth is built are the city and a name.” He associates the desire of “making a name for themselves” with becoming independent from nature and therefore from God. According to Ellul, in cities man attempts to declare himself master over nature and his own fate.

“In the order of things established by God after the fall in order that the world might go on, man is in fact master of things, he can make a tower up to heaven of bricks baked in the fire and bitumen. He can also make a name for himself, for no natural obstacle keeps him from manifesting this pride to high heaven. Such is the nature of this entire enterprise, of every one of man’s enterprises. Sin always eggs him on to use things over which he is master in a way
Ellul obviously has a very pessimistic view of technological development and seems to imply that the very nature of modern technological activity is evil. He sees the Babel story as reinforcing his notion that city and tower construction in and of itself is destructive. I don’t believe that an appropriate interpretation of the Babel story supports his view. Ellul tends to minimize the desirable aspects of mastery over nature, including the decrease in death and suffering achievable by technology. Mastery over nature does not necessarily imply destruction of nature. It is possible to design technological systems which respect nature and cause all parts of nature (including humans) to flourish. It is also possible to design technological systems with the recognition that our motivation for good design is to promote God’s kingdom and that we are responsible to God for the consequences of our activities.

Lessons and Applications

Despite the fact that the Tower of Babel story cites a technology, it is not primarily about technology. Based on this understanding, the story does not imply that God disapproves of all large-scale engineering projects and approves of small-scale projects. Both large and small-scale projects can be done with improper motivations and can have good and bad consequences. Engineers in practice should be assured that their contributions to large projects are possible ways of carrying forward their Christian service, as long as some of the lessons mentioned later are heeded. Engineering students should be presented with techniques that apply to both high-tech and low-tech solutions to problems. Which type to use in a given situation depends on which is most appropriate for the stakeholders affected by the design.

A nuanced interpretation of the passage does not imply that God is displeased with people working together for a purpose. Although the story seems to indicate that God does not want us to make too much progress technologically because we will gain too much power, this does not necessarily apply to contemporary technological developments. God had a particular purpose in mind at the point in history of the Babel story which is different than his purpose for us at the current point in time. Working together is required to address the problems that humanity faces. God still encourages us via the cultural mandate to seek out ways we can cultivate better relationships with other individuals, cultures, and the non-human creation. God meant us to be relational, united with others through an understanding of how he created us, but still reflecting and benefiting from all the diversity inherent in particular individuals. Engineering work can provide a drive toward more interaction, since large-scale projects require teamwork for success.

While it is not appropriate to read too much about technology into the story, it is also not fair to conclude that the story has nothing to say about technology. Technological capability was part of the society of Babel, and the motivations that were condemned then are still part of human nature today and can affect our technology. The Babel story makes it clear that technology alone will not be able to “fix” the human situation. Technology, like all other aspects of cultural activity, has been tainted by sin, but also has the potential to help further God’s purposes here on earth. Technology needs to be guided and governed by values that are outside of the technologies themselves. To be pleasing to God, technology has to be undertaken for the right motivations (certainly not to serve idols) and guided by normative principles. These kinds of values are developed through religious practices and thoughtful consideration of philosophy, sociology, and other liberal arts. This emphasizes the importance of all engineers having

conducive to a spiritual destruction that nothing, in the natural order of things, can stop. Such is
the city."\textsuperscript{15}
adequate humanities content integrated into their educational experience. It also emphasizes the need for encouraging spiritual development and maturity for those involved with technology development.

Technology can have the effect of making us proud. There is a fine line between celebrating the advantages and rewards that modern technology has made possible and worshiping that technology. Worship in our modern world likely does not include bowing down to the technology in an obvious way, but rather relying too much on the powers of modern technology to provide self-sufficiency. Technology is something we should do in response to God’s stewardship requirements, not something we go out and do ourselves to eliminate our dependence on him. Engineers and others who interact with technology need to be reminded that our built things are just as dependent on God’s sustaining power as the “natural” things are.

One way of decreasing the focus on technology as a means of providing self-sufficiency might be to broaden our horizons relative to who the stakeholders are for any given technological development. The Babel story reminds us of the dangers of having an inward focus and using technology for the purpose of benefiting the “insiders” while keeping the “outsiders” at bay. Lately, some politicians have justified the pursuit of sustainable energy technologies by emphasizing the need for the United States to be energy independent. The development encouraged by this justification has been the support for and growth of corn ethanol production. An approach to the need for sustainable energy with a more global focus might not have emphasized the use of corn ethanol because of the effect its production has on world food prices and availability. Ethanol vehicles may be of significant benefit to the U.S. by reducing our dependence on foreign sources of fossil fuels in order to protect our standard of living, but the Babel story reminds us that God may not be pleased with this sort of activity if it does not reach out to better address the energy needs of the rest of the world. We are part of a global society. Our goal should be justice of energy distribution and protection of creation, not primarily protection of our country’s interests at the expense of others. Engineering as a career has also sometimes been promoted as a way to allow America to keep its technological edge relative to other countries. While it may be true that America’s affluence depends on having enough good engineers, this should not be the ultimate motivation for choosing engineering as a career.

Energy independence has also been used as a rationale for individuals to purchase solar panels or wind turbines for their homes. Where these technologies contribute to overall sustainability they should be encouraged. But, we should be willing to rely on others in a cooperative system of energy production if that is more efficient. It is not clear that having each household generate its own electricity is a desirable technology development. Large-scale power plants, when designed in ways that are sustainable, may be a demonstration of God’s intention for us to be interdependent.

The Babel story emphasizes the need to recognize our own dependence on God, in all our activities, but also in our technology. Ellul assumes that mastery over things, which is part of our current technological paradigm, must lead to mastery over others (injustice) and mastery over God (human independence). I don’t think this has to be the case. Our mastery over things is a pleasure to God when those things are designed not to bring glory to particular individuals or societies, but to bring glory to God by serving others. This is not an easy thing to do as engineers working in the current business climate. We as Christians need to constantly fight to bring technology into service of others, especially the others that Jesus highlights in the New Testament: the poor and oppressed. We need to join with others (including non-Christians) who recognize the dangers inherent in technology development and are committed to implementing technology responsibly.
Conclusions

The Bible does not provide us with very many specific guidelines for contemporary engineering work. Because the Tower of Babel passage refers to something that most engineers easily recognize as an engineering design, it can be tempting to rely on it too much for guidance in our engineering activities. A careful consideration of the context of the story is needed to be sure that inappropriate conclusions are not reached. A careful reading of the story within its Genesis context has yielded some helpful insights. Continuing to seek God’s will for technological activities is important. This one passage may not hold the key, but in conjunction with broader principles, reflection on it may lead to engineering work that is more pleasing to God.

References


[3] One example of this usage occurs at http://www.guardian.co.uk/technology/2006/nov/23/guardianweeklytechnologysection.insideit1


[13] Ibid, p. 327


The Use of Technology in the Global Church

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Abstract

The majority of Americans believes in God and use modern technology in their daily lives. Technology continues to alter the ways people interact and communicate, corporations conduct their business, and individuals occupy their leisure time. Christians possess and use technologies that are largely indistinguishable from the rest of culture. It is no surprise then that modern technology has permeated a myriad of religious activities and practices ranging from operating the business of the church, to pastoral care, to the mission field, to tithing and stewardship.

Christians have often been among the first adaptors of new technologies, from the Gutenberg printing press to mass produce bibles, to evangelical radio and television broadcasts to reach the masses. More recent applications enabled by digital technologies include the wide dissemination of information and increases in productivity. And with the continued embrace of technology has come additions in the vernacular. For example, e-missionaries and cyber congregations are examples of the vocabulary additions that enunciate the penetration of technology into the Church. With the growth of technology in religious activities, cottage industries have developed that provide needed expertise and services including internet hosting, presentation software, and theological resources.

Much of the motivation to embrace technology within faith organizations is powered by the younger generation who has never experienced a world without digital communications. Educators face comparable challenges and use analogous approaches, such as distance learning, appropriate technology, research databases, and scholarly conferences. Not everyone views the effects of technology use by missions organizations as positive, and there are differing views on the best implementation strategies.

The examples presented here explore how technology continues to change the face of the global Church and draws parallels to common approaches practiced by university professors. Among these, engineering educators hold a unique perspective relating to technology. They are both the developers of new technologies and the conveyors of technological principles to the next generation of users and developers. Christian engineering educators may especially experience the fruits of their professional labors, both through a technological lens as well as within the operations of the Church.

Historical Perspective

Historical periods, or ages, chronicle thousands of years of human developments. The impact of education, religion and technological developments can be seen in the naming of different eras including the Age of Discovering beginning in the 15th century, the Protestant Reformation in the 16th century, and the Industrial Revolution in the 18th century. Because of the prominent influence of technological advancements on society and the increasing rate of such discoveries, the duration of named historical segments decrease as they approach present day. Throughout modern human history, the influences of matters of the mind, technological advances, and religious faith are intertwined.

A stark example of this synergy is the printing of the Holy Bible using the movable-print Gutenberg Press in the middle of 15th century. Gutenberg’s invention is a great engineering achievement, although Johannes Gutenberg was actually a goldsmith. He utilized mechanical technologies from East Asia,
metallurgy for molding type blocks, and chemistry to develop a more durable oil-based ink. Printing Bibles was one of his first works, which are now well known as Gutenberg Bibles. There are currently 48 Gutenberg Bibles still in existence. The invention and widespread use of the printing press made available for mass consumption reproductions of great works and led to a dramatic rise in literacy, and the reading of the biblical Word, across Europe.

More recent examples of how faith organizations have embraced digital and communications technology include radio and television broadcasts of sermons, revivals, and gospel music. These applications have produced Christian radio stations and televisions networks, some of which are only available on the internet.

**Adapting Technology**

From a historical perspective we are currently in the Information Age, also popularly referred to as the Connected Age. One feels disconnected and cut off from the world if he or she looses cell phone or internet service. This is particularly true for many young people in the developed world, who expect to carry electronic communication devices with them and have never experienced a world without instant communication and connectivity. Some even advocate that technology in the Church can’t be ignored when it comes to the spiritual lives of young people. This expectation gives rise to opportunities for churches and other faith organizations to incorporate modern communication vehicles into their worship services, outreach, and evangelism activities.

Some refer to digital communication technology as the mission field of the 21st century. There are many examples of internet use affecting outreach, evangelism, and education. Though reported successes outnumber failures, several pitfalls and negative consequences have also been identified. For example, there are some circumstances where digital communication cannot substitute for the body language associated with face-to-face contact. Some church staff members who are particularly well equipped to enable and manage information systems, could also be less spiritually mature to effectively accomplish the faith-related task at hand. Similarly, interactions and information dominated by online groups or associations that serve to promote particularly radical/fundamental positions may also lead to a relatively uninformed or unchallenged faith view. One prominent member of the clergy recently expressed his displeasure with technology by asking the attendees at a convention meeting this series of questions. “…what if we’d spend less time on these websites that we’d be able to spend more time witnessing? Do you think if we spent less time blogging we might have more time to so some baptizing? Do you think if we spent less time fumbling around with those computers we might have more converts?” And finally, many, especially those of us in the academy, are intimately familiar with information overload resulting from broadly cast email announcements and messages, so much so that often our first response is to hit the “delete” key. So not all view or experience technology within the church as positive or effective. But then too there are numerous examples of where digital communications have been successfully deployed within faith-based related organizations to improve the effectiveness of their overall mission.

The large majority of U.S. college and high school students are members and frequent users of social networking and video-sharing web sites that also permit chatting, messaging, and blogging. The most popular of these sites are MySpace, FaceBook, and YouTube. Many colleges and universities also make available internal institutional web sites for students to share and discuss information about campus issues. Christian social networking sites have recently been launched with distinctive faith outlooks. GodTube.com is a Christian video-sharing and social networking site that receives 1.6 million unique visitors each month and hosts 38,000 videos. The CEO of God Tube, Chris Wyatt, helped start the predecessor to the MySpace network. There is also a similar Jewish site, JewTube.com, and for Muslims, IslamicTube.net. One Christian alternative or equivalent to YouTube is E-zekeil.tv, developed by Axletree Media. E-zekeil is a website builder and host that permits churches to develop or link websites
and share videos. Among its attributes is the ease at uploading videos that are easily viewed and shared.\textsuperscript{14} The site, MyChurch.com, has been available online for a longer period and offers profile pages, commenting, blogging, bulletins, and the ability to add friends to one’s network. Like MySpace, it includes friend mapping, calendaring and profile securing settings.\textsuperscript{15}

Students and faculty members are well familiar with podcasts, usually in an MP3 format, for downloading and playing music and class lectures. Many churches now podcast the pastor’s weekly sermon and other events so that parishioners and others may listen in later and at their convenience.\textsuperscript{16} To help facilitate such projects, websites (such as ChurchPodcast.net and EasyPreach.com) and software are available. Related content also includes training on how to set up a web site and initiating a podcast service.

**Technology within the Church**

Megachurches (2,000 or more weekly worshipers) are the fastest growing element of church membership in the U.S. and are following the tradition of embracing the technology of the day.\textsuperscript{17} Comprising a small percentage of the total number of churches, megachurches account for around seven percent of weekly church attendance. For a large part they are growing at the expense of other churches.\textsuperscript{18} One factor driving this growth is the cost (through the economies of scale) and availability of expanded programs, facilities, and services, including technology. Church goers may touch a fingerprint scanner to register their attendance and parents swipe an ID card to check their children into Sunday School. Tithing can be done through automatic bank drafts. Worshipers use the Wi-Fi network in the sanctuary to look up bible verses. Satellite campuses or other remote locations may view the pastor’s sermon real-time on projection screens, or asynchronously. Technology also helps megachurches closely track each member and provide them with customized information and opportunities to meet their individual preferences.\textsuperscript{18}

Using the internet and websites for outreach is not unique to megachurches. Unlike consecutive linear messaging such as that often provided by weekly mailings and Sunday School literature, it provides a “pull” medium on the basis of individually defined interests. It reaches anyone, anywhere, anytime. The internet also provides the means for personal and confidential communications.\textsuperscript{19} With regards to using technology in the development of spiritual formation, pastors have reported using the internet for sharing prayer requests with deacons and for religious study and reflection.\textsuperscript{20} Of course, when face-to-face contact is needed, traditional personal visitation and in-person conversations are usually practiced.\textsuperscript{17}

The use of audio-visual technology during worship services is now widely practiced, though the degree and specificity of technology use varies. The most sophisticated have borrowed practices common in theatrical performances, including stage and lighting variations. Generally the worship-center technology is viewed to enhance communication. Projection screens are used to show video clips, project the words to hymns and Bible verses, and live feeds of the pastor, choir, and other worship participants. Presentation software specifically designed for worship services, including MediaShout, SongShow Plus, and Prologue Sunday, avoids some of the shortcoming of more general slideshow packages. Audio amplification allows the congregation to enjoy the sermon, music, and drama presentations in high fidelity acoustics. Some older and smaller churches may have difficulty fully incorporating audio-visual technology due to architectural challenges, infrastructure limitations, or high costs.\textsuperscript{17}

**Technology, Missions, and Service**

Missions frequently represent a significant portion of church budgets and activities. Technology is changing missions and the way missionaries work. Because information used to identify and assign missionary projects and volunteers is now integrated and shared, resources are used more efficiently. This efficiency streams down to interfacing with donors and sponsoring congregations, where digital photographs and video images effectively depict people, work done, and details of the project.
Missionaries in the field can more frequently and instantaneously speak and communicate with other colleagues and distant family members using cell phones or voice-over-internet-protocol (VOIP) connectivity.

Technology also provides unique opportunities for parishioners, especially those whose vocation lies in the high tech realm. This includes engineering faculty and students participating in discipline-specific mission projects. For example, Baylor University students and faculty designed and deployed appropriate technology for energy, transportation, and water systems projects in Kenya and Honduras.\textsuperscript{21, 22} LeTourneau University engineering students designed and built lower-leg prostheses for patients in Kenya and Bangladesh.\textsuperscript{23} Faculty and student organizations at secular universities also aim to provide missions-related services to developing countries, including Engineering World Health based at Duke University, and Engineering Projects in Community Service (EPICS) founded at Purdue University.\textsuperscript{24}

Other interesting missions technologies applied in developing countries include audio and video versions of a Bible Stick (a compact and dedicated digital audio player with the Bible loaded in MP3 format) in Sierra Leone and Cambodia. In some cases the devices have to be powered using solar converters.\textsuperscript{25, 26} Because the possession of printed Christian literature poses a safety risk in some regions, digital versions can sometimes be utilized and offer several advantages, including small physical size.

Besides applications relating the worship and missions practices, technology also affects the business of the church. Accounting, scheduling, and communication practices in many churches are software driven and similar to those in the corporate world. But there are significant differences. For example, many operations are manned by volunteers, and normal business software doesn’t always easily adapt.\textsuperscript{27} As a result a number of software solutions are available to assist in organizing and running church functions, including missions outreach and stewardship and fundraising campaigns. Several agencies also provide web design and support, and even temporary staffing.\textsuperscript{28}

There are also opportunities for faculty members possessing high tech knowledge or interests to volunteer to apply their craft or trade to the operations of their home church. Designing the server network, developing the web site, and coordinating audio and video productions are prime examples of where volunteer engineering talent is regularly utilized. Additionally, Christian faculty members who are mature and confident in their faith can provide a level of rationality to avoid some of the potential negative pitfalls mentioned earlier in the deployment of technology throughout their church enterprise.

\textbf{Vernacular and Staff Positions}

The ubiquity of technology has spurred additions in the Church’s vernacular and position titles. Below is a list of technology-flavored activities and programming that didn’t exist a decade or so ago.

\begin{itemize}
\item E-Missionaries: coined by Saddleback’s Rick Warren to evangelize in remote or dangerous regions through email and web communications.\textsuperscript{29, 30}
\item E-Discipleship: self-paced online bible study course that takes advantage of web attributes.
\item E-Vangelism (or internet evangelism): refers to evangelizing underserved populations using internet applications.\textsuperscript{31}
\item CyberMissions: “front-line use of computers and the internet as tools in achieving the Great Commission”\textsuperscript{32}
\item PastorPreneurs: Entrepreneur pastors often involved with church plantings and transformations and that have responsibilities for managing many elements of the church business and ministry.\textsuperscript{17}
\item CyberMinistry: principally the activities of a CyberEvangelist; i.e., minister using internet resources.
\end{itemize}

Likewise, with this new vernacular comes a new set of church staff positions.
• Pastor of Technology: The individual who decides what “… technology investments are essential to achieving our goals of communicating the Gospel.”

• CyberEvangelist: originally described as one who promoted use of the World Wide Web; in the current context it refers to evangelists for which a large portion of their activities are conducted online.

It’s interesting to note that the Second Baptist Church of Houston, Texas, was represented at Baylor University’s 2008 STEM Career Fair, seeking to hire computer science majors for technology positions.

There are also several phrases containing a play on words for recognized Christian expressions, but with a technology twist. These include:
• The Geek shall inherit the earth.
• Give me that on-line religion.
• Christianity is not a theory; it’s a life.

Beyond participating in discipline-specific missions mentioned earlier, there are several other commonalities relating to technology influences on religious practices, and engineering faculty members. For example, there are professional conferences, i.e., International Conference on Computing and Mission (ICCM), where academics and others involved in this area meet annually and share “a vision cooperation for effective use of technology bringing the Gospel to every nation.” Three other related professional associations or conferences are:
• AC²- Association of Christian Computer Centers
• IMC- Internet Ministry Conference
• CEEC- Christian Engineering Educators Conference

As within university communities, distance learning courses and training are also a growing component of education and outreach programs within faith-based organizations.

Future Courses

As Moore’s Law predicts, technological developments will continue to occur at an increasingly rapid pace. New developments will continue to present challenges for the Church to evaluate and embrace. Technology holds the potential to improve the Church’s operations and effectiveness. Communication is of special consideration, as digital technologies will increasingly provide the vehicle of application for local congregations as well as the unreached worldwide. Cyberchurches, some of which we only find in virtual spaces like Second Life, already exist. Campus Crusade for Christ predicts that within just five years the majority of new decisions for Christ will be facilitated principally using online evangelistic communications. Historical lessons suggest that new innovations will be exciting and useful additions to advancing the mission field, though not wrought without some advocating for the good-old-days.

Conclusions

While the Word of God remains truthfully constant, technology applications continue to march forward. Christians have long embraced technology, a practice which continues in today’s church. Young people are particularly adept at using and assimilating technology for communication. It is high tech and high touch. The utilization of technology affects how we worship and how we apply our profession on the mission field. As Christian engineering educators, we have a special opportunity to observe, participate, and even help drive the process.
References

Enhancing Science and Engineering Programs to Equip and Inspire Missionaries to Technical Communities

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Abstract

Enhancements to science and engineering curricula are being considered in light of theologically-significant scientific discoveries, as well as the applicability of the field of engineering to the formulation of a coherent cosmology and worldview. In addition to the inclusion of these ideas in existing science and engineering courses, a new “Science and Faith” course is currently being developed in an effort to better equip and inspire science and engineering graduates to serve as “everyday” missionaries in their chosen fields.

This new course will focus on the knowledge and skills necessary for graduates to engage in fruitful dialogue with seekers from high-tech and highly-educated societies. Students will receive training in science-related apologetics, including the attitude and behavior of the Christian apologist. They will gain an understanding of the importance of God’s general revelation, and how recent developments in science and engineering might contribute to the veracity of a Christian worldview. The latest developments regarding design evidence, creation/evolution, and natural theology will be discussed and evaluated. Various Christian positions on the relationship between science and scripture will be investigated. An extended design argument, based on evidence from many fields of knowledge and forming a cumulative case for the Christian worldview, will also be discussed and evaluated.

Given that complex design is largely the domain of the engineer, it is recognized that engineers have an important role to play in the current science/theology dialogue. The Apostle Paul’s assertion that God’s invisible qualities can be known, “being understood from what has been made” (Rom 1:20), may refer to knowledge obtained through a kind of reverse-engineering of the cosmos. Indeed, the systems engineering mindset has proven to be extremely useful in complex fields such as microbiology. A compelling argument can be made that the universe is so readily and profitably reverse-engineered, that it must have been engineered in the first place. The idea that many features of the universe strongly suggest (through a consilience of evidence) that the entire cosmos is an engineered system will be thoroughly investigated, including possible purposes for such a system. The concepts of constrained optimization and engineering tradeoffs will also be introduced to assist in wrestling with the problem of evil from the Christian worldview. It is hoped that as a result of this effort, students will graduate full of ready answers (1 Peter 3:15), and inspired to live a life of purpose and mission for the glory of God.

Introduction

In recent years, the problem of the origin of life, which essentially reduces to the problem of the origin of biological information, has become intimately connected to the problem of the origin of the cosmos. This is due to discoveries of the fitness or fine-tuning of the universe for life, and the recognition of the enormous amount of information that must have been present at the beginning. Thus any discussion about the origin of life and the cosmos is difficult because the subject is so vast. It branches across literally every area of science, especially such fields as biology, chemistry, physics, astronomy, cosmology, and earth sciences. The dialogue is also relevant to nearly every area of culture, such as education, politics, religion, and sociology. In order to be an expert in the entire subject of the origin of life and the cosmos, one would need a very diverse background in almost all of science. Actually, one would quite literally need to have the mind of God. This realization should motivate Christians to want to learn as much as possible in order to strengthen one’s faith and become a more effective witness.
Engineers are in a unique position to contribute to these ideas because engineering necessitates a practical knowledge of many areas of science. Engineers can also better relate to the difficulty of dealing with the design tradeoffs inherent in a system as complicated and intertwined as the universe. As a brief description of the undergraduate course to which this work refers, this paper will not attempt to scrutinize every detail, but will give an overview of current research and dialogue while discussing critical issues at a deeper level. First, some pertinent ideas are presented from various fields of science. Such information is important since recent scientific discoveries appear to be particularly applicable to these issues. This is followed by an in-depth discussion of the value of natural theology for apologetics and evangelism.

**Cosmology and Astronomy**

A discussion about the universe naturally begins with cosmology. No scientist would deny that the universe at least appears to be several billions of years old. Evidences from astronomy, radiometric dating, and the fossil record all seem to point to this same conclusion. Interpretations of the Bible greatly affect whether one considers age to be actual or only apparent. This class will attempt to be unbiased regarding creation models, allowing the evidence to fall where it may. However, the apologetic value of various models will be investigated. Thus for example, the Big Bang will be discussed as a possibility. If the Big Bang is historical, it is far from being evidence for atheism. Obviously there are huge philosophical questions regarding why something exploded out of nothing. The general acceptance of the Big Bang theory could be considered favorable to the Christian worldview because the theory necessitates a beginning. Interestingly, the name “big bang” was originally a negative term by astronomer Fred Hoyle, who said, “The big bang theory requires a recent origin of the universe that openly invites the concept of creation.” Possibly even more important is that the Big Bang must be the most finely-tuned event in history. An engineered explosion such as a fireworks shell is a simple analogy, but fireworks do not come close to representing the complexity, order, and precision of an expansion resulting in a universe beautifully arrayed with galaxies, solar systems, planets, moons, comets, and other bodies spinning so conveniently (for us) through space and time.

In general, three essential factors are required to achieve design outcomes in engineering: 1) the mathematical form of nature, 2) universal physical constants, and 3) boundary conditions. For example, to determine how gravity affects an object, the following must be known: the form of the gravitational equation (Newtonian: $F = G\frac{m_1m_2}{R^2}$), the gravitational constant ($G = 6.67 \times 10^{-11}$ N⋅m²/kg²), and several boundary conditions ($m_1$, $m_2$, $R$). From the perspective of a human engineer, only the boundary conditions can be altered. The other two can only be analyzed and hypothesized, but they must have been determined sometime in the past, somehow. Science currently estimates that there are 26 universal physical constants. This number might change, depending on if a future theory is able to define one constant based on others or if a natural process is discovered requiring a new, unrelated universal physical constant. The overall purpose of the search for a Theory of Everything is to reduce all of these constants and equations into one tidy equation. Some hope this will explain the order behind the universe, but even if it is successful, it is not a true threat to theism. It will only push the questions back another level. Models and equations can explain a lot, but they can never explain their own existence or comprehensible order.

Regarding the finely-tuned physical constants, Christian de Duve (Biochemist, Nobel laureate in medicine) writes,

> We live in a biofriendly world. Were it otherwise, we wouldn’t be around. The question is, therefore, how biofriendly is it? Physicists have addressed this question and have come to the conclusion that if any of the fundamental physical constants were a little smaller or a little larger than they are, the universe would be very different from what it is and unable to produce or harbor living organisms.
How have physicists come to this conclusion? The primary method is called “counterfactual variation”, where physical constants are varied and it is determined if the results are still favorable for life. One can determine the amount of variation that results in conditions unfit for life, and therefore one is able to determine how “finely-tuned” the dials on each of the physical constants are. In biology, this process is more difficult and subjective, but it is a relatively simple process for cosmology. Types of fine-tuning, other than universal constants, include specific conditions for quantities such as distances, and timing. As of 2006, astronomer Hugh Ross lists 93 constraints that are usually considered instances of “fine-tuning” in the universe. All of these conditions had to be embedded into the rapid expansion of a singularity if the Big Bang is historical.

How incredible are the instances of fine-tuning in the cosmos? The expansion rate relative the gravitational pull caused by the density of the universe must be accurate to the order of 1:10^{60}. If this ratio had been altered by such a small magnitude, the universe would have either collapsed rapidly back in on itself, or expanded so fast that galaxies would have never formed, prohibiting life as we know it. The ratio of gravity to the electromagnetic force is vital for star variety and therefore element variety and stars with long life spans. This precision is on the order of 1:10^{40}. Of course, many more examples could be listed here, but the overall point is that the biofriendly behavior of the universe is teetering on an incredibly sharp knife edge.

Besides fine-tuning, another type of evidence for design is presented in a book entitled The Privileged Planet. In this book, Gonzalez and Richards explain how several traits combine to make Earth an ideal location for discovery of the universe. It makes sense that God would want His existence to be confirmed through investigation of His creation. The atmosphere is dense enough to block the correct amount of harmful radiation, while remaining transparent enough for observation of the sky. Earth’s single moon regulates the tides and stabilizes Earth’s rotation, but it also only provides minimal obstruction of the night sky. The correct ratio of size and distance between the moon and sun make the two bodies appear the same size in the sky. This may only be coincidental, but it did provide an opportunity for scientists to test Einstein’s theory of relativity based on the bending of light due to the sun’s gravity. Possibly most importantly, this solar system is located near the outer edge of a spiral arm of the Milky Way Galaxy. In this region, harmful chaos is minimal, while beauty of the night sky is still impressive. The gas and dust in this region is diffuse compared to others, which means that approximately 80% of the universe is unobstructed from Earth’s vantage point.

**Physics and Chemistry**

It is difficult to separate cosmology and astronomy from the fields of physics and chemistry. Orbits are obviously based on the laws of physics. Fusion inside stars not only affects large-scale astronomical behavior, but it also determines the elemental composition of the universe. Besides typical fusion reactions, the rapid transitions that occur during the nova or supernova of most stars’ deaths are the source of almost all of the heavy elements in the universe. The most important elements for the existence of life are probably hydrogen, oxygen, and carbon. Carbon is important because of the incredible variety of compounds made possible by its four valence electrons. The most notable importance of hydrogen and oxygen is that they constitute water, a substance incredibly fit for life.

Hydrogen, oxygen, and carbon conveniently rank one, three, and four in prevalence in the universe. This is caused by the behavior of fusion within stars. Early reactions start with hydrogen atoms and then produce deuterium (mass 2), tritium (mass 3), and alpha particles (mass 4), but no stable mass 5 exists. This limits the creation of heavy elements and was once considered one of God’s “mistakes”. In actuality, the lack of a stable mass 5 necessitates bigger jumps of four which lead to carbon (mass 12) and oxygen (mass 16). Otherwise, the reactions would have climbed right up the periodic table in mass steps of one (until iron, which is the cutoff above which fusion requires energy rather than creating it). The process would have left oxygen and carbon to be no more abundant than any other element.
One might wonder why beryllium (mass 8) is not more prevalent. This is because beryllium reacts easily to make carbon due to carbon’s energy resonance level. Beryllium and helium have very nearly the exact same combined energy level as an excited carbon atom. If the resonance level of carbon was 4% lower, essentially no carbon would form. If it was 0.5% higher, it would rarely hold together. Fred Hoyle predicted this situation based on an anthropic assumption. When it was later confirmed, Hoyle (an agnostic) seemed to be unnerved, leading to some interesting quotes such as the following:

A commonsense interpretation of the facts suggests that a superintellect has monkeyed with physics, as well as with chemistry and biology, and that there are no blind forces worth speaking about in nature. Another agnostic scientist struck by how the universe is so well-suited for life was Lawrence J. Henderson. In 1913, he wrote a book entitled The Fitness of the Environment. The central claim of the book is summarized in the first chapter with the statement, “Fitness there must be, in environment as well as in the organism.” Among other topics, Henderson studies the fitness of water extensively.

Water’s most famous trait is that it expands into the solid state, causing ice to float rather than accumulate on the ocean floor. A short list of some of water’s other impressive properties includes the following: A very high specific heat maintains relatively stable temperatures in oceans and organisms. Its thermal conductivity is four times that of any other common liquid, helping organisms distribute heat. On the other hand, ice’s thermal conductivity is low, making it a good thermal shield. Water has the highest latent heat of vaporization of any substance – more than five times the heat necessary to raise the same amount from freezing to boiling. This allows water vapor to store huge amounts of heat in the atmosphere, and it also helps humans dissipate heat through sweat. Water’s high vapor tension enables the atmosphere to hold more water, and thus it enables precipitation. A low viscosity allows blood to flow through small capillaries. Water has unequaled solvency properties, enabling blood and the oceans to transport all of the necessary contents for life. Jeffrey P. Schloss also notes that some of the traits of water are optimized at various temperatures. At body temperature, the specific heat of water is lowest and water’s viscosity (decreasing with temperature) is optimized with the solubility of hydrophobic molecules (increasing with temperature). In short, every property of water seems to be ideally suited for life.

This situation should be amazing to an engineer. How can a simple substance containing only three atoms exhibit all of these functionally impressive qualities? Many of these qualities are caused by water’s hydrogen bonding and strong polarity, but this is an oversimplification. That every property is suited for life seems too incredible to be a coincidence. God’s design process for water must go very deep, including the design of forces, masses, sizes, and other quantities all the way down to the quantum level. This must be engineered in a way that accounts for the behavior of all of chemistry, not just water. The problem is of such high order that it suggests the action of a calculating intentionality.

Biology and Biochemistry

Considering all of the evidences for superb engineering mentioned to this point, as well as the possibility that they were embedded into an expansion from a singularity, some Christians extend this logic to propose that God also front-loaded the origin of life into the original event of creation. This suggestion encounters criticisms from both science and theology, but one must at least consider the possibility that these criticisms are not insurmountable. One’s faith should not be challenged based on whether God created the first living organism by natural processes or more immediately. Study of the origin of life is primarily a subject of biochemistry. It requires considerable knowledge about the components of the simplest known cells, especially DNA, RNA, and proteins. DNA is an especially challenging hurdle because it contains the codes for reproduction. A naturalistic explanation of the origin of DNA becomes a “chicken or the egg?” conundrum, and it also requires an explanation for a pathway to the excellent DNA design with limited occasions for natural selection as an explanatory
method. Prior to the existence of codes for self-replication, the only type of natural selection is the tendency for certain reactions to occur more readily than others.

There are two general categories of theories for a naturalistic origin of life. Geneticists usually claim that life began with replication, while metabolists consider genetic replication to be a later function of autocatalytic-metabolic cycles. There is currently no full model for either type of theory. Most claim that RNA was an ancestor to DNA, but RNA needs its own ancestor as well, and no one knows how many steps might be necessary prior to that. TNA has been studied as a more stable predecessor to RNA, but it encounters most of the same problems because its composition is primarily only different in that it contains four carbon atoms instead of five in its sugar building block. RNA cannot be directly produced abiotically because of many difficulties. Nucleotides (the structural units of DNA, RNA, and TNA) include a base, a ribose, and a phosphate. It appears that none of these can be created abiotically. The pathways to the bases are antagonistic, all sugars are unstable in prebiotic conditions, and no source for abiotic phosphate has been found. On top of this, nucleotides themselves are also unstable. This means that these nucleotides must come later in any naturalistic explanation, after shelter from the environment has been created. There is also currently no plausible abiotic reaction scheme to assemble the nucleotides. A pathway to DNA and a reaction scheme to create it still would not account for the code it contains. The four bases create a four “letter” code capable of housing all the information to produce a human or any other living organism. This code could not have been synthesized randomly, since the odds become astronomical very quickly. The human genome was first mapped by a team led by Francis Collins, who said,

> When you have for the first time in front of you this 3.1 billion-letter instruction book that conveys all kinds of information and all kinds of mystery about humankind, you can’t survey that going through page after page without a sense of awe. I can’t help but look at those pages and have a vague sense that this is giving me a glimpse of God’s mind.

The method to decode the message was discovered before the code was mapped. Triplets of nucleotides, called codons, refer to one of the 20 possible amino acids in the production of a protein. Three codons are stops, like a period at the end of a sentence.

Although DNA is the instruction manual for reproducing life, proteins carry out almost all of the essential functions in cells. Proteins are composed of chains of amino acids. Almost half of the 20 amino acids can be reliably produced in prebiotic experiments, so natural explanations assume the others must have been invented later by metabolism. Complex proteins are folded by stacking simpler folds. There are a limited number of configurations – probably somewhere between 1000 and 6000 possible folds. Biologist Michael Denton explains why the discovery of this “periodic table” of folds is exciting:

> The discovery that this elegant set of atomic architectures represents a set of natural forms determined by physical law (and therefore that many of their genetic properties are ‘antecedent’ to biology) not only is profoundly beautiful and intellectually attractive in itself, but has far-reaching consequences. It implies, aside from the question of the actual biological fitness of the folds, that protein-based life is an integral part of nature and may be properly designated an emergent property of matter.

This builds on the argument that the universe is improbably fit for life. Denton also lists some of protein’s impressive abilities: “architectural diversity, marginal stability, robustness, and possession of a hydrophobic core.” Architectural diversity refers to the variety of folds, which is obviously vital for the variety of processes necessary for the life of a cell. Marginal stability and robustness might seem like opposites, but picture something elastic. Slight energy variations can cause simple adaptations, which are vital to such processes as the intake of oxygen into
hemoglobin. On the other hand, proteins assume their folded form without energy input, which makes them very robust. The hydrophobic core is a useful feature that acts as a reaction chamber excluding the presence of water. It also provides the ability of proteins to stack to make assemblies like filaments and microtubules. Scientists have a lot to learn about proteins because so far research can only test, not predict, how combinations of amino acids will fold or how this sequence determines the protein’s function. Regardless of the results of future research, it is hard to deny the evidence of great engineering design in proteins.

The origin of life is a difficult problem, but the variety of life’s forms is an equally confusing question. The theory of evolution has resulted in a major conflict in society since Darwin wrote *The Origin of Species* in 1859. Christians believe in varying amounts of power for the roles of mutation and natural selection in creating the current variety of species. Some place almost no power in evolution, claiming that God created every species almost exactly as it appears today. Others claim that God used evolution to create every organism from the origin of life to the first man. To either prove or falsify the theory of evolution is very difficult. A reasonable proof would require a logical evolutionary pathway to every organism along with evidence that these pathways were taken. Science and the fossil record are nowhere near this goal. To disprove evolution as an all-encompassing theory would really only take a single example of an organism that could not possibly evolve in reasonably small steps. One of Darwin’s quotes that has become a favorite of those opposed to evolution is, “If it could be demonstrated that any complex organ existed which could not possibly have been formed by numerous, successive, slight modifications, my theory would absolutely break down.” However, such arguments are usually condemned as arguments from ignorance. Scientists often use the evolutionary landscape as a metaphor for evolutionary pathways, where fit organisms are on top of hills. An un-evolvable organism would be situated on top of a tall tower, but proving that there are no stairs hidden behind a back door is very difficult.

Michael Behe’s *Darwin’s Black Box* (1996) is one of the most famous books exposing the difficulties facing the theory of evolution. The black box to which Behe refers is the cell. Behe’s most famous concept is called irreducible complexity, for which Behe uses the analogy of a mousetrap. The whole does not work without every part in place, so small steps are not advantageous. Behe’s microbiological examples of irreducible complexity are cilium/flagellum, blood clotting, protein transport, the immune system, and AMP generation. Cilium and flagellum are incredible because they are efficient propellers with all of the necessary parts corresponding to their mechanical equivalents. Blood clotting is basically an 11 part Rube Goldberg mechanism. Protein transport includes 21 steps to tackle all of the difficulties of bringing proteins through the assembly line to their correct locations by using microscopic versions of tags, delivery trucks, and so forth. The immune system contains billions of versions of white blood cells, making it ready for even synthetic bacteria. AMP is a molecule that becomes one of the building blocks of DNA. Its generation in the cell requires 13 steps, including 12 enzymes, five energy bursts (via ATP), and eight specific types of molecules.

The afterword of the 10th anniversary edition notes that as of 2006, despite great attention from evolutionist scientists, still no scientific literature exists that contains evidence for how molecular evolution might have occurred in the examples Behe gives. However, it has been rebutted by suggesting in a more general sense that the individual parts may have served other advantageous uses before combining into their current form. In this way, evolution may still select advantageous parts without a preference towards their final purpose. This argument is reasonable, but it lacks specific examples.

The study of evolutionary mechanisms is still in its infancy. Specific, detailed examples of pathways are not common. Regardless of the power and extent of advantageous mutations in biology, the extended design argument still seems to be strong. William Dembski writes that “Many of the systems inside the cell represent nanotechnology at a scale and sophistication that dwarfs human engineering. Moreover, our ability to understand the structure and function of these systems depends directly on our
facility with engineering principles.”

Life contains many hallmarks of well-engineered systems, such as modularity, specificity, adaptability, and durability. Whether these traits were caused directly by the Creator’s hand or by a tool in His hand is really a side issue. An efficient tool still demands an explanation.

Homo sapiens pose an even more difficult evolutionary question. Each person knows from experience the amazing capabilities of the human mind, but yet very little is scientifically known. The concepts of consciousness and free will might forever remain beyond the scope of science. Since atheism requires only cause and effect explanations, it necessarily claims that free will is an illusion. Christianity claims that an eternal spirit exists in every human. Author Roy Abraham Varghese explains the relationship of the spirit to the body like a radio to its message. He writes, “When its batteries run out, the radio can no longer transmit the messages it used to pick up. The physical components of the radio, however, are by no means identical with the messages, let alone with the person or persons from whom the messages originate.” The spirit could not originate through any naturalistic process, so a Christian model of evolution at least needs divine intervention at this point unless it is going to stray significantly from orthodoxy.

The Anthropic Principle

Even disregarding a Christian worldview, one can make the case that the cosmos seems to be centered on humans. Mankind is matched to creation in such a way that people are able to comprehend and predict its natural laws. At a more basic level, the ground can be tilled to produce enough food without expending too much energy in the process. The logic of days, seasons, and years provides a simple backdrop for living. The list can go on. In the end, the true purpose for creation is to provide a setting for God’s redemptive plan of love and grace. Orthodoxy says that God did not need to create, but He chose to create as an act of love. In this sense, all of nature is a display of God’s love. Science is a witness of His affection for us.

The innate beauty of creation is another expected trait if it has been engineered. Beauty is generally impossible to quantify. Thus, “beauty is in the eye of the beholder.” This delights artists and is entirely fitting. If beauty could be quantified, it could be optimized and bottled, ironically losing its beauty. Since beauty is subjective though, it makes a definitive argument for a divine Artist all but impossible. The concept of beauty should not be dismissed from this discussion, though. Science might describe, but never explain the view of a sunrise, the taste of chocolate, the touch of a soft breeze, the sound of birds chirping, or the smell of flowers after a rain. These all convey a purpose that naturalistic science can never appreciate. Beauty is not necessary, yet it is prevalent and good, so the very existence of beauty strengthens the case for a Creator. Certain aspects of the argument for a Creator are more forceful than others, but the strength of the theory lies in the cumulative case, not necessarily in the individual evidences.

On the flipside, as overwhelming as the task of explaining nature and the cosmos naturally seems, the current theory that poses the biggest potential is the multiverse theory. The strength of the multiverse theory is its nearly infinite explanatory power. If there are nearly infinite universes, then there is probably literally another one just like this one where this paper was never written. The multiverse theory can explain all of the fine-tuning and even any astronomically unlikely events for the creation of life. However, the multiverse theory still requires an ultimate cause, so it still really needs a transcendent creator. The theory also suffers from its absurdity and lack of evidence. What determines the possible array of universes? Tegmark proposes a universe obeying mathematics based on fractals or non-Cantorian sets. Paul Davies suggests that some universes might not even obey mathematics, but instead obey purely teleological principles. Do the possibilities stop? What would be the cause of such a strange variety of universes in which mankind as it exists here is just one infinitesimal occasion?
Even if no alternative to a Creator is ever satisfactorily suggested, the problem of evil and pain will still bother people. This subject comes up almost every time the topic of origins is discussed. Unfortunately, evil seems to be a necessary side effect of free will. Besides this, death (and probably the uncertainty of its timing) seems to be necessary so that God can bring us fully back to a glorious state. Although pain and evil may not be good, God is a master at using it to accomplish His purposes. In his book, *Miracles*, C.S. Lewis writes,

> So much for the sense in which human Death is the result of sin and the triumph of Satan. But it is also the means of redemption from sin, God’s medicine for Man and His weapon against Satan. In a general way it is not difficult to understand how the same thing can be a master-stroke on the part of one combatant and also the very means whereby the superior combatant defeats him. Every good general, every good chess-player, takes what is precisely the strong point of his opponent’s plan and makes it the pivot of his own plan. Take that castle of mine if you insist, it was not my original intention that you should – indeed, I thought you would have had more sense. But take it by all means. For now I move thus… and thus…and it is mate in three moves. Something like this must be supposed to have happened about death.\(^{21}\)

The redemption of an apparent failure is actually a characteristic of a well-engineered system, as engineer and author Henry Petroski writes in his book *Success Through Failure: The Paradox of Design*,

> Failure is thus a unifying principle in the design of things large and small, hard and soft, real and imagined… Whatever is being designed, success is achieved by properly anticipating and obviating failure.\(^{22}\)

The concept of God using a refining fire is throughout scripture. Isaiah wrote, “See, I have refined you, though not as silver; I have tested you in the furnace of affliction.”\(^{23}\) God can also use pain to get our attention. C.S. Lewis also writes, “God whispers to us in our pleasures, speaks in our conscience, but shouts in our pains: it is His megaphone to rouse a deaf world.”\(^{24}\) Engineering design is full of tradeoffs, and it seems that this is the biggest tradeoff (and the biggest risk) of God’s plan. Despite pain and evil, God’s plan still can be optimally good.

In summary, the Christian worldview is robust. Some people disagree because the supernatural seems irrational to them or possibly because of the implications. However, the full picture of the cosmos discovered by science displays an impressive system of precision, order, and purpose. Engineers cannot rival the efficiency and complexity found in nature. The full picture, including astronomy, chemistry, physics, biology, and all other sciences, creates a consilience of evidence pointing towards a transcendent Engineer. Since engineers tend to be very rational, every Christian engineer needs to be competent to discuss this topic if he or she is going to be a successful witness among other engineers, scientists, or educated skeptics.

**Apologetics: Communicating Truth**

Unfortunately, the worldviews carried by all people color their perceptions of reality. It is not enough for the Christian apologist to use science, reason, and philosophy to demonstrate the viability of the truth claims in Scripture. The method of presentation is critical. To this end, Christian engineers who understand the science of design and its fitness for understanding the natural world benefit greatly from some exposure to apologetic techniques. With this in mind, the content of a missions-oriented Christian engineering course may effectively fall into two categories: 1) foundational knowledge and worldview and 2) apologetic techniques for effective transmission of truth.

The New Testament writer Jude encourages the first century Church to "…contend for the faith that was once for all entrusted to the saints;"\(^{25}\) Dembski explains that "The very idea of contending for the faith rings foreign to our modern and postmodern ears. To contend for something, after all, presupposes
we have something worth contending for—that the faith is something definite and precious, all too easily lost, and therefore in need of being vigorously preserved. I want therefore to begin this essay by showing that it is legitimate to think of the faith in these terms, that is, as something definite, precious and worth fighting for.26 In the last two hundred years, firmly held beliefs in many areas of study seem to have been turn upside down:

Physics—Newtonian mechanics $\rightarrow$ relativity theory and quantum mechanics
Biology—systems are designed $\rightarrow$ systems are the product of naturalistic mechanisms
Sociology—Marx proposed that economic forces govern history.
Psychology—Freud proposed that psychic forces beyond our control govern our personalities.
Arts—absence of any stable reference points has been celebrated27

Because of these changes, many young people wonder if faith in God should be something fought for or just left to be interpreted in ever changing ways. Sean McDowell uses a simple illustration in teaching his students about the objective reality of faith in Christ. He places a jar of marbles in front of them and asks, "How many marbles are in the jar?" After some guesses he tells them the correct answer and asks, "Which of you is closest to being right?" They all agree on one of the guesses. Then he passes out Starburst candies and asks, "Which flavor is right?" They all recognize this as an unfair question. He affirms this and asks, "Are religious claims like the number of marbles in a jar or are they a matter of personal opinion, like preference for flavors of candy?" After this door is open he then explains that Christianity is based on objective fact. While many people reject the historical resurrection of Jesus, it is not the type of claim that can be "true for you but not true for me." He then proceeds to the objective Christian views of creation, nature of the triune God, nature of man, and authenticity of the Bible.28

Much foundational knowledge about the nature of God may be observed by scientific study or general revelation. Heie proposes a view of God's redemptive plan that includes not just individuals but the whole creation. This view gives Christian engineers a purpose for engineering beyond secular achievement. We are, in Heie's view "to be agents for knowledge, for greater understanding of all aspects of the created order, that we may live in proper relationship with that order."29 By establishing the moral requirement that engineering education focuses not just on the most profitable solution, there is room to instill a true foundation of ethical responsibility rather than an afterthought piled on for public image protection.

The Cumulative Case

There is a point however, when explaining the natural data in a common sense way leads to the need for additional (special) revelation like Scripture. If this transition is approached wisely, there arises a compelling cumulative case for the Christian worldview. It is suggested that it be presented in the following order:

1. Cosmological evidence—universe was caused by an agent with great power and intelligence.
2. Design evidence—fine-tuning and complex functionality suggest plan and purpose for humans.
3. The human condition—tension between positives and negatives raises important questions.
4. The need for additional revelation—the expectation of a remedy for the human condition.
5. The arena of religious traditions—which revelation is most consistent with previous data?
6. The evidence of miracles—Jesus’ resurrection solidly confirms our expectation of a remedy.
7. Making the truth believable—a devotional experiment to break the chains of habitual unbelief.
8. Religious experience—rational trail of evidence culminates in a genuine experience of God.30

Once the evidence (from science) for a Creator has been presented, a study of the positive and negative aspects of the human condition naturally leads to unanswered questions, and the need for additional revelation. This leads to a comparison of the evidence in support of various world religions and possibly inspired writings. Hopefully, the investigation culminates with a devotional experiment in which the seeker opens up to a personal relationship with the Creator.
Throughout the process of delivering truth the apologist must be sensitive to the reception, or good answers may fall on deaf ears. Paul, in reaching out to the skeptics of his day proceeded in a similar fashion:

1. Evidence from nature (Rom. 1:19-21)
2. Human condition (Rom. 1:23-25)
3. Relating to the religious traditions (Acts 17:3)
4. Made the truth believable and wrapped it in the language of the culture (Acts 17:22)
5. Special revelation

Besides his form of reasoning, Paul used great wisdom in relating to the people's common understanding. He talked of how some of the pagan poets called humans children of God. He also appealed to common sense and was therefore received to an extent by the greatest philosophers of the day. Similarly, Jesus was gentle and wise in his presentation. His method as identified by Heeren is as follows:

- Determine how far they are along their spiritual journey (Matt. 7: 6)
- Not “take-it-or-leave-it”; ask another question; make them think (Matt. 21:23-27)
- Give an answer but don't let them label you an extremist (Matt. 22:15-22)
- Broaden the issue to the more important one (Matt. 22: 23-33)
- Find common ground (Matt. 22: 31-32)
- As soon as they are ready point to Jesus for a decision (Matt. 22:41-46)

Apologetic Systems

Since the first century, Christian apologetics has been greatly refined to the point of entire methods of apologetics being studied and classified. Wayne House gives three basic types:

1. Classical apologetics (Natural Theology)
   - Step One: Arguments for undeniable first principles (laws of logic, self-existence, existence of truth, reality, meaning, morality)
   - Step Two: Traditional theistic arguments for existence of God (cosmological, teleological, ontological, and moral)
   - Step Three: Empirical and historical evidences for Christian truth claims (miracles; the life, death, and resurrection of Jesus Christ; truthfulness of Scripture)

2. Evidentialist apologetics
   - Step One: Use evidences to demonstrate God’s existence and the truth claims of Christianity
   - Nature of evidence: Historical, archaeological, rational, scientific, and experiential

3. Presuppositional Apologetics
   - Assumption: Assumes truth claims about God and Christ as revealed in Scripture
   - Procedure: Demonstrate that only Biblical presuppositions make sense of reality and attempt to show unbeliever that his or her presuppositions are irrational. Last of all reveal that only Christianity provides proper foundation for life and thought.

By carefully planning for the presentation of truth to a person's mind and emotions we are actually employing a discipline called systems engineering in which the whole is considered rather than isolated parts.

One benefit of systems engineering for the Christian apologist is that it gives a framework to analyze the value of belief systems. In this way skeptics may be witnessed to in stages. In *Mere Christianity*, C.S. Lewis shared the idea of modular belief systems. In other words, someone may have a worldview that is 90% wrong, but 10% right. Acknowledging this not only provides common ground for further discussion, but also requires that each element of the total worldview be examined individually. Then
the elements are reassembled into the whole so that the clearest picture may be obtained. Instead of force feeding a skeptic with the truth I have discovered, why not put each worldview to the systems test?

Kenneth Samples proposes nine tests for evaluation of various worldviews:

1. Coherence Test: Is a particular worldview logically consistent?
2. Balance Test: Is a worldview properly balanced between simplicity and complexity?
3. Explanatory Power and Scope Test: How well does a worldview explain the facts of reality ("power"), and how wide is the range of its explanation ("scope")?
4. Correspondence Test: Does a particular worldview correspond with well-established, empirical facts, and with a person's experiences in the world?
5. Verification Test: Can the central truth-claims of the worldview be verified or falsified?
6. Pragmatic Test: Does the worldview promote relevant, practical, and workable results?
7. Existential Test: Does the worldview address the internal needs of humanity?
8. Cumulative Test: Is the worldview supported by multiple lines of converging evidence that together add increasing support for its truth-claims and extend the breadth of its explanatory power?
9. Competitive Competence Test: Can the worldview successfully compete in the marketplace of ideas?

**Why Engineers Make Good Apologists**

After listing these criteria, Samples evaluates various worldview competitors to Christianity on the basis of these nine tests. In particular, Naturalism, Postmodernism, Pantheism, and Islam are evaluated. By studying the basic inconsistencies in each major worldview competitor, an apologist is able to refrain from becoming defensive or dogmatic. Patience is critical when expecting major shifts in thinking, and the Christian who knows why he or she believes what is true can be more understanding and flexible when immaturity is displayed by potential converts. The apostle Peter exhorts Christians to "...in your hearts set apart Christ as Lord. Always be prepared to give an answer to everyone who asks you to give the reason for the hope that you have. But do this with gentleness and respect," Christian engineers are particularly well equipped to give reasons to those who do not believe in Christ. They understand that engineers and scientists may require more than the average amount of evidence, and possibly from a broader range of sources to be convinced of any particular proposition.

Frezza and Caulfield further suggest that engineers generally share a set of beneficial traits (listed below) to understanding and defending the Christian faith. Several of these traits are also identified in Samuel Florman’s book on The Civilized Engineer.

1. Believe in scientific truth—truth that can be verified by experiment.
2. Understand that scientific truth is not enough, that there is a point where application of truth to human objectives comes into play.
3. Are at home in the world—share in the understanding of the extent to which the forces of nature have been comprehended, the structure of the universe revealed, and this brings some measurement of contentment.
4. Are humble before the unknown, and stand in awe of the unknowable.
5. Believe in hard work, demanding it of themselves and of all new engineers.
6. Pledged not to engage in just wishful thinking—e.g., that sermons and poetry alone are not an adequate foundation on which to build human society.
7. Prudent in the undertaking, yet willing to make decisions knowing that something may go wrong.
8. Learn from theirs, and other's experience, including an ability to learn through failure.
9. Willingness to accept responsibility.
After showing the extreme likelihood of God’s existence for a multitude of reasons, this apologetic of systems engineering may be further extended to learning about the nature of God through the natural world He created. Such questions as "How can God be all powerful and still give me free will?" may be addressed in exciting new ways. With the systems approach, one may deal with this question as a matter of partitioning viable systems. If the whole of creation is represented by a huge orchestra with God as the conductor, there is predetermined music to be played but each musician makes choices about the act of playing. While each musician playing separately may sound good, the whole orchestra must be coordinated for it to create beautiful music.

**Emergence**

This property of systems, that the whole is greater than the sum of its parts, is known as emergence. In this way worldviews like postmodernism with relative truth and situational ethics may be confronted on the grounds that without engineering and coordination, a system cannot possess emergence and thus fails to be the best it could be. If a person's worldview is considered to be an emergent system, coherence between different parts of the worldview are critical to the overall harmony and usefulness of that system. If a scientist or engineer believes in absolute truth when testing scientific theories but not in personal morality, there is an inconsistency that hinders emergence. Emergence is seen everywhere. A winning formula one race car cannot be made by taking the best parts from the ten fastest cars and putting them together. Good components are only part of the solution. Engineering those components to work together makes the difference. While few answers alone provide compelling explanations for hard questions like the existence of pain and suffering, the concept of emergence may be used to combine multiple answers from many fields into a cohesive worldview in line with the Creator's intentions.

This concept of divine engineering can open up potentially rich discussion with those who have no belief in God. Since the best human engineering produces emergent systems with finely-tuned components, what can we conclude about the exquisite engineering in natural systems that makes life possible? Simple tuning only requires feedback, time and technical knowledge, yet engineering requires creativity. The generation of a system that works together well is not simply a matter of time and chance but of well coordinated and creative ideas. An extended design argument may begin with cosmology and astronomical precision and progress to the bio-friendly environment of earth, the interplay of a multitude of simple biological systems or cells, and even the efficient and robust information content of the DNA codes.

**Questions and Definitions**

Once enough positive evidence has been presented it is quite appropriate to point out that various questions that are tough for faith to answer point to even tougher questions for those without faith. The following examples may prove useful:

- Genetic similarity to apes? (Uniqueness of Humans)
- Common Ancestry? (How life points to a purposeful Creator)
- Are humans destined for extinction? (Our creation for a relationship with God)

Throughout the process of dialog with skeptics it is helpful to remember some basic techniques such as the Socratic questions. These may be questions for any of the following purposes:

- For Clarification
- To Probe Assumptions
- To Probe Reasons and Evidence
- To Reveal Viewpoints and Perspectives
- To Probe Implications and Consequences
- To Better Understand the Questions
Apologist Greg Koukl provides excellent examples of good questions to ask in his article entitled “Tactics: Applying Apologetics to Everyday Life”. Besides these types of questions, it is essential to define terms to avoid misunderstandings. A common example of this is exactly what is meant by the term “evolution”. Is it simply the ability of living organisms to adapt to their environments over time, or is it a complete worldview entailing atheism, or more likely something in between. Misunderstandings are difficult enough to set straight when the parties are perfectly honest with each other. Unfortunately, this is often not the case. The dishonesty is not always intentional but often is simply inappropriately shifting the burden of proof through the use of logical and rhetorical fallacies. It should always be remembered that the goal is not to win an argument, but rather to assist all who are willing to come to knowledge of the truth.

The Value of Apologetics

John David Weaver wraps up his book, *In the Beginning: Modern Science and the Christian Doctrine of Creation*, with a chapter on apologetics where he writes,

> What we are seeking to do in the area of apologetics is two-fold: to meet people where they are in their search for answers to their own life; and to demonstrate the reasonableness of the Christian understanding of the world, so providing an environment where God is seen to be worthy of faith and trust.

The value of apologetics is not in its ability to save, since it has none, but rather as a kind of pre-evangelism tool. Philosopher Angus Menuge stresses this point below:

> Apologetics is best viewed as pre-evangelism. As John the Baptist prepared people for Christ, an apologist prepares the soil for the seed of the Gospel. Apologetics does not provide the seed, but it can remove some of the “thorns” which Jesus tells us include “the desire for other things,” (Mk. 4:18-19) or in other words, man-made substitutes for the true God. The apologist works to make himself redundant, clearing away the ideologies and objections which the natural man uses to reject the Gospel, before an evangelist proclaims it.

Indeed, in Jay Richards’ brief overview of the contemporary design argument, he cites the example of how the famous atheistic philosopher, Antony Flew, became converted to theism based on scientific evidence, such as the specified functional complexity of biological structures.

In addition, Christians should remember that attending to God’s general revelation will help to keep us in-tune with our Creator, as C. John Collins emphasizes in his book *Science and Faith; Friends or Foes?* where he writes,

> How shall we keep our hearts adoring our God?...By attending to the evidence God has given us...And a crucial part of this attending is mulling over the glory he has revealed in the natural world, and the supernatural design of which it speaks so clearly.

Clearly, the pursuit of science-based apologetics has much value for both believers and unbelievers. The engineering mindset is well-suited to this endeavor as described in recent papers on the applicability of engineering design principles for worldview formulation, and the coherence of an engineered world. It has been the experience of the authors that when the ideas discussed in this paper are made explicit in coursework for undergraduate engineering students at a Christian university, those students become better equipped and inspired to serve as missionaries to educated people groups, especially scientists and engineers.

Conclusions

Nature readily lends itself to our investigations (science) and improvements (engineering). Through these activities, it also teaches us some very fundamental things about the significance of mankind in
the universe. Thus, engineering students with a Christian worldview are in a position to play a key role in preparing the world for the truth of the Gospel. Contrary to recent, much publicized philosophies touting atheism as the logical conclusion of scientific studies, a thorough and open-minded investigation of both science and engineering suggests the influence of a caring and calculating intentionality; a transcendent engineer who’s precision and provision inspire a hope that all things can work together for good for those who are willing to submit to the Master’s designs.

References


[23] Isaiah 48:10 NIV


[25] Jude 1:3b NIV


[27] Dembski, p. 32


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Wider and Deeper Norms for Technology Design

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Abstract

The design norms proposed in the book *Responsible Technology* are based on Dooyeweerd’s categorization of the structure of reality into fifteen facets. This approach is continued in the further writings of several of the *Responsible Technology* authors including Schuurman and Van Poolen. The norms are celebrated, revisited, and revised by a variety of later authors, including Adams, Bradley, Ermer and VanderLeest, Newberry, Van Antwerp, Funk, and others. Following a survey of the literature on design norms, two difficulties are addressed, which result in widening and deepening the idea of norms for technology design. First, additional guides (virtues) are considered that have apparent ethical impact on design decisions. Because they do not fit nicely into the existing list of design norms, a wider approach is suggested. Second, although Herman Dooyeweerd was a thoroughly Christian philosopher and scholar, *Responsible Technology* does not explicitly link Biblical principles to the design norms it links with the top eight of Dooyeweerd’s aspects of reality. This paper makes a preliminary attempt to deepen the norms by connecting them more directly to scriptural values.

Introduction

Starting in the fall of 1983 with funding from the Calvin Center for Christian Scholarship, a team of six scholars and two students met for a year to think and write about technology. The authors included Cliff Christians, Eugene Dykema, Arie Leegwater, Stephen Monsma, Egbert Schuurman, and Lambert Van Poolen. The result was the seminal work, *Responsible Technology: A Christian Perspective* (hereafter referenced as *RT*). The book arrived during a spate of works extending before and afterwards that have fallen in a category we might label as “appropriate technology”. However, it was more: the authors attempted to place technology (and engineering, the discipline that designs and develops technology) firmly in a broader context with a faith foundation. Within this larger task, one of their significant contributions was the idea of technology design norms – guidelines for developing technology that honors God and aligns with His will. This was a bold move, claiming that one’s Christian faith should regulate not only personal behavior but should also impact technical design decisions.

In seeking an appropriate organizing theme for these guidelines, the authors turned to the Christian philosopher Herman Dooyeweerd. Although other systems of thought were available to help organize moral behavior, Dooyeweerd offered a system that was relatively complete and distinctive. His philosophy attempted to characterize the deep nature and structure of reality, dividing all existence into fifteen aspects. The authors of *RT* appropriated Dooyeweerd’s method, using the highest eight aspects to categorize moral principles of design for technology.

In this paper, I hope to continue the conversation about design norms by first reviewing the history of the norms proposed in *RT*, then presenting two areas related to the norms that provide opportunities to widen and deepen the approach.

Literature Review: A Brief History of the RT Design Norms

Dooyeweerd’s philosophical treatise exhibits several theme including the historical motifs of creation, fall, redemption; a strong emphasis in the sovereignty of God; and a recognition of the pervasiveness of sin. However, his most significant contribution for the purposes of this paper – his idea of the modal aspects – does not have a direct tie to scripture (though he did acknowledge that divine revelation provided the basis for his philosophical thought). Dooyeweerd identified fifteen modal aspects which describe the whole of reality. These can be found in the second volume of his massive work, *A New
**Critique of Theoretical Thought**. Within each modal aspect, Dooyeweerd identifies a domain, called a “law-sphere”, which provides norms for that aspect. Kalsbeek, a Dooyeweerd scholar, observed that each sphere is divided into two halves: “On the one side there is the law or norm which is peculiar to this modality; on the other side there is whatever is subject to this law or norm.” The list is sequential, with each modality leading to more complex modalities: arithmetic/numerical, spatial, motion/kinematic, energy, biotic, psychic/feeling/sensation, analytic/logic, historical/formative, semantics/lingual, social, economic, aesthetic, law/juridical, morality/ethical, faith/pistic. The later norms are not necessarily “better” than the earlier – Dooyeweerd was insistent that all of them operated and existed simultaneously.

Although *RT* based the design norms on Dooyeweerdian philosophy, little explanation is provided for this particular choice as an organizing structure for the design norms. The authors identify three guiding principles that should characterize their approach to norms: (1) the approach must have a wide scope (i.e., broader societal implications of a technological product must be considered), (2) the approach must make appropriate distinctions that recognize the diversity of creation, and (3) the norms must be integrated and “pursued simultaneously” so that “there is no conflict among its facets.” After setting out these criteria, *RT* considers no other alternative than Dooyeweerd, which is offered as “[a] helpful, compelling scheme for developing such a structure.” In turning to this philosopher, the authors recognize that all fifteen of Dooyeweerd’s aspects would be involved in technology design, but they limited the norms to the last eight because the first seven “by their very nature involve ‘laws’ or principles that cannot be broken. They are automatically obeyed by all persons.” The resulting design norms proposed to guide technology design are listed in Table 1, along with the corresponding Dooyeweerdian modal aspect. In one case, two of the aspects are combined into a single norm.

**Table 1: RT Design Norms**

<table>
<thead>
<tr>
<th>Design Norm</th>
<th>Modal Aspect</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cultural Appropriateness</td>
<td>Historical/Formative</td>
<td>Design honors and respects culture; is not overly intrusive</td>
</tr>
<tr>
<td>Open Communication</td>
<td>Semantics/Lingual</td>
<td>Design does not obscure value judgments used in decisions and does not hide important features that could affect safety</td>
</tr>
<tr>
<td></td>
<td>Social</td>
<td></td>
</tr>
<tr>
<td>Stewardship</td>
<td>Economic</td>
<td>Frugal use of resources; development that brings out and enriches created nature of materials</td>
</tr>
<tr>
<td>Delightful Harmony</td>
<td>Aesthetic</td>
<td>Form follows function so that design is a joy to use; design promotes harmonious relationships</td>
</tr>
<tr>
<td>Justice</td>
<td>Law/Juridical</td>
<td>Design gives humans and rest of creation what each are due; respect of all person and things</td>
</tr>
<tr>
<td>Caring</td>
<td>Morality/Ethical</td>
<td>Design provides loving service; safeguards well-being</td>
</tr>
<tr>
<td>Trust</td>
<td>Faith/Pistic</td>
<td>Design is dependable, but ultimate trust must be in God</td>
</tr>
</tbody>
</table>

After the book was completed, several of the authors continued to address the technology design norms in their individual work. Egbert Schuurman returned to the norms in several of his subsequent publications. For example, in *Faith and Hope in Technology*, he continued to use a list of norms that closely reflected those found in *RT*. He credits “reformational philosophy” rather than naming Dooyeweerd directly, though his terms more closely align with Dooyeweerd than any of the later writings of other *RT* authors.
For example, he uses the label “cultural-historic,” rather than “cultural appropriateness” and he keeps the “lingual” and “social” norms distinct, as did Dooyeweerd. Lambert Van Pooelen continued to use the list of norms with only small modifications from the book. RT based the norm of communication on Dooyeweerd’s lingual aspect and the norm of openness on his social aspect. RT then combined the two into a single norm called “open communication.” Similarly, Van Pooelen lists lingual/social as a single aspect based on his reading of Kalsbeek (a philosopher of Dooyeweerd) which he corresponds with a single design norm called “proper and open communication”\(^{10}\). He also clarifies and expands other norms, noting that stewardship is “of resources,” that harmony is between man and machine, that justice means “right-standing”, and that trust might better be termed “dependability”. Cliff Christians defended the use of ethical norms (using a more flexible list) in an address to librarians: “Refusing to confront normative issues on every level weakens the agenda of universal humanness. How can one legitimately appeal to the supreme value of human life, to an affirmation of unmitigated human dignity, without accepting a network of primal norms justice, compassion, reciprocity, stewardship that are nonnegotiable? Everything else comes and goes, both ideologies and the cultures they sustain. If temporality exhausts one’s intellectual vistas, wherein lies the possibility of justifying an ethics of human mutuality in the face of anarchy, dialecticism, or equivocation? Without norms that are more than contingent, one cannot finally condemn oppression and dehumanization except on the grounds of personal prejudice or emotional makeup. Absent a defensible conception of the good, praxis will be vitiated by arbitrariness. In fact, without a commitment to norms, an emancipator intention is radically jeopardized and the byproduct is moral agnosticism.”\(^{11}\) Christians thus maintains that the norms are foundational, giving us the anchor to make prudent ethical judgments even in the face of changing cultural seas. However, this then begs the question: which norms are appropriate? Christians provides a partial list: justice, compassion, reciprocity, stewardship. But what are the criteria by which these values are judged “primal”? Other authors have picked up on the idea of the design norms. For example, in a paper for ASEE\(^{12}\), Ermer and VanderLeest discussed using a set of design norms based on the list from RT as a tool for teaching engineering ethics, suggesting that the design norms could become additional criteria in a decision matrix to help sort out the trade-offs in choosing design alternatives and make the ethical dimensions more explicit. While using the same basic list of norms as suggested by RT, they took the liberty of renaming two: “transparency” rather than “open communication” and “integrity” rather than “delightful harmony”. Ermer followed up on this paper with a more detailed analysis of the Christian foundation of the norms in her 2002 CEEC paper\(^{13}\). Bradley\(^{14}\) adopted the eight design norms from RT for use by computer scientists\(^{15}\), although he doesn’t provide details about the nature of the adaptations. Adams notes the norm of delightful harmony in discussing the aesthetics of engineering design\(^{16}\) and later applies the entire set of norms as principles for an Office of Information Services.\(^{17}\) Eisenbarth and Van Truener mention the norms briefly in their exploration of engineering ethics.\(^{18}\) Newberry\(^{19}\) connects the norms to vocation. In their 2004 CEEC paper, Green, et. al., suggest using design norms as part of the selection process when choosing international humanitarian design projects.

Some authors have identified difficulties with the design norms. Van Antwerp raises a number of important concerns regarding use of the design norms in his 2006 CEEC paper\(^{20}\), exploring some practical difficulties with using them in actual designs. VanderLeest explored humility as an additional norm needed in technology design in a 2006 ASEE paper\(^{21}\). Funk considers the design norms\(^{22}\) and finds them lacking: “I find an organization of principles based on a biblical hierarchy of value to be more conducive to thinking Christianly about things. Moreover, in my view, Monsma, et al. omit the most important ones or only address them secondarily.”\(^{24}\) Instead, Funk identifies three intrinsic, prioritized goods: (1) communion with God (individually and communally), (2) human welfare (based in part on being created in image of God), and (3) natural world (including cultural mandate and stewardship). In reflecting on these proposed priorities, he notes that “Monsma, et al., RT, give inadequate emphasis to this principle [Principle 1], their principles focusing primarily on the two lower levels of the hierarchy of the good.”\(^{25}\)
Wider: Missing Norms?

Having reviewed the history of the RT norms and the relevant references in the literature, the remainder of the paper will now focus on two difficulties with the norms: (1) whether the RT list of norms is complete (discussed in this section) and (2) whether a more direct Biblical basis for the norms can be identified (discussed in the next section). On both issues, the intent of this paper is not so much to critique the norms as to expand and deepen them as worthy guidelines for design.

Engineers typically use a list of decision criteria when making design choices. So the list of norms that can also guide choices likely resonates with technology designers. But is the list complete? Are these the right norms? The authors of RT based their list on Dooyeweerd’s list of aspects of reality, each governed by its own law-sphere. However, Dooyeweerd himself thought that his list might not be conclusive, thus raising the question of whether other normative criteria might be considered: “In fact the system of the law-spheres designed by us can never lay claim to material completion. A more penetrating examination may at any time bring new modal aspects of reality to the light not yet perceived before. And the discovery of new law-spheres will always require a revision and further development of our modal analyses. Theoretical thought has never finished its task.” 26

The danger with proposing a supposedly complete list is that an engineer might then have a false sense of security that all relevant issues have been considered when making decisions about various design alternatives. In a sense RT anticipated this issue by looking for a norms approach that had a wide scope, that considered the broad societal implications of design decisions. Thus, if one can identify other norms that are relevant to technology design, this should raise concern, since it calls into question the completeness of the RT list.

One example of a “missing” norm proposed previously 27 is the virtue of humility. Engineers should design technology with a certain modesty, knowing that (as created beings) we are finite, and thus cannot predict all the ways our technology might be used or abused. We are also fallen. The effects of sin on our own design work must be recognized and limited whenever and wherever possible. Humility as a prescription for good engineering is not limited to our behavior towards others, but should impact our actual design decisions. For example, in recognition of our finiteness, humility about the efficaciousness of computers should lead one to design redundant systems for safety-critical applications, so that even if one part fails, the system can continue to operate. Humility about the dependability of automobile tires should lead one to provide tire changing tools as standard items in a vehicle. Examples of sin affecting design might be blatant (such as purposefully including a flaw in a design), but they might be less obvious. Negligence that leads to a design flaw might be due to our finiteness as humans, but also may be a reflection of our fallenness.

Humility is not the same as trust (which, as a technology design norm, is defined in terms of dependability by the RT authors). Depending on technology, i.e., trusting that it will not fail, in some ways is the opposite of humility. Humility on the part of the engineer recognizes that failure is possible and thus healthy skepticism of our models is warranted; humility on the part of the user recognizes that misunderstanding of technology is possible and thus caution is warranted. These are healthy deterrents to overdependence on technology. In fact, the RT authors broach on this issue, recognizing that our ultimate trust should be in God but at the same time arguing for dependable technology that users can trust.

If humility is important, if one finds it difficult to dismiss humility as applicable for engineers, if humility is a reasonable norm, then why does it not appear in Dooyeweerd’s catalog of reality aspects? Is this evidence of some missing pieces? Perhaps. Although RT provides scant justification for the completeness and connection between the proposed design norms, Dooyeweerd provides a rich description of the connections and a robust argument for the connections between each law-sphere – relationships he calls anticipation and retrocipation. For example, in describing the aesthetic aspect (which RT translated as “delightful harmony” with respect to technology), Dooyeweerd says “The nuclear
moment of the aesthetic aspect is harmony in its original sense, a modal meaning-moment found in all the other law spheres only in an unoriginal, retrocipatory or anticipatory function... Even on close examination of each Dooyeweerdian aspect, it is difficult to find a place for humility or for any of the other virtues, such as patience or kindness or diligence. These “missing” norms do not seem to be in the same domain as Dooyeweerd’s aspects — they are outside his system.

While thinking about this conundrum, I first considered whether Dooyeweerd’s aspects compared to the virtues might simply be two different coordinate axes of the ethical landscape. But this approach does not solve the problem because many of Dooyeweerd’s aspects do not seem to have a directional character, but are rather more of a structural description (further, they speak to more than ethical facets of reality). This is reminiscent of Wolter’s description of the creational structure of reality that remains even after the fall. Sin is directional in character, turning us away from God, even while this tug-of-war plays out on the underlying structure that remains true to its created origin. Perhaps we can read Dooyeweerd’s aspects as the structural and read virtues as the directional. Virtues point us toward God; vices point us away from God. With these mappings in mind, Wolter’s description of the directional struggle taking place in and for the structural takes on a new light: “When we use the distinction between structure and direction, we must always bring them together under the theme of ‘grace restores nature’. It is not enough simply to say that creational ordinances or structures hold for reality everywhere and that a religious conflict is at work in that reality. No, we must say that the religious conflict rages for the sake of the created structure. The everyday components of our lives – our family, our sexuality, our thinking, our emotions, our work – are the structural things that are involved and at stake in the pull of sin and grace. The directional battle does not take place on a spiritual plane above creaturely reality but rather occurs in and for the concrete reality of the earthly creation.”

Dooyeweerd identified the normative, directional aspect as distinct law-spheres, where each aspect had its own set of laws or norms. Dooyeweerd recognized that sin was defined in terms of direction (turning against God) on the plane of reality: “Sin, as the root of all evil, has no meaning or existence independent of the religious fullness of the Divine Law.”

Thus virtues and vices may be the ethical axis from God to sin that stretches across the landscape of reality described by Dooyeweerd. However, it is not clear how Dooyeweerd’s sphere sovereignty, which calls for a distinct set of norms for each aspect, holds because the virtues seem to apply in multiple aspects. For example, the virtues of generosity and moderation (along with the vices of greed and gluttony, respectively) both speak to the economic sphere and its associated norm of stewardship, but they could also apply for the norms of caring or justice. The virtues of humility, diligence, and patience all have impact on dependability (the norm of trust) but could also apply for the norm of cultural appropriateness.

I have argued for an expansion of the design norms, not by adding new aspects to Dooyeweerd’s regime, but by suggesting that virtues also guide technology design as an overlay of ethical (directional) dimensions on the structure of the aspects. Another possible expansion of the norms rises from the other seven aspects neglected by RT. Engineering design occurs within all fifteen aspects, not just the top eight that form the basis of the design norms from RT. The other seven were neglected because they related to laws that were inviolate. But is it really the case that these will be obeyed automatically, that we don’t have a choice? While it is true that once thrust into reality, the design will simultaneously obey all physical laws, it does not follow that the engineer fully understands all these laws and has designed the product accordingly. Thus the product might not meet its specifications or may violate a design norm because the engineer did not foresee some possible consequence of this confluence of the complex richness and diversity of physical reality imposed on the new technological product or perhaps the virtues of diligence, patience, and humility should have been used in greater measure. Furthermore, there are usually multiple methods of achieving specifications (as long as the system is not overly constrained). Each alternative obeys the same physical laws, but in different ways. That is, there are multiple means that achieve the same end. So while the engineer cannot choose to obey the law of gravity to a greater or lesser extent, the engineer might be able to anticipate and utilize particular physical constraints to
different degrees. In this sense, the engineer is wise to consider all of Dooyeweerd’s aspects, not only the last eight.

Of course, consideration of the lower aspects is a normal part of an engineering education and thus comes naturally to the technology designer. Putting them into the wider context of an ethical landscape is the call that is not as often heard. The virtues and the norms (both the lower “hard” norms and the higher “soft” norms) apply to the entire technology life cycle, though perhaps some are more important than others at certain stages. More broadly, they apply to our personal and professional lives, as illustrated conceptually in the figure below. A decision matrix can be used to make the trade-offs between various aspects of the design (or professional) decisions to honor the various requirements, business criteria, virtues, and norms. Of course judgment and prioritization are still vitally necessary.

![Diagram of Engineering Design Phases and Virtues](image)

**Figure 1**: Virtues and Norms Broadly Applied

**Deeper: Biblical Foundations for Norms**

A second difficulty with the *RT* norms is that although the design norms have a strong philosophical underpinning, it is more difficult to see their theological lineage. *RT* itself provides little Biblical basis for the norms, although there are a few scattered examples. The authors find some basis for the norm of cultural appropriateness in noting that culture is a gift from God and that the diversity of creation is reflected in the diversity of culture. They further define the norm in terms of “the will of God for that people.” The authors describe the meaning of the norm of stewardship as “proper respect [for] the objects and creatures God has created.” But despite these preliminary assertions, the lack of more substantial scriptural support probably flowed from the fact that Dooyeweerd, the foundation for the
norms, did not tie his philosophy overtly in a Biblical grounding. He recognized that the scriptures did not lead directly to his idea of aspects: “The relation existing between the law-spheres, indicated here as the relation between foundation and superstructure, is not explicitly mentioned by Divine Revelation, because this Revelation does not set forth a philosophical theory about the temporal structures, but aims at the religious pre-suppositions of the latter.” A Biblical foundation is important and useful to help us carry out design activities to the glory of God, as 1 Corinthians 10:31 calls us to do.

Regardless, it is important that we do not leave ethical considerations to the end of the design process. We cannot simply “add in” the ethics and norms, nor can we consider the societal impact after the fact. We ought to make Biblical considerations foundational – the design choices along the way to a final product should be influenced by faith-based principles. Because the end product is greater than the sum of its parts, in that it always has consequences (unintended) that go beyond the designed function of the device, we need to use broad theological guidance to better manage our technology. Thus, in this section I consider each of the RT design norms and attempt to forge a more direct Biblical basis for each. In doing so, I am not attempting to supersede philosophy with theology, but rather exploring how the two must provide a coherent explanation and guide for navigating technological waters using a consistent worldview compass. Neither am I attempting to provide evidence that the design norms are sufficient (indeed, I think certain virtues are needed to supplement the norms), but rather, that they are necessary because they are Biblically supported. One last caution is also in order. In order to avoid proof-texting (using narrowly selected passages out of context in order to prove a pre-conceived point), I have attempted to provide multiple Biblical references so that alignment of the norms with broad scriptural motifs can be perceived.

Cultural Appropriateness

RT translates the Dooyeweerdian historical/formative modal aspect into the design norm of “cultural appropriateness.” Although some consider this aspect of Dooyeweerd to be an outgrowth of the cultural mandate (e.g., Wolfe terms this sphere “will and cultural mandate”), RT chose to consider this sphere in terms of a set of five opposites. Although the connection to Dooyeweerd is not clear, this set of opposites is later reinforced by Schuurman. In this interpretation, normative design finds the proper balance between “continuity and discontinuity, differentiation and integration, centralization and decentralization, uniformity and pluriformity, and large scale and small scale.” Further, RT suggests that technicism (fanatical pursuit of technology in the name of progress for its own sake) tilts the scales towards discontinuity, integration, centralization, uniformity, and large scale. While this may be true, it is also the case that other considerations (including other design norms) may encourage the same “tilt.” For example, stewardship may persuade a designer towards the greater efficiencies provided by large scale, integrated production. Or consider that any new technology by definition represents a paradigm shift, which could be considered a discontinuity of sorts. While it is not obvious how balancing these sets of opposites necessarily leads to design appropriate to a culture, in addition, a naïve reading of this norm might discourage any kind of technological development, for fear of negatively changing a culture. However, this approach runs counter to the cultural mandate of Genesis 1:28 calling humankind to develop the creation, which presumably includes technological development. A better tactic might be using the idea of respect for our fellow human beings as image bearers of God, which has significant Biblical support, as a motivation for culturally appropriate decisions. However, RT reserves respect as the primary component of justice, a different design norm. Since Dooyeweerd himself suggested the cultural mandate as a basis for the historical/formative aspect, then perhaps the appropriate approach is to return to this focus as the foundation for this design norm. The mandate is found early in scripture – it is the first command that God gives to humans, the pinnacle and appointed steward of His creation:

*God blessed them and said to them, “Be fruitful and increase in number; fill the earth and subdue it. Rule over the fish of the sea and the birds of the air and over every living creature that moves on the ground.”*

Genesis 1:28
While humans have certainly been successful at fulfilling this directive literally by (over?) populating the earth, the command more broadly is to steward the creation by developing it, helping it to flourish, and importantly, by further unfolding the creation by the development of culture. Technology is certainly a part of that cultural creativity along with art, literature, music, government, and more. God calls us to be stewards of technology for his glory — and not stewards in a simple static sense, but in the mold of the servant who received five talents and multiplied it to ten. That is, we should encourage a flourishing creation through technological as well as other types of development.

Founding this design norm more firmly on the cultural mandate, we should not shy away from new technological products simply because they change our present culture because cultural flourishing is part of our calling. But at the same time, we would be wise to keep technology from becoming the heart of our culture in place of God. This norm ought to turn us in the direction of technologies that not only help us further our own culture but also help us share our various cultural traditions with others. For example, technologies that help us produce or enhance music, listen to music, or share music with others would all be examples of products that help us follow the cultural mandate.

Some might think that the Great Commission replaced the Cultural Mandate, narrowly interpreting it as a call to spread the gospel via baptism (only), but I believe the Cultural Mandate is still in effect, though perhaps subsidiary to the commission (or perhaps included in it implicitly as part of the broader call to “obey everything I have commanded you”). Regardless, the New Testament still recognizes cultural differences. Peter notes the international character of God’s call:

*Then Peter began to speak: “I now realize how true it is that God does not show favoritism but accepts those from every nation who fear him and do what is right.”*

Acts 10:34-35 (TNIV)

Paul reflects this thought in describing the created diversity which finds unity in Christ:

*...for all of you who were baptized into Christ have clothed yourselves with Christ. There is neither Jew nor Greek, slave nor free, male nor female, for you are all one in Christ Jesus. If you belong to Christ, then you are Abraham’s seed, and heirs according to the promise.*

Galatians 3:27-29

Finally, Paul goes on to recognize that we might best follow the Great Commission of spreading the gospel by recognizing the diversity that naturally results from the Cultural Mandate – just one aspect of the broader theme of God’s diverse creation.

*...I make myself a slave to everyone, to win as many as possible. To the Jews I became like a Jew, to win the Jews...To the weak I became weak, to win the weak. I have become all things to all men so that by all possible means I might save some. I do all this for the sake of the gospel, that I may share in its blessings.*

1 Corinthians 9:19-23

*Open Communication*

The design norm of “open communication” combines the semantics/linguistics aspect with the social aspect. However, it may be helpful to follow Schuurman and keep these separated, to emphasize the communication facet of technology in the semantics/linguistics realm and the relational facet in the social realm. Regardless, open communication implies truthfulness, which certainly has broad scriptural support. Truthfulness is expected of God’s people in the Old Testament:

*The LORD detests lying lips, but he delights in men who are truthful.*

Proverbs 12:22

*A truthful witness does not deceive, but a false witness pours out lies.*

Proverbs 14:5
The call for truth in our communication also appears in the New Testament:

“... You have not lied to men but to God.” When Ananias heard this, he fell down and died.
Acts 5:4-5

Do not lie to each other, since you have taken off your old self with its practices and have put on the new self, which is being renewed in knowledge in the image of its Creator.
Colossians 3:9-10

Stewardship
In the economic modal aspect, Dooyeweerd identifies frugality, the “awareness that an excessive or wasteful satisfaction of a particular need at the expense of other more urgent needs is uneconomical.”

RT then translates this aspect as the norm of stewardship, which calls us to care for the creation. For example, consider this precept from the Old Testament to wisely choose the trees used for wood in laying a siege:

When you lay siege to a city for a long time, fighting against it to capture it, do not destroy its trees by putting an ax to them, because you can eat their fruit. Do not cut them down. Are the trees of the field people, that you should besiege them? However, you may cut down trees that you know are not fruit trees and use them to build siege works until the city at war with you falls.
Deuteronomy 20:19-20

Humanity is put in charge of the creation as a steward and caretaker, entrusted with the Creator’s work:

The LORD God took the man and put him in the Garden of Eden to work it and take care of it.
Genesis 2:15

You made him ruler over the works of your hands; you put everything under his feet...
Psalm 8:3-6

The thrust of these verses allows for prudent use of creation’s resources, but not gluttonous abuse that is wasteful or wanton.

Delightful Harmony
RT translates the aesthetic aspect into the design norm of “delightful harmony”. The RT authors claim this norm calls for technology that promotes “harmonious relationships”, though this seems more apropos to the social aspect. This norm also encourages technology whose form follows its function. This is in keeping with the Scriptural view of beauty, which often decries beauty that hides internal moral weakness:

Like a gold ring in a pig’s snout is a beautiful woman who shows no discretion.
Proverbs 11:22

Woe to you, teachers of the law and Pharisees, you hypocrites! You are like whitewashed tombs, which look beautiful on the outside but on the inside are full of dead men's bones and everything unclean.
Matthew 23:27

Your beauty should not come from outward adornment...
1 Peter 3:3

We can thus draw the conclusion that designs should not be “prettied up” with merely cosmetic, surface decoration. Rather, the choice of materials and shape should come through in an aesthetic way.
Justice
Justice is certainly one of the most frequently mentioned principles in the Bible, behind perhaps only love and mercy. Interestingly, few Biblical passages provide any definition of justice, assuming that the reader understands implicitly what justice means and requires:

\[He\ \text{has showed you, O man, what is good. And what does the LORD require of you? To act justly and to love mercy and to walk humbly with your God.}\]
Micah 6:8

\[Blessed \ are \ they \ who \ maintain \ justice, \ who \ constantly \ do \ what \ is \ right.\]
Psalm 106:3

\[Evil \ men \ do \ not \ understand \ justice, \ but \ those \ who \ seek \ the \ LORD \ understand \ it \ fully.\]
Proverbs 28:5

One can find a few references that provide a short explanation of the causes of justice, for example:

\[Do \ not \ pervert \ justice; \ do \ not \ show \ partiality \ to \ the \ poor \ or \ favoritism \ to \ the \ great, \ but \ judge \ your \ neighbor \ fairly.\]
Leviticus 19:15

\[Take \ your \ evil \ deeds \ out \ of \ my \ sight! \ Stop \ doing \ wrong, \ learn \ to \ do \ right! \ Seek \ justice, \ encourage \ the \ oppressed. \ Defend \ the \ cause \ of \ the \ fatherless, \ plead \ the \ case \ of \ the \ widow.\]
Isaiah 1:16-17

\[The \ wages \ you \ failed \ to \ pay \ the \ workmen \ who \ mowed \ your \ fields \ are \ crying \ out \ against \ you. \ The \ cries \ of \ the \ harvesters \ have \ reached \ the \ ears \ of \ the \ Lord \ Almighty.\]
James 5:4

The RT authors define justice primarily as giving each his due and paying proper respect, but is this sufficient to fully describe the retributive and distributive justice that is demanded of God’s people in His Word? For example, Laurendeau laments that Christians often “do not understand that technical solutions routinely help the rich get richer, and that such solutions often strain any focus on distributive justice or human flourishing. In other words, Christians must still be taught that technology can easily be an instrument of social power and that it can never be a substitute for the hard work required to create a more just world.”

Caring
RT translated the Dooyeweerdian moral/ethical modal aspect as caring. Although love is described as the underlying foundation that binds the norms together, this particular norm of compassion most clearly demonstrates love. Dooyeweerd notes this connection: “Then the standard of the moral good can only be a modal temporal refraction of the central commandment of Love as the religious meaning-totality of the whole temporal coherence of the will…” Among many scriptural references to caring, two example where we can find the norm of caring in the call to compassion are in the story of the Good Samaritan and in the second half of Jesus’ summary of the law:

\[“He \ went \ to \ him \ and \ bandaged \ his \ wounds, \ pouring \ on \ oil \ and \ wine. \ Then \ he \ put \ the \ man \ on \ his \ own \ donkey, \ took \ him \ to \ an \ inn \ and \ took \ care \ of \ him... \ Which \ of \ these \ three \ do \ you \ think \ was \ a \ neighbor \ to \ the \ man \ who \ fell \ into \ the \ hands \ of \ robbers?” \ The \ expert \ in \ the \ law \ replied, \ “The \ one \ who \ had \ mercy \ on \ him.” \ Jesus \ told \ him, \ “Go \ and \ do \ likewise.”\]
Luke 10: 34-37

\[And \ the \ second \ is \ like \ it: \ “Love \ your \ neighbor \ as \ yourself.”\]
Matthew 22:38
Trust

The pistic modal aspect (derived from a Greek word for deep seated faith) refers to the foundational commitments we hold. *RT* renders this faith aspect into the design norm of trust, identifying two components: reliance on God and placing our faith in Him as our ultimate source of strength (rather than technology or other human sources); secondly, the call to design technology that is dependable (technology that one can trust). The first component is a straight-forward application of the Dooyeweerdian modal aspect and one which obviously has strong Biblical support. Here is just one example that praises trust in the Almighty as opposed to trust in technology:

Some trust in chariots and some in horses, but we trust in the name of the LORD our God.
Psalm 20:7

The second component named by *RT* is harder to connect to these ultimate faith commitments. It seems that highly dependable technology might actually draw one’s trust away from God if one’s own gadgets are consistently reliable. Dependability in our technology seems more related to the designer’s integrity or perhaps as a call to do one’s best and pursue excellence in design to the glory of God. If any of the norms or aspects are implicated in the dependability of technology (or lack thereof), it appears that justice is the more suitable guide. Justice holds the designer at least partially responsible for their work. Justice calls for the engineer to be accountable for the foreseeable consequences of their designs. Here are two scriptural passages that emphasize this accountability:

When you build a new house, make a parapet around your roof so that you may not bring the guilt of bloodshed on your house if someone falls from the roof.
Deuteronomy 22:8

If a man uncovers a pit or digs one and fails to cover it and an ox or a donkey falls into it, the owner of the pit must pay for the loss; he must pay its owner, and the dead animal will be his.
Exodus 21:33-34

In each verse, one must take into account the future harm that one’s actions might bring to another.

The story of Uzziah in 2 Chronicles 26 provides a case study of the two kinds of trust. Uzziah has God’s favor even while amassing material goods, technology, and property, but loses that favor at the moment he becomes proudful. It seems that trusting in technology is acceptable as long as it does not take the place of God nor becomes more important than God. When we take credit for the benefits of technology and become personally proud of accomplishments achieved via “our” technology, we have placed ourselves, through the proxy of technology, on the throne ahead of God.

Conclusions

In recognition of God’s sovereignty over all creation, Christian engineers who seek to integrate their faith into all aspects of their lives must give careful consideration to how faith guides technology design. The *RT* design norms have been proposed as a helpful set of guides in this task. In this paper, I have attempted to trace the history of the design norms in the literature. Furthermore, I have addressed two opportunities to build on the idea of the norms. First, there are additional ethical considerations that apparently do not fit within the original design norms list. Virtues such as humility provide a hint of more complex approaches that broaden the “structural” norms with “directional” influences on technology design decisions. Second, the norms are based primarily on philosophy rather than theology. In response, I explored some Biblical underpinnings to deepen each of the norms.

Acknowledgements

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4 Monsma, p. 66.

5 Monsma, p. 69.

6 Monsma, p. 70.


8 Schuurman, p. 195.


10 Van Poolen, p. 323.


15 Bradley, p. 117.


24 Funk, p. 203 (footnote).
25 Funk, p. 203 (footnote).
26 Dooyeweerd, p. 556.
28 Dooyeweerd, p. 128.
30 Wolters, p. 88.
31 Dooyeweerd, p. 35.
32 Monsma, p. 172.
33 Monsma, p. 174.
34 Dooyeweerd, p. 53.
38 Monsma, p. 71.
39 Dooyeweerd, p. 246.
40 All scripture quotations are from the New International Version except where noted.
41 Dooyeweerd, p. 66.
42 Monsma, p. 175.
44 Laurendeau, p. 198.
45 Dooyeweerd, p. 146.
The Person and Work of the Holy Spirit in Engineering

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The Holy Spirit is given to individual Christians and to the Church as a whole. The Holy Spirit also operates independently in the world. The Holy Spirit is living and active in the discipline and practice of engineering in the same ways that He is in the rest of Creation and human lives and institutions.

Introduction

This paper is divided into three sections. The first outlines several different theological perspectives on the person and role of the Holy Spirit and examines how those views might shape an engineer’s work and practice. Secondly, the paper examines the role of the Holy Spirit in the professional life of a Christian engineer. The third section offers some practical suggestions for being a Spirit-filled Christian in teaching, research, and practice.

1. Some Theological Perspectives on the Holy Spirit

One’s theology of the Holy Spirit will influence how one would look for the Holy Spirit to work in the world. For instance, Ulrich Zwingli (1484–1531) taught that prayer and the presence of the Spirit were necessary to properly interpret the Scriptures. One could conclude that if Zwingli held this view of God’s special revelation (i.e., Scripture), he might also have held this view on general revelation (i.e., the created universe); in other words, fully or properly understanding the universe requires “consult[ing] the mind of the Spirit of God.” Thus, the deepest scientific or engineering insights come from those who are most in harmony with the Spirit. (This would be in contrast to Martin Luther, for instance, who taught “that the Holy Spirit is channeled to the believer exclusively through the sacramental structures of the church.”) Luther and Zwingli would then be expected to have differing views on how the Holy Spirit might inspire the Christian engineer.

The purpose of this paper is to examine how the Holy Spirit interacts with the discipline of engineering. A full survey of the theology of the Holy Spirit is beyond the scope of this paper. The interested reader will look to the references at the end of this paper and the citations to other works contained therein. Instead, this paper presents brief descriptions of three modern theologians from the Eastern Orthodox, Roman Catholic, and Protestant traditions. These three are not meant to be “representative” as there is considerable variation and overlap within those three groups, nor are these brief descriptions meant to be complete. The focus will thus be on the extrapolation of these three theologians’ actual work to what they might have said about engineering.

John Zizioulas (1931-) is the Eastern Orthodox metropolitan (bishop) of Pergamon and chairman of the Academy of Athens. His theology is permeated with the view that the church is koinonia, a communion. For him, “the church is ‘instituted’ by Christ, and ‘constituted’ by the Spirit.” This means that the local church is the “primary entity” for ministry. “The life and ministry of the body of Christ is conceived pneumatologically, in terms of the gifts of the Spirit. Be it a question of the ordination or of the role of the laity, the proper context is the koinonia of the Spirit among the members of the body of Christ. The charismatic life constitutes, rather than being derived from, the church’s being.”

For Zizioulas, the Christian engineer would be entirely acting out of the basis of her or his koinonia. One would expect more holistic, grounded designs that focus on service to society.
The designs would be of a more ‘humble’ nature. Process would be valued. Zizioulas’s engineer would value the design norm of open communication in the design process.

Karl Rahner (1904-1984) was a German Roman Catholic theologian. He taught that humans were naturally oriented to inquire about the nature of God and that God revealed himself to each person in a personal, “transcendental” manner. The act of revealing (grace) is the Holy Spirit inside each person. “God … has already communicated himself in his Holy Spirit always and everywhere and to every person as the innermost center of his existence.” Rahner went on to say that other religions, other transcendental experiences were equally valid encounters with God and could lead people to become “anonymous Christians.” For Rahner, as for Zizioulas, the church was where the Spirit was, not vice-versa, and thus the Church was larger than the “official” organization (due to the presence of “anonymous Christians”). In fact, he called it an “open system.”

This view motivates a Christian engineer to “tread lightly” with other peoples and cultures. For Rahner, “genuine human transcendence in love is possible only because of the gracious self-communication of God in the Spirit.” If God is in everyone (c.f., Mt 25:40-45) the engineer will design products that respect human dignity, promote safety, and serve society well.

Jürgen Moltmann (1926-) is a German Protestant theologian. He sees the Spirit of God as the Spirit of Life and Creation in the most holistic way. He writes that “experience of the life-giving Spirit in the faith of the heart and in the sociality of love leads of itself beyond the limits of the church to the rediscovery of the same Spirit in nature, in plants, in animals, and in the ecosystems of the earth.” Moltmann extends the notion of the communion of the Spirit beyond individual humans to include everything from human social units to elementary particles of matter. Moltmann is concerned with issues of social justice as well as holistic environmentalism: “if charismata are not given to us so that we can flee from this world into a world of religious dreams, but if they are intended to witness to the liberating lordship of Christ in this world’s conflicts, then the charismatic movement must not become a non-political religion, let alone a depoliticized one.”

For an engineer following Moltmann’s thinking stewardship and social justice are prime concerns. He writes, “So the people who truly affirm and love life take up the struggle against violence and injustice. They refuse to get used to it.”

2. The Holy Spirit as the Counselor

Jesus said that the Holy Spirit, the spirit of truth (John 14:17), would lead Christians into all truth (John 14:26), and that includes engineering truth. There are several ways that the Counselor can assist engineers.

Inspiration

Engineering is a creative endeavor, a fusion of science and technique. Humans are made in the image of God and one key way that we manifest our imago Dei is when we “sub-create.” Exercising our creativity is something humans were created to do, and we will do our best work when we are in a right relationship with God (another purpose for our creation). In Classical literature the Muses were invoked for inspiration. The primal idea that inspiration is a Divine gift is a result of human apprehension of God’s law (Rom 1:20-23). This inspiration (literally, to have the Spirit come into oneself) is something that every Christian may (and ought to) pray for. Personally, when I have prayed for inspiration on a project I have achieved results that surpassed my expectations (Eph 3:20).
Knowledge
Knowledge, skill, ability, and understanding (Job 32:8, Prov. 1:23) are all gifts from God, and those gifts come to us by the Holy Spirit. Exodus 35:30-36:5 tells how Bezalel and Oholiab were filled with “skill to do all kinds of work as craftsmen, designers,” etc. This gifting is evident throughout engineering history. For example, in 1938 Roy J. Plunkett apprehended that his sample of tetrafluoroethylene gas had polymerized. Further, he realized that the new material had useful properties. Given the subsequent usefulness of Teflon in many diverse applications, its discovery was providential. The ability to recognize the new polymer and the recognition of its potential usefulness were both God given gifts.

Guidance
The Holy Spirit is given to Christians also as a guide for our practical decision making. The Holy Spirit showed Paul where to travel on his missionary journeys (e.g., Acts 15:6-10; 21:10-14), and told both Philip and Peter where to go (Acts 8:26-30; 10:19-20). The Holy Spirit continues to provide practical guidance for Christians today (e.g., God Guides). For engineers, this guidance is available to us in our professional as well as our personal lives. Critical to this guidance are openness in prayer and a sense of mission and calling in our profession.

Wisdom
In the Old and New Testaments (Prov. 8:22-31, James 1:5) there is a close association between Wisdom and the Holy Spirit. Engineers need wisdom for deciding trade-offs in the design process (e.g., balancing human factors, environmental, and technical issues), navigating ethical/moral dilemmas, and deciding “big-picture” issues, like the place of technology in society. Past CEEC papers have addressed the normative nature of technical design and concluded that applying design norms takes wisdom.

3. Be Practical, Be an Engineer

It is not enough to know about the Holy Spirit, our Counselor, the bringer of gifts, the Spirit of life, the Spirit of fellowship; we must also know the Spirit personally, for he is a person, not a force.

“We have, as a Christian family, frequently relegated our understanding of the spirit and the Holy Spirit to a locked cabinet labeled, ‘Correct Doctrine.’ We know they are there, but we never feel compelled to bring them out. Yet the Epistle of James tells us that if our faith is simply an agreement of the mind, it is not a living faith [James 2:19]. It is not enough, in other words, to have correct doctrine – to say, for example, that we believe the Apostles’ and Nicene creeds in an intellectual sense. Nor should we use doctrine to place ourselves above others whose understanding is not complete. No, our glimpse into the wonders of the Triune God, and the Incarnation, should do more than feed our brains, or make us feel good about ourselves – it should change us!”

For the engineer who wishes to know the Spirit I say ‘pray.’ Prayer is our communication with the Holy Spirit (Rom. 8:26). Effective prayer depends on three factors. The first is being saturated in the Scripture. Those who have true communion with God are immersed in His word. Memorization, daily reading of Scripture, and psalmistry/hymnody have written God’s words on these saints’ hearts (Jer. 31:33). The second key to effective prayer is repentance, obedience, and righteousness. The epistle of James tells us the prayer of a righteous person is powerful and effective (James 5:16). For a person to be “righteous” involves not only following the strictures of God’s word (His commandments), although this is necessary, but also the further steps of obeying the inner promptings of the Spirit (part of the process of learning to recognize His voice – John 10:1-5,27) and repenting of our sins, both personal and corporate (Dan 9:1-20).
The third key to effective prayer is to pray for the right thing. God moves in the world when we pray in concert with His will. For the engineer this means knowing what God wants you to do with your engineering (and to some extent, why he wants us to be working on that). This allows us to pray for our work effectively. If Jesus were to walk into my lab or classroom, I wouldn’t have to explain to him what I’m doing or why. When I pray (privately at least) I can pray about all the technical details.

Discerning God’s will is a topic beyond the scope of this paper, although there are many excellent resources elsewhere. However, I will offer this caution in closing:

“We may feel spiritual, but we need to watch the checks and balances that have been given to us – the story of Scripture, the witness of the Church through the ages, and the voice of the entire communion today.”

References
Engineering as Mission
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Abstract
The world mission of the church is a theme that runs through the entire Bible. In Genesis 12:3 God tells Abraham that through his faith “all the families of the earth will be blessed.” Jesus’ last words in Acts 1:8 say that we will be his witnesses “to the ends of the earth.” What does this mean for the Christian engineer?

As practical people, engineers have used their engineering skills as a missions tool. However, most of the publications about this topic do not fully develop the concept of engineering as mission. This paper will take a broader perspective and examine the mission of the church, a Christian foundation for engineering and how they both impact engineering as mission.

Instead of detailing particular engineering projects, the goal of this paper is to examine the various types of missional activities in which an engineer could engage. Emphasis will be on what Christian engineers can do to help advance the gospel message in cultures where there is either no church, a financially poor church, or a weak church. This would frequently be in other countries, but there are also some cultural groups within the United States that would fit into this situation.

Introduction
Engineering as mission can be done by some engineers as a full time career. However, for most it will be done part time as a volunteer with a non-profit group. This paper will look at the theological and practical aspects of the following approaches to engineering missions.

1. Helping poor people better their lives. This provides a direct blessing to others. This is often done by engineers working with secular organizations in other countries.

2. Using engineering projects as a way to build credibility with the people we are helping. They see what Christ can do in us (as they see us volunteering our time and talents) and it makes the faith seem more reasonable.

3. Using engineering projects to build credibility and openness with governmental officials. Western engineers are welcome to go to many countries where professional missionaries are not allowed. By our example, and by our low key witness, people can be shown the reality of Christianity.

4. Using engineering projects to build up the local church. For example, helping local faith communities build businesses that use some of the technology we help them develop. The local church is seen as a source of economic as well as spiritual development.

This author wishes to make a distinction between engineering as mission and the mission of engineering. Many Christian engineers are called to engineering as a profession and spend their professional lives working in corporations. They should show the light of the gospel message to all with whom they work. This is something worthwhile, and may be what most Christian engineers actually do. This paper examines engineering as mission, with an emphasis on how Christian engineers can promote the world mission of the church. It will examine how Christian engineers can work in cultures where there is not a strong church.
The Mission of the Church

In order to understand the mission of the church we need to look at the perspective given to us in the Bible. Many people see missions as something added at the end of the Gospels. However, the story of missions begins in the book of Genesis. The call of Abraham is described in Genesis 12:1-3:

> Now the LORD said to Abram,  
> “Go forth from your country,  
> And from your relatives  
> And from your father’s house,  
> To the land which I will show you;  
> And I will make you a great nation,  
> And I will bless you,  
> And make your name great;  
> And so you shall be a blessing;  
> And I will bless those who bless you,  
> And the one who curses you I will curse.  
> And in you all the families of the earth will be blessed.”

God is going to bless the entire world through the spiritual descendants of Abraham. Speaking at Urbana 76 John Stott writes about this last phrase in Genesis 12:3:

> It is this expression more than any other which reveals the living God of the Bible to be a missionary God. It is this expression too which condemns all of our petty parochialism and narrow nationalism, our racial pride (whether white or black), our condescending paternalism and arrogant imperialism. How dare we adopt a hostile or scornful or even indifferent attitude to any person of another color or culture if our God is the God of “all the families of the earth”? We need to become global Christians with a global vision, for we have a global God.

The concept of missions is continued in the Psalms. There are many examples that could be chosen, but Psalm 96 is a good illustration of God’s interest in the entire world.

1 Sing to the LORD a new song;  
   sing to the LORD, all the earth.  
2 Sing to the LORD, praise his name;  
   proclaim his salvation day after day.  
3 Declare his glory among the nations,  
   his marvelous deeds among all peoples.  
4 For great is the LORD and most worthy of praise;  
   he is to be feared above all gods.  
5 For all the gods of the nations are idols,  
   but the LORD made the heavens.  
6 Splendor and majesty are before him;  
   strength and glory are in his sanctuary.  
7 Ascribe to the LORD, O families of nations,  
   ascribe to the LORD glory and strength.  
8 Ascribe to the LORD the glory due his name;  
   bring an offering and come into his courts.  
9 Worship the LORD in the splendor of his holiness;  
   tremble before him, all the earth.
Jesus reiterated the need to go into the entire world. Probably the most well known version is given in Matthew 28:18-20:

18 Then Jesus came to them and said, “All authority in heaven and on earth has been given to me. Therefore go and make disciples of all nations, baptizing them in the name of the Father and of the Son and of the Holy Spirit, and teaching them to obey everything I have commanded you. And surely I am with you always, to the very end of the age.”

Many people have read this passage and concluded that the missionary task is essentially done since there are now churches in every nation on earth. However, it should be noted that the Greek word translated nations (εθνε) does not mean political nation states as we think today. It more properly refers to people groups. John Piper writes about this passage:

“there is no good reason for construing this to mean anything other than that the missionary task of the church is to press on to all the unreached peoples until the Lord comes. Jesus commands it and he assures us that it will be done before he comes again.”

A people group is a group that has a self identification as to which people are outside the group and who is inside the group. Often this is based on a different language. Even groups using the same language can be different people groups if their cultures/lifestyles are different enough that they do not want to associate with each other nor learn from each other.

An unreached people group is one where there is no viable church within it. The people cannot hear the gospel message from someone who is part of their group, but must hear the gospel from someone from outside who goes into that group to share the gospel.

Approximately 1/3 of the people in the world live in the approximately 10,000 unreached people groups. A high percentage of these people groups are also poor people. For the most part these are groups that could tremendously benefit by Christian engineers working among them to help them physically and spiritually.

There are two big changes in the missions movement in the last 50 years that should be noted. The first one is that missions is not just a western phenomenon. There are now more missionaries coming from the non-Western world than from the Western world. Larry Keyes has estimated that in 2000 there were 164,000 non-Western missionaries working around the world compared to 132,000 missionaries from Western countries. This leads to the second big change. Western engineering missionaries need to be willing to work with (and work under) Christians from the developing countries. We need to go to other countries offering to help them meet their needs. We should not go in with preconceived notions of solutions we think they need.

Engineering as mission is in many ways not a new concept. A holistic approach to missions is seen in the life of William Carey, often regarded as the father of the modern missions movement. He went to India in 1793. Carey did many other things in addition to preaching the gospel. He translated the Bible into several languages. Carey fought for social justice (seeking to outlaw the practice of having widows burned on their husband’s funeral pyre). He was a remarkable botanist (using science as mission). He created newspapers and a publishing house. He printed many Christian materials, but also materials that were part of the Indian cultural heritage. When modern engineers do engineering as mission, they are only following in Carey’s footsteps.

The Nature of Engineering
To understand engineering as mission, we need to understand the basic nature of both missions and engineering. We will now turn our discussion to engineering.
Engineering is in many ways harder to describe than is science, and apparently fewer people have attempted to do so. The following section is adapted from the definition we used in our 2002 CEEC paper.

Creating a definition of engineering is not simple. There are some activities that are clearly the practice of engineering. There are some activities that are clearly not the practice of engineering. There are many activities in which it is not clear whether or not engineering is being performed. There are many written definitions of science and the scientific method, but fewer attempts have been made to define engineering. We are indebted to the careful thinking on the nature of engineering that has been done by Dr. Billy Koen of the University of Texas. His definition of the engineering methods is “the strategy for causing the best change in a poorly understood or uncertain situation within the available resources and the use of heuristics.”

Koen’s definition deals with several key points involved with engineering. One key point is that engineers must use the available resources to solve problems. Another one is that the facts of a given situation may be poorly understood. However, we believe that his definition is too broad. For example his definition could, in many situations, apply to Christian ministry. Many pastors are trying to solve problems with available resources in situations that are poorly understood. We have therefore created our own definition of engineering:

“The application of science and human experience to solve problems faced by people. This is often done in poorly understood or uncertain situations, using the available resources.”

Our definition includes an explicit reference to science, as well as human experience. The human experience part is important, for in many situations we may know what works, but not yet understand why something works.

A Christian Foundation for Engineering

Modern engineering, with its significant scientific base, did not exist during the time of the Bible’s writing. A type of engineering, empirically based on practical experience, did exist in some cultures. Examples of such engineering work include the Great Pyramids at Giza and ancient Roman aqueducts.

We therefore need to infer a Biblical approach to engineering practice from what the Bible has to say about certain other topics, such as building, work, and excellence in work. We have written about this in two previous papers and are expanding upon it in this paper.

Building things is praised in the Bible. An example of this is in the building of the ark of the covenant. It is written in Exodus 31:1-7.

Then the LORD said to Moses, “See, I have chosen Bezalel son of Uri, the son of Hur, of the tribe of Judah, and I have filled him with the Spirit of God, with skill, ability and knowledge in all kinds of crafts—to make artistic designs for work in gold, silver and bronze, to cut and set stones, to work in wood, and to engage in all kinds of craftsmanship. Moreover, I have appointed Oholiab son of Ahisamach, of the tribe of Dan, to help him. Also I have given skill to all the craftsmen to make everything I have commanded you: the Tent of Meeting, the ark of the Testimony with the atonement cover on it, and all the other furnishings of the tent.

It appears from this Exodus passage that the interest and skill in doing this work was a gift from God. Similarly, our interest in engineering, and our ability to solve engineering problems are gifts from God. This does not mean that hard work is not required for us to able to use our skills
to their fullest potential. The competent practice of engineering is hard work. However, we do need to recognize that our engineering interests and abilities come from God.

While God commends building and creating, we need to recognize that what we build is not going to last forever. This is pointed out in Ecclesiastes 2:4-6, 10-11, where the teacher states:

4 I undertook great projects: I built houses for myself and planted vineyards. 5 I made gardens and parks and planted all kinds of fruit trees in them. 6 I made reservoirs to water groves of flourishing trees. 7 I bought male and female slaves and had other slaves who were born in my house. I also owned more herds and flocks than anyone in Jerusalem before me. 8 I amassed silver and gold for myself, and the treasure of kings and provinces. I acquired men and women singers, and a harem as well—the delights of the heart of man. 9 I became greater by far than anyone in Jerusalem before me. In all this my wisdom stayed with me.
10 I denied myself nothing my eyes desired; I refused my heart no pleasure. My heart took delight in all my work, and this was the reward for all my labor.
11 Yet when I surveyed all that my hands had done and what I had toiled to achieve, everything was meaningless, a chasing after the wind; nothing was gained under the sun.

Fortunately the above quotation is not a final statement about building. However, it makes the point, that if all we care about are the things we create, we will inevitably be disappointed. This does not mean that building great structures is bad, only that such actions cannot completely satisfy your life.

While we work, we need to do what we can while we can. Our current world, and our personal lives will not last forever, and we need to accomplish all we can in the limited time we have. Paul makes this point in Ephesians 5:15-16:

15 Be very careful, then, how you live—not as unwise but as wise, making the most of every opportunity, because the days are evil.
16 We do not have unlimited time, so we need to be wise in how we choose to use it. We also need to strive for excellence, even if no one is watching. Paul makes this point in Col 3:23:

23 Whatever you do, work at it with all your heart, as working for the Lord, not for men,

These two passages make the point that all of our work has God for an audience. Even if no one else appears to be watching, God is. It is therefore God’s opinion about our work that really matters. Guinness refers to this as working for an “audience of one”. Guinness writes:

"When asked why he was not stung by a vicious attack from a fellow Member of Parliament, Winston Churchill replied: “If I respected him, I would care about his opinion. But I don’t, so I don’t.” Similarly we who live before the Audience of One can say to the world: “I have only one audience. Before you I have nothing to prove, nothing to gain, nothing to lose.”

We need to do all of our work so that our Audience of One is pleased with what we do.

This paper is based on the conclusion that God wants engineers to work in a productive manner that helps meet real peoples real needs. For most of us, our work will be “secular”, but we should not ignore the fact that we are working to please God and not just other people. We need to recognize that the things we create will not last.
Engineering as Mission: Various Approaches

The concepts in this paper have been influenced by a similar movement concerning how business can play a major role in missions. This emerging movement is known as Business as Mission. One example of this is the Business as Mission network17 website: www.businessasmissionnetwork.com/ which attempts to link various efforts in this area.

The concept of business as mission rests on businesses that have a social purpose as well as an economic one. Sometimes it is presented as businesses with a triple bottom line. They sustain themselves by making a profit, they provide jobs for poor people while making products that help poor communities, and have a social impact, such as spiritual transformation in the local culture. An example of this is the Treadle pump. This was developed by International Development Enterprises18. About 2 million of these human powered water pumps have been built and sold throughout the developing world. Several million people have escaped extreme poverty because the water provided by these pumps helped increase the yield of their farms. These pumps are not only built for poor farmers, but they are built by thousands of small shops whose owners also benefit by making a profit on the sale of the pump itself.

Another example of business as mission is in the group Bridge to Rwanda19. This group was created by an Arkansas businessman, Dale Dawson, and Rwandan Bishop John Rucyahana. This group is an excellent example of how engineering missions can be done. Westerners with specific skills go to a developing country to work with local Christians, helping the local people achieve their own goals. This group has used western Christians’ skills to help start a microfinance bank, local schools, and provide clean water through a company that drills water wells.

Engineering as mission can be done by some engineers as a full time career. However, for most it will be done part time as a volunteer with a non-profit group. This paper examines the following approaches to engineering missions. These descriptions below are very brief. This paper is intended to be a first step in the development of a fuller concept of engineering as mission. It is the author’s intention to expand this significantly in future work.

1. Helping poor people better their lives. This provides a direct blessing to others.

This is often done by engineers working with secular organizations in other countries. While the engineering work may not be any different than what would be done by a Christian organization, the motive of the individual engineers may be very different.

The use of engineering as a missions tool has been previously reported at CEEC conferences. Most of these are direct attempts to help poor people. This is a legitimate approach as we are called to help the poor, whatever their worldview perspective. Treese20 has reported on work in Nepal. In 2004 Kelley and others21 reported on work in the Kurdistan portion of Iraq. At the 2006 conference there were three papers,22,23,24 dealing with projects in Uganda, Thailand, and other locations. These papers all give useful insight into how Christians can practice engineering in a developing country. Many of them give an explicit Christian justification for what they have done.

2. Using engineering projects as a way to build credibility with the people we are helping. They see what Christ can do in those of us who are volunteering our time and talents and it makes the faith seem more reasonable.

Most of the papers shown under approach #1 above describe projects that also had this as a goal. As the local people are shown Christian faith in action, it will appear to be more desirable. This is frequently followed up with direct presentations of the gospel by either the engineers or their hosts. The author has presented a paper about a project in western Kenya at an ASEE
conference. This project worked with a Christian school for deaf children. In addition to helping to provide them with clean water and some electricity this project was also done to show the children (many of whom are not Christian) some of the reality of the Christian faith. While most of this paper describes work that has been done by engineers related to universities, there are also groups that work with professional engineers. An example of this is Engineering Ministries International (EMI). This group has professional engineers design a solution a problem while here in the United States, and then has them go on an implementation trip to the actual location. Many of their projects are related to infrastructure and require civil engineering expertise.

3. Using engineering projects to build credibility and openness with governmental officials.

Western engineers are welcome to go to many countries where professional missionaries are not allowed. By our example, and by our low key witness, people can be shown the reality of Christianity. This does not mean the Christian engineers deceive anyone about what they are trying to accomplish. It does mean that they emphasize the technical aspects of their work in public statements and in their interaction with governmental leaders.

The work done by Bridge to Rwanda is an example of this. In addition to approaches one and two mentioned above, they have had as a goal the desire to help the local government increase its involvement with community development. As a result of this the President of Rwanda has appointed a Presidential Advisory Council (PAC). The PAC includes fourteen individuals committed to using their professional expertise, leadership, networks and influence to help Rwanda achieve its Vision 2020 National Development Plan. The group includes leaders in business, church and academia and experts in global competitiveness from Rwanda, Rwanda’s Diaspora, US, Canada, Australia and UK. Several people from Bridge to Rwanda are part of this council.

4. Using engineering projects to build up the local church.

It is the goal of the author to work in Rwanda with Bridge to Rwanda. Using engineering skills from our students will assist the local church in fulfilling their goals of Christian community development.

All of the above approaches can be used with engineering missions. Many people, including the author, have done projects largely using only approach number one above. While these can be very beneficial, engineers should consider a more broad based approach.

In working in other countries, it is important that the local people are involved with the project. William Oakes and Marybeth Lima have written an excellent book on engineering service learning. Many of their suggestions can be applied to engineering missions projects. Oakes suggests that the practice of engineering service learning should be done in a democratic way. This does not mean that everyone votes on everything. It does mean that the local community gets input into the decision making process. This includes not only what topics to design but also how the final product actually works. If the design works in a culturally offensive manner, it will not be used.

This local involvement has another issue with which the engineering project must deal.

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Two examples from international projects at our university will be used to illustrate this point. The pedestrian bridge in Africa that we are working on is being done with a non-profit called Bridging the Gap Africa. Before they will work on building a bridge it must first be requested
by the local community. The local community must also commit to help build the bridge and agree to maintain the bridge. This ensures that the bridge is something that the local community wants to have.

Another example of involving the local community is in the projects we plan to do in 2009. In early January 2008 the author visited with several groups in Rwanda. He went there with several people from Bridge to Rwanda. We identified several projects where the local people have already requested our help. One example of this is the Sonshine School near Ruhengeri, Rwanda. This is an excellent school that was originally created largely to teach children who were orphaned in the 1994 genocide. At the school they now teach many other children as well. They have needs for purifying their water. Currently the workers boil it in wood charcoal based stoves, which takes a lot of work and pollutes the kitchen area. There are also problems with electricity. The school’s source of electricity is not stable and very expensive. Teachers and students are trying to use computer labs and need a better source of cheap electricity that is also stable. A photograph of part of their school is shown below in Figure 1.

Our work for the above project will be based upon specific requests from the people who need help. There would not be any issue of community buy in to the project. We will still need to work to make sure our designs are safe and sustainable by the local people.
Conclusions

Engineering as mission is not a totally new concept. The founder of the modern missions movement, William Carey, used science as mission and business as mission concepts in his work.

There are many areas in the developing world where engineering missions can play a key role in helping the local Christians develop their country economically and spiritually. Engineers who are willing to work with (and under) local Christian leaders have the potential to have a significant impact on enlarging God’s Kingdom in our world.

Engineering as mission is a developing concept that will continue to be refined during the next few years. The author intends that this paper is only the beginning of what he hopes will be a much larger and more detailed analysis of this concept.

Appendix—Engineering organizations working in the developing world

There are a variety of organizations that promote engineering service projects in other countries. Some of them are listed below. This list is not exhaustive, there are many other groups also doing work in the developing world. Some of these groups are largely engineering groups, while others promote engineering work as part of a larger organization.

Christian organizations
1. Engineering Ministries International (http://www.emiusa.org/). This group promotes professional engineers working on short term projects in other countries.
2. Bridging the Gap Africa. (www.bridgingthegapafrica.org/). This groups designs and builds bridges over rivers in rural east Africa. These help the local rural communities.
3. Bridge to Rwanda (www.bridge2rwanda.org/). This group promotes economic development in Rwanda. Some of their projects need engineering assistance.
4. Business as Mission Network (www.businessasmissionnetwork.com/). This group promotes business as mission. It is useful for people who want to combine engineering with entrepreneurship in developing countries.
5. Living Waters (http://www.water.cc/). This group helps develop sources of clean water for poor communities in developing countries.

Secular organizations
1. International Development Enterprises (www.ideorg.org). IDE (started by Paul Polak) promotes economic development through engineering innovation in developing countries.
2. Engineers without Borders (http://www.ewb-usa.org/). This organization, loosely patterned after Doctors without Borders, organizes teams of engineers and engineering students to do engineering projects in developing countries.
3. Engineers for a Sustainable World (http://www.esustainableworld.org/) This group promotes sustainable engineering. Their goal overlaps Engineers without Borders, but emphasizes things such as curricular development rather than just doing engineering projects in other countries.
4. The International Journal for Service Learning in Engineering (http://www.engr.psu.edu/IJSLE/home.htm). This on-line, refereed publication presents work others have done in engineering service learning. It deals with both international and domestic service engineering projects.
5. Technoserve (http://www.technoserve.org/). This non-profit organization works on economic development projects in poor countries. Some of their projects require engineering assistance.
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Providing Engineers Cross-Cultural Experiences: Is it truly needed?

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Abstract

This paper looks at research data measuring engineering student cultural sensitivity along a continuum defined by the Developmental Model for Intercultural Sensitivity (DMIS). This model measures intercultural sensitivity from the strong ethno-centric position of denial through the culturally normative position of minimization to a fully integrated, ethno-relative sensitivity position. Data has been gathered from students as incoming freshman, outgoing seniors and pre- and post-testing from short term study abroad activities. The freshman data show engineering students that are predominantly below societal norms in intercultural sensitivity development. Graduating engineering students have shown a tendency to move in a direction of cultural reversal. The pre- and post- study abroad data was performed on students from various degree majors and does not indicate that current course content is truly changing our students. The quantitative data has been supplemented with qualitative focus groups to try to understand what helps or inhibits development.

Along with the research data, the author will share course ideas to incorporate global issues across a four-year curriculum with the intent of raising awareness and intercultural skills of our students without creating a negative impact to core engineering course requirements. He has successfully integrated many ideas into a freshman concepts course and is currently developing a course on international problem solving. He will also share on-going course activities to expand undergraduate research beyond meeting the technical need of a third world community to truly understanding the needs of that community and the redemptive nature of what can be done as we practice our profession.

If our students should receive a call to “Come over to Macedonia and help us.” (Acts 16:9, NASU), they must be prepared to respond as Christ would have us. If we continue to graduate students per the current data pattern, we can expect them to be ethno-centric and ill prepared to interface with and meet the needs of other cultures. Our students need to understand how to accept cultural differences, adapt while not compromising Biblical teachings, and model God’s love and truth to others. The ethno-centric engineer will tend to be guilty of “Americanizing” others. A Christian, ethno-relative engineer can work in other cultures without offending and develop relationships that permit the sharing of God’s truth.

Introduction

To be effective engineers and global citizens, today’s engineering students must understand the global nature of society and the complexities of a world economy. The literature summary below includes multiple statements of the need for global engineers. The literature review itself would appear to answer the question posed in the subtitle above. However, the author looks to take the next step of assessment and from the data determine if different and better cross-cultural experiences are still needed. Efforts have been made by universities to incorporate global
initiatives into their curriculum. Over the past five years, early efforts to address this issue have been ongoing at John Brown University (JBU). This article addresses assessment results from current JBU global educational experiences showing whether or not our courses are meeting the need or are different experiences needed for proper development of our graduates. Suggestions are also made for improving cross-cultural study offerings.

The National Academy of Engineering projects that, because of growing political and economic ties among nations, engineers will discover that their designs have much broader and more significant impacts than they once did. As a result, engineering practice will be driven by attention not only to the familiar topics of intellectual property, project management and cost-benefit constraints, but also multilingual influences, cultural diversity, moral/religious repercussions, global/international impacts, and national security.¹

In 2000, Smerdon noted that, “Perhaps there is no single factor of greater importance in its effect on engineering education than the internationalization of engineering practice.”² A recurring theme Smerdon recognized is that engineers will continually be adapting and learning as they encounter rapidly changing technologies throughout the world and become cognizant of societal, economic and ethical issues. International design requirements will challenge engineering students to understand other cultures and the ways their designs will affect multiple societies. If these designs are developed with cross-cultural teams, there will be the added challenge of managing various cultural dynamics.

The Engineering Criteria 2000³ was targeted to make engineering education programs more relevant, attractive and connected. Action items were identified to provide a better education in the professional skills without detriment to the technical skills. An important element of these criteria is the emphasis on assessing the following professional skills:

- Ability to design systems, components, or processes to meet needs (globally) with realistic constraints such as economic, environmental, social, political, ethical, health and safety
- Ability to function on multidisciplinary (multi-cultural) teams
- Understanding of professional and ethical responsibility (as understood in multiple cultures)
- Ability to communicate effectively (across language barriers)
- Broad education to impact engineering solutions for a global, economic, environmental, and societal context
- Recognition of the need for, and an ability to engage in lifelong learning (as new markets and issues emerge around the world)
- Knowledge of contemporary issues (globally)

The author has highlighted existing global statements or added parenthetical modifiers to demonstrate how effective global education relates to these skills needed for international competency. Downey and Lucena⁴ have gone as far as recommending the focusing of global elements into an additional ABET outcome for all programs.

The political arena has recognized the need to face issues of global competitiveness. In his 2006 State of the Union Address, President Bush addressed the rise of new technology competitors around the world, especially in China and India. He noted that technical advancements provide
economic strength. As a competitive and innovative nation, the U.S. must continue to lead the world in human talent and creativity. Key elements of his initiative were to develop new technologies and improve students’ science, math and technical skills. In addition, engineers must have the competencies to function globally in leadership positions. Congress recently passed the America COMPETES Act and actions are on-going to create the Senator Paul Simon Study Abroad Foundation Act.

Other recent publications note the need for U.S. technological workforce changes to remain competitive in a global world. Freidman (2005) points out that technology has significantly changed the work environment as traditional barriers to competition have been removed and new dynamics are developing. This change should not be envisioned as a threat, but an opportunity. To meet the challenges of this new opportunity, many changes will be necessary for the engineering community. The Council on Competitiveness notes that a key national strength is innovation. To capitalize on the innovative spirit, the council has recommended that key initiatives focus on developing talent, investments and infrastructure. An important element of talent development is equipping workers to perform in a global economy. The National Academy of Engineering reinforces this need for talent development by outlining the challenges of a global world.

Ultimately globalization is impacting all engineering graduates. Their designs will often be targeted to a global marketplace, but the technical expertise of international users and the appropriateness of certain technologies will vary significantly. Many companies are already global with many more going global every day. Engineers participate on global teams as individuals are spread around the globe to implement complex projects. As our science and engineering labor force become more internationally diverse and more internationally mobile, globalization issues also expand. However, few universities have been intentional about integrating global, cross-cultural education into the engineering curriculum.

The Abraham Lincoln Study Abroad Commission Report states that less than 2 percent of all students enrolled in American universities and colleges study abroad annually. Of over 4200 colleges and universities, just 180 institutions account for over 50% of all students abroad. Historically study abroad has been dominated by humanities, liberal arts, and social sciences. Eight percent of all students abroad are engineering majors.

For those institutions that are encouraging cross-cultural learning, there is broad diversity. Deardorff’s study involved both universities and intercultural experts. Her study looked for common terminology. She identified that institutional terminology included intercultural competence, global competence, cross-cultural competence, global citizenship, international competence, cross-cultural understanding, and global awareness. Along with these terms, she identified an equally broad range of definitions and assessment techniques. A surprising 54% of the participating institutions said they were encouraging cross-cultural development, but did not even assess the cross-cultural competence of students in their programs.

The Georgetown University Consortium Project is completing their evaluation of learning environments abroad. Their research looks at various humanities and professional disciplines within three learning domains of languages, technical content and cultural sensitivity. Although
most of the results from this study have not been published, there are some initial findings being made available.12 Of interest is that male students show some level of regression for cultural sensitivity after their study abroad experience. This is particularly interesting in the engineering schools that have a majority of male students.

As Christian engineering educators, global issues should be important. Graduates should remember that their job performance is not just a reflection on themselves and their employer, but also a reflection on God and their relationship with him. They have witnessed to others through their work practices, lifestyle, and ethical behavior. Now we can add to this list: their attitude and reaction to diverse cultures. To perform well in today’s diverse work environment, graduates need to develop cross-cultural skills. Relational and cultural skill development that works well in the workplace will also open doors to share Christ through lifestyle evangelism. Actions that would belittle, attack or ignore cultural differences can close those same doors.

John Brown University has recognized the need to make global issues an integral part of the students’ education. In 2003, JBU embarked on Project Campus Globalization, a campus-wide endeavor designed to integrate global and cross-cultural elements into all department curricula and into the campus culture. The university core curriculum now requires every student to take at least one three-hour global studies course in fulfilling degree requirements. The Department of Engineering has embraced this activity and is working to incorporate global issues into courses that span the typical four-year course plan. This initiative is seen as an opportunity to significantly strengthen the engineering program, improve ABET outcomes, and further strengthen ties with our liberal arts colleagues. For course purposes, globalization is defined as exposure to other cultures, understanding how problems are defined differently in different cultures, and developing skills to work in culturally diverse environments.

Assessment

As the Engineering Department at JBU incorporates global issues into multiple areas of the curricula, it is important to concurrently have an assessment system to measure progress. The author decided to use two different instruments for this task. First, the Intercultural Development Inventory13 is a proven, psychometric instrument that evaluates cultural sensitivity along a continuum from ethnocentric to ethnorelative. The second survey collects demographic data to be used as independent variables.

The Intercultural Development Inventory (IDI) is based on Bennett’s Developmental Model of Intercultural Sensitivity (DMIS).14 The DMIS is a cultural development model that begins with denial as the most ethnocentric element. In the denial stage, individuals do not even recognize that the existence of other cultures. They may intellectually know that they exist, but from a sensitivity and behavioral basis they are not considered. From this beginning, the continuum moves through stages of defense/reversal, minimization, acceptance, and adaptation to the most ethnorelative positions of integrated. Defense/Reversal basically places attitudes into an “us/them” consideration. The defense states their original culture is right and all elements of other cultures are inferior. In reversal, the scene is flipped. A new culture is superior and the original culture is inferior. After testing the survey instrument on over 3000 people, the creators found that the minimization stage is the mid-point of societal distribution.15 In this stage, there is
a basic attitude that all people are alike. We put our pants on the same way. We have similar values. There is significant commonality. Acceptance begins the process of understanding that there are differences in culture and there is both recognition of those differences and acceptance of the importance of the differences. Adaptation is the ability to make some changes in action and attitude as an individual moves between cultures. The final ethnorelative stage is integration where an individual is can move between cultures, think and act in new cultures, and feel comfortable. This continuum is shown in Figure 1.

![Figure 1. DMIS model.](image)

The IDI measures individual evaluations across the above continuum from denial through adaptation. As a person moves through the various stages more ethnocentric issues are identified as resolved and more ethnorelative issues begin to be addressed within their life. When all issues through adaptation have been resolved an individual would be identified as being integrated. Data from the sample of over 3000 participants show that society mean is in the middle of minimization with this region covering a standard deviation above and below the mid-point. Therefore the outcome from the instrument has been divided into two sections: Min1 (below) and Min2 (above). Each of the other regions is one standard deviation in width.

The IDI instrument is considered to be value neutral as it measures attitudes along the developmental continuum. Christians are able to develop all along the continuum while maintaining a Biblical worldview and value system. Many cultural differences can be accepted and adapted without compromising values. There may be some situations where one would consider full participation in some cultural practice to be impossible in view of Biblical values. In those situations, individuals should strive to understand the differences and seek to adjust in a manner that allows co-existence without compromising values or offending others. The goal would be to keep communications open while continuing to demonstrate a Christian life. Let the Holy Spirit do the convicting and changing.

Along with administering the IDI survey, a second survey obtained various demographic data from the students. 60% reported having lived in another culture and 28% had done so from three months to ten years. 19% were foreign students now living in the United States. 90% reported some level of foreign language ability. To understand the impact of JBU global educational interventions, it will be necessary to perform post-testing of these students prior to graduation.
This survey provides a cultural sensitivity snapshot of the participants. The response of the engineering freshman (two years, 53 students data) can be seen in Figure 2. The red represents the participants’ perception (PER) of where they think they are (raw data). The blue is normative data that represent where the participants actually are developmentally (DEV). This information provides a baseline of where the students are as they begin their academic career. From this analysis, it is obvious that there is plenty of opportunities for continued cultural development as the measured developmental levels are predominantly below the population mean which lies in the center of the graph between Min1 and Min2.

Figure 2. Baseline Freshman Engineering Responses.

The IDI was also administered to fifteen graduating seniors and can be seen in Figure 3. This data is only a snapshot of responses at the end of their academic program. There is no earlier data showing where they were prior to their undergraduate educational experience and there can be no conclusion drawn on what has influenced their cultural development. However, we can draw some conclusions on their level of preparation for cultural issues. 76.6% of the respondents are graduating at a level below the societal mid-point. 73% of these students were either foreign students or had been raised as missionary children in a foreign country. The student group identified as Denial/Reversal is particularly interesting. 86% of these are demonstrating reversal. That is to say they have developed an “us-them” attitude, but they consider a non-native culture to be better than their native culture.

The reversal development has interesting implications to mission’s activities. Most of these students have strong advantages over domestic students that may be considering a career in missions. They know the language and customs that should allow them to cognitively move quickly into a mission’s role. But from an attitudinal perspective their responses indicate two issues. First they want to remain in the new, non-native culture that they have identified as
superior. They will take extra steps to avoid returning to their native culture where many of us would have expected them to be able to quickly begin to minister. Second, their attitude could cause them to look down on individuals from their native culture. This “us-them” attitude would need to be understood and carefully managed to avoid issues that could impede relationship building and ministry.

Figure 3. Graduating Senior Engineers Responses.
At JBU, the study abroad courses are predominantly tied to the liberal arts core and there are no international classes directly for engineers. Therefore, engineers participate in study abroad opportunities with credit for core liberal arts courses. Over the past year, the researcher looked at three different study groups: short term to Guatemala, short term to Ireland and semester program in Ireland. Short-term courses lasted five to eight weeks. An on-campus control group of students not going on a study abroad was also evaluated. The IDI was administered to each group as both a pre- and post- survey looking for change as a result of the study. The primary measurement for this study is the developmental factor.

Figure 4 graphically depicts the developmental rating within each study abroad group for both their pre- and post- surveys. If an individual did not complete both surveys, their data is excluded from the graphs. An initial glance at the charts would indicate minimal movement for the Guatemala study, and some noticeable advancement for defense/reversal category for each of the Ireland programs. However, the details show a much different story.
The mid-point of the graphs have a numerical rating of 100. Going up or down the scale represents a numerical change of 15 points as you move to each new stage. For example, the point between defense and minimization 1 has a rating of 85 and the point between minimization 2 and acceptance has a rating of 115. This pattern continues as one moves toward either end of the continuum.

The Guatemala class had eleven students with ten responding with pre- and post-surveys. 70% of the students improved their score with numerical changes varying from 4.8 to 12.9. The median positive change was 6.9 and a mean of 7.7. The lone individual with a post-rating of denial showed a negative numerical movement of 25.0. The remaining two individuals had a mean negative movement of 1.5, which is statistically insignificant. This cohort could not be evaluated for male/female differences since only two students were male.

The Irish short-term class contained eleven students with ten responding with pre- and post-surveys. 40% of the students increase their numerical rating with positive changes varying for 5.6 to 22.6. The mean positive change was 12.1. For the balance of the class, 40% demonstrated negative movement and two students were statistically insignificant. The negative movement ranged from 4.2 to 32.3 with a mean of 15.3. Four of the five responding males showed a positive numerical change three of the five females showed a negative movement with two of insignificant changes.

The Irish semester abroad program included thirteen students, but only nine provided both pre- and post-experience responses for evaluation. Three students showed basically no change. Two of the students showed positive movements of 12.7 and 13.3. The remaining four students showed small negative movement ranging from 3.8 to 7.1 with a mean of 5.3. The gender evaluation for the males was one positive movement, one negative, and one insignificant. For the females there were one positive, three negative, and two insignificant.

The on-campus control group showed no movement between their pre- and post-surveys.

Just looking at the quantitative data, there are limited conclusions that can be made. The number of research subjects is limited and therefore generalizability is restricted. However, for this
sample, change is taking place in student’s cultural sensitivity, but it appears to be uncontrolled. The movement toward either ethnocentric or ethnorelative is about equally distributed. There is no distinctive difference in response patterns due to gender, length of program, or language differences.

To add contextual relevance to the quantitative data, focus group discussions were held with each of the groups on their return to campus. Students that participated in the post-survey also participated in focus group providing some interesting observations.

The Irish semester cohort had a common statement that one of their most memorable activities was to spend time in solitary walks in the countryside. They used the time to reduce the stress level in their life. There was a stated lack of contact with the local people. Only one person in the group stated that she obtained contact information so that she could maintain some relationship level after leaving Ireland. She stated that more than once she would be in conversations after church and the group was waiting on her so that they could return to their apartments. This student also demonstrated a high level of change toward ethnorelative development.

For the Irish short-term cohort, a group of the male participants stated that one of their greatest memories was a political argument that developed over a dinner hosted by locals. They indicated that the focus of the discussion was the relative merits of Americans versus Irish. The details of the memories appeared to be very ethnocentric at first observation. But it was noted that the development of these participants showed some of the strongest ethnorelative movement. With deeper probing, it became apparent that the students developed a deeper respect for the Irish because of this discussion. They did not have to agree with all of the statements, but they did accept that there were merits to the different views and those differences should be considered as cultural understanding increased.

The Guatemala cohort was asked to identify the main thing they would want to change from their experience. One student quickly responded that their greatest mistake was to take a laptop on the trip. From the hotel room, a wireless connection was available from an adjacent coffee shop. This student stated that she would quickly return to her room and surf the internet. She stated that this activity kept her from walking around town and getting to know the people. This individual also showed the greatest level of movement in an ethnocentric direction as a result of the course.

The Guatemala cohort also had the unfortunate experience of students getting sick and requiring medical attention including hospitalization. A first impression would be that this experience had to have a negative impact on cultural development. The opposite was true. The medical requirement opened visibility into the local culture and those that were most involved demonstrated ethnorelative movement.

The conclusion from this additional information is that courses need to be controlled to improve intercultural development. This statement is not really profound. As engineering professors, we are very careful to manage course technical content and processes for optimum learning. But cross-cultural learning often is less controlled. Is this because cultural training is also new for the professor? Is this because cultural learning receives a lower priority to normal, technical course
content? The data from this study cause these types of questions to be raised, but do not offer answers.

**Course Opportunities**

In discussions with other professors, some ideas for incorporating global studies into four-year engineering curriculum have evolved. Global studies changes could be pursued by 1) integrating initiatives into foundational course work; 2) changing study abroad courses to add controlled exposure to cultural issues; and 3) add an on-campus Global Studies course for engineering students. These ideas are discussed in greater detail below. These options are presented without placing a relative value on each, only the observation that more is considered better.

*Integrate into Foundational Courses:* There is the opportunity to develop various cultural modules to be inserted into both mechanical and electrical engineering courses that cover the cultural and historic significance of many fundamental engineering concepts.

For example, Blaise Pascal, noted French mathematician, physicist, and theologian, gave us advancements in the binary system that form the basis for modern computers. Throughout his career he conducted many notable experiments on vacuums, barometric pressure, arithmetic triangle, theories of probability, and a strong defense of the scientific method. From this beginning, binary math has led to digital electronics, electronic calculators, computers and the many controllers and software languages that now are a dominant force in society. Theologically, he identified “1” representing the perfection of God and “0” representing Satan.

Studying other international scientists and engineers can help students to understand much about technical advancements while reinforcing the global diversity of the engineering profession. The French are well known for their mathematical advancements that play an important role in current engineering theory. This historical perspective plays an important role in the current elite cultural position of French engineers and their approach to design problems. The British educational system is based on apprenticeships and practical knowledge over theory. German engineers are trained with a strong nationalistic pride that is driven by quality. This background significantly influences how they approach the design tolerance aspects of engineering. It also accounts for areas of conflict within design teams where cultures do not have the same quality values. Japan is well known for its abilities in manufacturing with high quality results. Russia has strengths in mechanics and applied physics. Many examples like this create excellent platforms to develop teaching modules that can be effectively incorporated into our foundational courses and strengthen the student’s global understandings.

Although some may see the above discussion as stereotyping, cultural difference on the Airbus development project created problems that had to be addressed. Throughout the development each of the national teams were task with various engineering tasks that would be integrated into the final product. When the British would determine the solution to a problem via a graphical solution, the French considered this approach to be inferior. A complete mathematical derivation was the appropriate solution for them. As the project looked to move from planning to implementation, the Germans were at odds with the British. The British wanted to conceptually plan, implement and test ideas and then adjust the plan based on findings. The Germans wanted
an in-depth plan with extensive, precise analysis. When the plan was completed to their satisfaction, they saw the project proceeding with no adjustments allowed. No system was wrong. Each process was driven by a native culture that created conflicts with others.

In a course implementation, the author has redesigned the Freshman Concepts class using this concept. A key to redesigning this course was to make changes that would augment existing instruction but not add so much content that existing information would have to be sacrificed due to time constraints. Most concepts courses spend time looking at the various units of measure seen in our profession. It is also appropriate to look at different forms of calendar dating.

Calendar dating has been known to cause some interesting misunderstandings in the business world. It is quite common for dates to be designated by numbers separated by slashes or dashes; i.e. 9/11/08. However, the meaning of this numerical arrangement has no worldwide standard. When a team member, agrees to provide information on the above date, are they agreeing to September 11, 2008 or November 9, 2008. Just looking at the numbers, one cannot decide. Knowing the country of origin does not often provide the solution. Australians writing for Australians would see this as the November date. However, if they are writing for an American it could be either date depending on their own reference point at the time of creating the numbers. This course redesign opened discussions on this issue so that the students would be able to understand the differences and begin to show sensitivity to others and wisdom in clarifying the true meaning of the originator.

Another key element of engineering design is communications. An important element of this stage is the creation of engineering drawings that accurately portray a design and allow for reproduction. As a teaching exercise, the author created a classroom situation to demonstrate the difference in verbal communications and the written accuracy of a completed drawing package. A student chooses a small, simple item for a bag of parts. The student must verbally describe the item to the class without showing it to anyone. It is the job of the rest of the class to create a mechanical drawing of the item.

For variation and demonstration of cultural issues, the author chooses an international student to describe the second item in the bag. However, the ground rules are modified ever so slightly. The purposeful selection of an international student has also resulted in a student that is very fluent in a foreign language. The verbal description must proceed in the native language of that student. As would be expected, the initial reaction of the rest of the class is astonishment, confusion, and some level of frustration. With a little encouragement, the class realizes this could be a real-life scenario and they have to learn to adapt. The process proceeds at a slower pace, but it proceeds nonetheless. The result has always been in someone being able to create a similar drawing. The learning process allowed the class to understand that not all engineering situations will be familiar and culture, in this case the language sub-element, is an important part of their professional activities.

Restructure Study Abroad: Many engineering programs use service learning to meet humanitarian and community needs in international locations. From the perspective of a Christian university, this has often been a missions activity rather than providing course credit. While some existing programs have integrated service learning with design courses,
multidisciplinary efforts,\textsuperscript{21, 22} and co-curricular activities,\textsuperscript{23} most such efforts tend to be little more than a senior capstone design course with an international client or destination. Actual student travel to these locations and focus on understanding the cultures has been limited. Technical solutions have been the focus, and any understanding of cultures has been incidental.

In contrast, a course that is designed to build global skills would incorporate global and cultural aspects into the structure in a very intentional manner. A recent international task at JBU was sponsored through an Environmental Protection Agency (EPA) grant. The stated research was to improve the operation of slow sand filtration so that smaller systems could be used at a community level. The first task in the project was to take a team of students to the village of Santa Cruz, Baja Verapaz, Guatemala for a site survey. To complete the technical aspects of the research various technical data was needed. But the majority of time was spent trying to understand the culture. Shortly after arriving at the village, we were provided a written report from Plan Guatemala that provided valuable technical data.\textsuperscript{24} A water collection and distribution system was built for the village some years ago using United Nations funding. The storage tank has a storage capacity of 46.2 cubic meters. The vertical drop from the mountain catchment area to the holding tank is 520 feet. This creates a significant hydraulic energy source that is currently unused and could be converted to a purification technology.

The team also evaluated the local technical skills and available resources. The local construction consisted of concrete, concrete block, wood and corrugated metal. Sand was found in abundance. These items are directly compatible with the chosen slow-sand filter. Even though the area is tropical in latitudinal location, the mountains create a cooler environment and the August water temperature at the source was measured at 16 degrees Celsius. This temperature will be colder in the winter months and therefore biological/algae growth will be slower than originally expected. Electricity was found to exist at almost every home in the village. Power was limited as there was a single 110-volt line, 15-amp service. The electrical service also demonstrated a fees collection system as each home pays a very low flat rate to maintain this service for their community and home.

As the student team traveled in the area and learned more about the culture, a notable outcome was recognition of the needs of the people, the pain that is being experienced due to the fall of man, and the need for redemption. This redemption was not just of the soul, but an ability to apply engineering training to remove pollutants from the environment and use waste by-products to create micro-enterprises for the people.

Create Global Studies Class: Not all students will travel internationally. Thus, the department will add a Global Studies course for those engineering students who cannot participate in a study abroad program. Virginia Tech and Colorado School of Mines have reported success with a similar course that uses historical and ethnographic information to explore engineering culture on a global basis.\textsuperscript{25} The course content requires students to explore various attitudes and engineering processes to see how different countries approach the profession. Different cultures define problems and solutions different, apply knowledge through different national patterns, and implement process through different cultural norms. This course demonstrates a possible way to provide global understanding without traveling abroad.
The course content will consider social/cultural awareness, politics, international business and communications issues, the global nature of technology, understanding societal problems, design and manufacturing, locally available resources and skills, attention to sustainability, and lifestyle impacts. The course challenges engineering students to understand other cultures and to perceive how their profession can have a direct impact on people around the world.

Summary

Data show that the intercultural development of current students is below societal norms. If students should receive a call to “Come over to Macedonia and help us” (Acts 16:9, NASU), they may be prepared from a technical perspective, but there is more that can be done to prepare them culturally. Christ set an example of understanding the people and meeting their personal and social needs along with their spiritual needs. We can expect current graduates to be ethnocentric and ill-prepared to interface with and meet the needs of other cultures. If students are going to bridge cultural gaps and develop relationships as a part of their ministry, they need to accept cultural difference, adapt while not compromising Biblical teachings, and model God’s truth and love to others. An ethnocentric engineer will tend to be guilty of trying to make all people fit the American mold for living and values. The goal of a Christian university should be to develop a Christian, ethnorelative engineer who can work with other cultures without offending and develop relationships that permit both a good working environment and sharing of the gospel of redemption. The need still exists for cross-cultural learning experiences. Data show a need to change or increase course content for better results.

References


On Providing Christian Engineering Students with Ministry and Culturally-Appropriate Design Experiences in Developing Countries

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Abstract

The Bible gives mandates to subdue the earth and to make disciples in “all the nations.” This paper describes our pilot program for engaging undergraduate engineering students to enable and encourage African believers in their ministry of meeting humanitarian needs and propagating the gospel in Liberia. This program helps undergraduate students discern God’s call on their lives as they complete engineering projects targeted for a developing country. Important components for the program's success were: 1) infrastructure and culture at the academic institution, 2) relationships with appropriate intermediaries, and 3) a receptive national host that needs engineering services. These components were similar to those identified by others in recent literature.

A case study is presented that evaluates our pilot program which took a team of students and faculty to Liberia, West Africa in May 2007. ELWA Ministries comprises a Christian radio station, a Christian hospital, and a Christian school; the 134-acre campus is also home to many families and provides housing for Non-governmental organizations. Four projects were selected focusing on ELWA’s physical plant that provides mechanical services. The team successfully installed a student-designed cooling system for diesel-powered generators and built a medical waste incinerator for the hospital. Students also prepared CAD drawings of the campus and documented the water system by taking many measurements. An additional project helped rural pastors; the students designed and distributed solar-rechargeable reading lights.

Overnight trips to remote villages provided engineering students and faculty an opportunity to see how the rural dweller lives. These experiences provided the students intercultural worship opportunities and insight how to develop engineering solutions which blend into the culture. The ELWA services personnel and Liberian pastoral leadership expressed profound gratitude for the team’s ministry; student assessment also confirmed the value of the experience.

Introduction

This paper presents a model that was used to give our engineering students an opportunity to design culturally-appropriate solutions to technical problems in a developing foreign country, and then immerse the students in the country to implement them. After a faculty survey trip in 2006, the first team of engineering students produced their designs during the 2006-07 school year and traveled to West Africa in May 2007. They worked with ELWA Ministries near Monrovia, Liberia in a strategic partnership intended to help spread the gospel. ELWA is a private organization that runs a radio station, hospital, and school. Of the eight projects completed, the team’s major accomplishments were to:

- design and install a cooling system for institutional power generators,
- build a medical waste incinerator,
- survey and measure the performance of an over-utilized water distribution system, and
- design, build, and deliver solar-rechargeable reading lamps.

We hope that this paper will be helpful to other engineering faculty seeking to establish a similar program at their institutions.
Background

Academic institutions are encouraged to instill an appreciation for “the impact of engineering solutions in a global and societal context.”\(^1\) In particular, the Department of Engineering and Computer Science has a stated educational objective that graduates “will be knowledgeable of opportunities to serve in and support Christian ministries both in their communities and around the world.” Furthermore, studies show that today’s college-age students are global-minded and seek to make a difference.\(^2\)

There have been a variety of efforts to give engineering students a global perspective or to integrate engineering design projects with international humanitarian needs. Some of the previous work has been done at faith-based institutions with engineering programs. Vanderleest and Nielsen\(^3\) describe a course offering which integrated “global engineering and the liberal arts by immersing the students for one month in the engineering, business, and cultural aspects of a foreign (European) society.” In 2002, Duda\(^4\) described groundwork being laid at Grove City College for international humanitarian capstone design projects in electrical or mechanical engineering. This included faculty survey trips to identify likely projects, and plans to address challenges such as ensuring educational merit and providing for additional costs.

Green, Wood, Vanderleest, Duda, Erikson, and Van Gaalen\(^5,6\) (2004) presented parallel papers discussing common key elements among international humanitarian design projects which had run at the following faith-based institutions: Calvin College, Grove City College, Messiah College, and Dordt College. The key elements were 1) team formation, 2) project selection, 3) funding, 4) obstacles identified, 5) deliverables, and 6) teaching and mentoring. The projects included designing a women's hospital, a crop irrigation system, a dolly-mounted solar power module for remote areas, and an ultraviolet water purification system. Most of these projects were senior capstone design experiences. Several included international implementation. At Messiah, the Dokimoi Ergata\(^7\) student organization has been using appropriate technologies for several projects on foreign soil over several years.

Liberia is a resource-rich country on the North Atlantic coast in west Africa which has been decimated and impoverished by a military coup in 1980 followed by bloody civil wars in the years 1989-1996 and 1999-2003.\(^8\) Rebels with guns looted at will to the extent that anything of value that could be removed from ELWA was stolen and sold on the street. The medical staff bought back their own drugs off the street. If personnel had not moved back onto the campus, the rebels would have removed the roofs from the buildings to sell on the street. It was anarchy. Anyone who had leadership responsibility had reason to fear for their lives. As a result, technical expertise was drained from the country, and is now really needed at the very time in which rebuilding is crucial.

Recognizing this need, Ray Hutchison, an experienced missionary who lived in Liberia before the civil wars, approached Drs. Zavodney and Thompson about establishing an on-going collaborative relationship that takes engineering students and faculty annually to Africa, to work alongside with the Africans, and help them rebuild from the war, find solutions to technical problems, and encourage the Christians.

A Short History of ELWA \(^9,10\)

What began as a dream for three Wheaton College students in the early 1950's continued as a challenge and prayer as they and others envisioned a radio station in Liberia. An initial invitation from President Tubman of Liberia followed by a providentially-arranged meeting with Postmaster General DeShield, continued fulfillment of the dream as West Africa Broadcasting Association (WABA) began to put roots down into Liberian soil. In 1952, the government granted the permit for broadcasting.

Liberia is located on the SW coast of West Africa.
After several months, WABA joined Sudan Interior Mission (SIM), an organization with many established works in Africa. Together they were able to acquire 180 acres of unclaimed land along the ocean, only 12 miles from the capital Monrovia. The government granted duty-free privileges which allowed expensive equipment, needed for the station's establishment, to enter Liberia without greater expense. The call letters assigned ELWA—Eternal Love Winning Africa—expressed the vision and challenge of SIM, “that all may hear the propagation of the tenets of the Christian faith by means of broadcasting.”

In amazing ways funds, equipment, Liberian laborers and staff, foreign missionaries and technicians came together at strategic times and places to begin broadcasting ELWA’s first program in 1954, desiring to spiritually bless millions of Africans. They faced the obstacles of 28 languages, a mix of religions (paganism, Christianity, Islam), thieves, and heavy rains daily for six months of the year. Many helped hand-clear land, form and lay block, weld sky-scrapping towers, gather and safely store necessary equipment to set up and sustain the “big voice” calling out to Africa. Their purpose was to “minister to and encourage believers, as well as to witness to the unsaved and unreached with the gospel message by spoken word, drama and music.” They desired to educate and rekindle hope, helping heal and strengthen scarred and broken lives. The “voice under every palm” from the “box that catches it” broadcasted preaching, drama, children's programming and reading as well as news, government notices, public announcements and music.

Eventually ELWA, with 70 missionaries and over 100 Liberians, used its transmitters to send radio to all of Africa, South America, parts of Europe and the Middle East. Their programming could be heard in 42 languages for hundreds of hours per week. In the privacy of his own home a person could hear what his heart longed to know, and could be linked, without fear or prejudice, to countless listeners around the globe.

**Value of Immersion Experiences for Engineering Students**

A cultural immersion experience for engineering students is beneficial because true solutions to problems must always harmonize with the culture into which they are applied. Culture may be defined as the collection of social customs, communication media, and ways of living that characterize a connected group of people. Engineering design is the application of physical principles and models to solve problems and create opportunities for people. Since an engineering design will only be effective if it blends with the culture, it is important that the engineer be intimately aware of not only technical but also social customs and cultural issues. For example, it might be possible to design a device to grind corn more efficiently, but if this device would preempt the social custom of village women gathering to socialize while they grind corn, it might either have detrimental cultural outcomes or never be adopted. Because cultural differences alone do not make one culture superior to another, engineers should take care not to unwittingly despise or diminish a culture by introducing inappropriate designs.

While it is certainly possible by reading literature to increase one's understanding of and sensitivity to such cultural differences, a cultural immersion experience is usually the most effective way to change engineering students’ attitudes towards and appreciation of other cultures. By living for a time in the culture, the student gets to experience first hand the comforts, the discomforts, the joys, the sorrows, the music, and the sights, sounds, and smells of that culture. They get to sit next to, work alongside, and form friendships with the people. They can feel the climate and explore resources and techniques.

As a result, the students will be enriched not only as engineers, but as global citizens. They might be able to borrow ideas or designs and methods from other cultures. For example, in many cultures, heavy loads are carried on top of the head. This technique could be adapted to create a device which reduces back strain or even exercises the spinal musculature. As the engineers return home to practice engineering they will be able to create designs which are sustainable in view of the world of cultures. They may also retain an enduring desire to help those who have fewer resources.
Institutional Infrastructure

There are several institutional and cultural factors which serve to give students cross-cultural immersion design experiences. First, there must be an academic institution that values cross-cultural immersion experiences for students. Institutions that favor such often have policies to help protect students and have support staff to help with the many logistics. An example of a policy might be that dating foreign nationals would be strongly discouraged.

We found that having a liaison who lived in the country and had already established connections was indispensable. If international travelers do not have help in communicating and working within a foreign culture (especially if language is a barrier), they could be hampered by cultural blunders which could make them appear insensitive. The liaison should be able to communicate with the students and faculty in order to provide cultural orientation—preferably before the trip.

It is also important to have a host organization in the target country which is aware of technical needs which must be met. The host should have sufficient resources of personnel and facilities so they can help coordinate the transportation, housing, emergency medical treatment, and meals for the visitors. And it is equally important that we communicate to the host institution that they are helping us by enabling us to see and learn about their culture, their customs, and their way of life. Going to a foreign country to help a host organization helps to legitimize the engineering team's presence and enhance the credibility of the host organization in the eyes of foreign officials.

Case Study

This case study consists of a summary of our groundwork, our survey trip taken in 2006 to identify projects, our project selection process, team formation and preparation, and the field excursion with eight students in the summer of 2007.

A. Groundwork

Our university, that presently has 3000 undergraduate students, has been sending student teams into cross-cultural short-term immersion experiences since 1970. Over 5000 students have traveled to 89 countries to participate in humanitarian, cultural, sports, youth, music, drama, and ministry-related programs. So, taking a team of engineering students to do some engineering-related work in Liberia was well received when we first proposed it.

Our university sponsors a conference every year. About 100 guests come to participate in campus-wide activities, speaking in daily chapel and evening services, conducting workshops, displaying their organization's work worldwide, and meeting with students to discuss short- and long-term service opportunities. During one of these conferences we met Mr. Ray Hutchison, a regional director of SIM, an organization that is working in Africa, Asia, and South America.

He began by telling us about what an engineering professor and a group of engineering students from Messiah College was doing in Burkina Faso. Every summer a group would go over and work on solar-electric and mechanical engineering projects. He suggested that we consider doing something in Liberia. Since he had lived in Liberia with his family before the civil war ravaged the country, he had some connections already established, and from a recent trip to Liberia in 2005 knew that there were tremendous needs that might appeal to our engineering students. As a result of his patient encouragement, the cessation of the civil war and presence of 15,000 UN Peacekeeping forces, we agreed to go with him on a survey trip.

In addition to the encouraging university culture, the Engineering Department began a new student organization called the Society of Engineers Aiding Missions, known as SEAM. This group of students meets regularly to pray for missionaries and takes on projects to help others, typically in developing countries, with engineering and technical services.
B. Survey Trip

We took a 10-day survey trip to West Africa in May of 2006 to evaluate the following: 1) engineering project possibilities, 2) nature of the projects, 3) political stability in a country that just came through a civil war, 4) accommodations, 5) available emergency health care, 6) food and water, 7) receptiveness of the national hosts to foreign engineering students, 8) available transportation, and 9) to discern the nature of the cross-cultural immersion experience our engineering students would get. Of the 10 days, four were consumed by travel leaving only six in-country working days. As a result of the survey trip, we concluded that working on projects in Africa with ELWA and ECUL (the Evangelical Church Union of Liberia) would be a good experience for our students and that the primary focus of our work would be to help the ELWA campus maintenance services group recover from the devastating civil war.

Presently the 134-acre campus comprises many residential homes and Non-governmental organization (NGO) offices such as Living Waters and Samaritan's Purse. Since there is no power grid in Liberia today, ELWA must generate its own, and also provide water and sanitation utilities to those who live and work there. Because of the civil war, many of the trained technicians are no longer there, leaving a handful of workers to maintain operations. Now that the war is over, efforts are underway to rebuild Liberia. However, with 85% unemployment, reconstruction is moving at a very slow pace. Thus, there are many opportunities for engineering students to work on a variety of projects.

We met with the administrative team of ELWA on the first day, toured their facilities, and heard their needs first hand. During the next few days we walked around, took pictures, talked to many of the workers, toured the supply shops in Monrovia, and met again with the administrative team before we left, primarily to update our project list and get a sense of priority from their perspective. Tops on their list was engineering help to provide relief from their task of generating electricity; they were paying upwards to $0.60 per kW-hour in diesel fuel costs alone. With a very limited budget, they had three mismatched generators and were struggling to cool them with their damaged cooling system. It was not uncommon to have the power go off several times during the day. Power generation was shut down at night to conserve fuel.

Included in our six-day visit was a two-day overnight trip to a remote village 100 miles north of Monrovia. This village was accessible only by foot or canoe. We drove all day mostly on dirt and muddy roads (we were in the rainy season), struggled to cross two log bridges (one vehicle got stuck on the first bridge and one vehicle could not cross the second bridge), and reached the end of the road much later than planned. As a result, our two-hour hike through the jungle was attempted at night. Half a dozen river crossings and an hour later we came to an extremely swollen — and hence impassible — river. We returned to the village near the end of the road and spent the night there. The village chief welcomed us; the men slept in the open community “palaver” hut, which sheltered us from the rains while the women slept in one of the villager's huts. We saw how the rural villager lives in Africa; many small villages do not have wells, and none have electricity. Many small villages do not have roads to provide vehicle access, so everything has to be carried in on foot. During our two days of travel, we talked to nationals about some of the needs of the rural dwellers. It was indeed a very insightful experience and the highlight of our trip.
Some of the projects are listed in the next section. They include projects for ELWA such as solar-power generation, a cooling system for their generators, providing hot water for their hospital, providing good water pressure throughout their campus, and projects for the rural dweller such as solar-rechargeable reading lights.

C. Project Selection Process

Of the two dozen projects on the list, we selected half a dozen of them for two groups of students: those working on capstone senior mechanical engineering design projects and those working on extra-curricular projects, comprised typically of underclass mechanical, electrical, and computer engineering students. The project descriptions were drafted such that the scope was targeted for completion in one academic year. The selection criteria included appropriate academic merit, the field need, and student interest. Senior design projects at Cedarville must build on the core curriculum, but also require an independent research element that stretches the students in new areas in order to complete the project. The projects that did not have sufficient academic merit were not considered for senior design, but if the the next criterion was met—whether the project meets a real humanitarian need—they were presented to the students for consideration as extra-curricular.

The faculty reviewed the project list and decided which ones were suitable for senior design projects. For the first year the list included the following:

- Solar electric power generation,
- Solar panel manufacturing in Liberia using locally available materials,
- Alternative power generation; from the ocean there is a steady breeze and waves,
- Solar powered security light,
- Cooling system for the diesel power generators,
- Improving the water system on campus (Phase I, II, and III),
- Portable well-drilling machines that can be carried by foot, and
- Scarecrow hawk for farmers.

The extra-curricular projects on the list from which the underclass students could chose consisted of the following:

- Solar-rechargeable reading lights,
- Alternative well-drilling methods,
- Hospital medical waste incinerator,
- CAD package suitable for Liberia,
- Mapping the campus in a CAD package,
- Low-cost water filters for individual families,
- Playground equipment that pumps water, and
- Muffler for the generators.

Surprisingly, for the seniors choosing capstone projects, designing well-drilling equipment that could be carried into remote villages on foot was the most popular, even competing with the SAE Formula race car project. Although the cooling system for diesel power generation was less popular, we made an administrative decision to work on an ELWA project (vs. a project for the remote dweller) the first year because we recognized the significant importance of developing the infrastructure of ELWA. They needed reliable electric power generation, and the cooling system they had was destroyed during the war. We also discovered that they did not have any engineering drawings of their site or facilities. We put CAD on their project list, recognizing the importance of having engineering drawings of their site. In so doing we realized that we would have to persuade them of the value of the drawings, and would have to provide training on how to prepare CAD drawings themselves.

One of the strategic elements in getting students interested in working on these projects and then in going
overseas was having a well-defined list of achievable projects that were clearly seen as viable, necessary, and helpful to the people we were serving in Africa. It was clear that they all required various levels of engineering—whether it was analysis, design, or services.

D. Team Formation
While having a supportive academic institution, a liaison, and a receptive group in a developing country is necessary, an important part is assembling a team of the right kind of willing students to go over and do the work. To this end we advertised the opportunity to all of the engineering students, starting with the students in SEAM. At one of their regularly scheduled meetings, we gave a report of our 2006 survey trip, showing photographs of the facilities, the excursion up country, crossing log bridges, and wading through water. We showed them the projects that were begging for solutions—and we got an enthusiastic response.

The SEAM students adopted the solar rechargeable reading light project for the rural dweller. Four seniors chose to design a cooling system for the power generators for their capstone project. Two students were interested in helping with the incinerator project for the hospital; another student keen on computers wanted to help with the CAD project. By the time the deadline arrived, we had eight students who committed to going. Another graduating senior wanted to go and help with the cooling system, and one of the students helping with the lights wanted to go.

E. Team Preparation
Preparation for the trip included weekly one-hour meetings that dealt with trip logistics, historical background about the country of Liberia (PBS documentary “Liberia—America's Step Child”), meetings with Liberian nationals, meetings with people who had worked in Liberia, planning the work they would be doing in Africa, and raising funds to pay for their trip expenses. Most of what we did was funded by ourselves and donors. The total expense per student was $3200, the biggest portion being the airfare.

Each member of the team needed a current passport, visa, and immunizations and accompanying yellow card and malaria medicine. These details were handled by the Missions Involvement Service (MIS) office and the University Medical Service (UMS) office. Health risks, including AIDs which is epidemic in Africa, were handled in our weekly team meetings by the faculty advisor. Health care issues available while in Africa were also discussed and conveyed to the parents. For our work mainly on the ELWA campus, there was a hospital with an American doctor available. The MIS office also screened each of the student applicants; they sent out email to the faculty and staff asking for any character feedback that might preclude a student from participating on this trip. At each weekly meeting progress on a variety of tasks was noted, including parental concerns.

One of the important resources mentioned earlier was the role of a receptive host in the country. For us, our hosts were the ELWA administrators and the SIM personnel on the ELWA campus; they provided transportation to and from the airport and provided meals and lodging during our stay for a nominal fee. We had to coordinate all of the logistical issues related to our trip, including the work projects and tools that were needed to complete our projects. For example, we purchased a surveyor's level and tripod, grade stick, measuring tape and measuring wheel to conduct our survey of the site and determine the locations and elevations of the water lines.

In addition, we scheduled orientation time with the team and our liaison, who was an American who lived in Liberia before the civil war and was well acquainted with our host in Liberia. He provided cultural and social sensitivity orientation during our layover at Brussels, since the team was not fully assembled until we rendezvoused in Washington DC en route to Belgium. He also helped lead our daily team meetings in Africa. These meetings were often less than 20 minutes long, but helped us focus our energies and see where help was needed for a particular day; they also provided a structured forum for the students to share anything that happened the day before or how they might deal with a particular situation that developed. Student assessment after the trip confirmed that the students felt that they were adequately prepared to mix with the people in Liberia, and work effectively with them.


**F. Field Excursion**

Having completed the project designs and necessary preparations for the trip, the next task was to get the team to Liberia. Because the shipping container that had our high-temperature mortar was delayed, we had to carry (in our luggage) 100 pounds of high-alumina mortar (gray powder) to construct the incinerator. Additionally, we carried 30 pieces of two-foot long by two-inch diameter PVC Schedule 40 pipe with three dozen caps for the cooling system, and ten solar rechargeable lamps with their charge-regulating circuits.

**Project Descriptions**

The following discussion provides details of how one senior design project and one extracurricular underclass design project were designed, and brief summaries of the other three major projects. We discuss some of the cultural constraints that are not typically encountered in the USA. Factors which differentiate “developing country” and “cultural issues” criteria for engineering design from criteria in the United States are:

- lack of capital,
- limited building materials,
- level of technical training of the maintenance personnel,
- cultural appropriateness, and
- acceptance by the local people.

Whatever we designed and built would have to be understood by the end user, and be able to be fabricated and maintained by them.

**A. Diesel Generator Cooling System**

The diesel generator cooling project had sufficient academic merit that it was run as a senior capstone design project. The senior design team reviewed the literature and identified four popular methods of cooling water that would be most suitable for construction in Liberia. We chose four since there were four students on the team; each student would design a functioning prototype of a different system, and the team would provide a comparison of the four systems, including estimated original capital cost of materials and equipment, cost of construction, and cost of operation. Details of the different engineering systems and some of the constraints are published in a companion paper presented at the recent ASEE 2008 conference.

The four prototype solutions were presented to the ELWA Technical Services team with a cost comparison. We set up a website that allowed our Liberian partners to download the preliminary report and see our cost estimates. After they evaluated the different designs and considered their own manpower and technical expertise, they chose the fountain spray system.

The second semester was devoted to designing the fountain spray system. The team divided into a mathematical modeling group and an experimental verification group to test the model. The model was developed further and accounted for the heat transfer and water loss due to evaporation. Simulations were run for the wet season and the dry season. Students accessed the weather METARs at Robert's International Airport in Liberia to track the hourly wet and dry bulb temperatures, the winds, and the variations during the wet and dry seasons.

An experimental apparatus was set up in the...
laboratory. An electric hot-water heater was used to provide hot water to cool. Various spray heads were tested in both elevated positions spraying down and low positions spraying up. The test area was cordoned off from the rest of the lab with a plastic curtain. A child’s inflatable swimming pool collected the water which was pumped back into the 80-gallon hot water heater for the next test. Temperatures and pressures were varied and a set of performance curves were generated. When we exhausted the height range of the laboratory ceiling, we moved the spray head outside to study performance and observe spray patterns in light winds.

Laboratory setup to verify the mathematical model and to compare the efficiency of spraying from top down to that of spraying from bottom up. With a full hot water heater, we were able to get about a five minute test run during which a steady-state natural convection was established. Temperature and humidity were measured at the air inlet and exit areas. We also measured water temperature at the nozzle and just before it fell into the pool at the bottom. Water pressure was easily controlled with compressed air and an air pressure regulator.

From these measurements we were able to corroborate the model predictions and we were able to specify the nozzle spray head. Unfortunately, none were available off the shelf. Since the cooling pond was 30 feet long, we stacked 10 spray heads on one 30-ft line. To maximize the spray area, we designed an oval spray pattern. To achieve this, the students drilled 78 holes in four rows using four different angles in two-inch PVC plastic caps. The PVC caps provided a low-cost solution that was easily understood by the Liberians. The screw-on heads provided an easy means of aligning them, removing them to clean out the algae, and replacing them.

The heads were elevated to give the water more air time. The two-foot dimension was chosen for several reasons—one being that it was the maximum dimension of our largest suitcase. The other reason was that during the many thunder-storms, the wind velocity can be substantial. These pipes were held in position with just a few supports, so extra length would have exposed more pipe to the fierce winds.

The team of two graduates, with help from a Liberian helper, assembled the system in less than two weeks. We chose to leave their present system operational and installed “T’s” and valves to form a parallel line in the event that the tiny 0.043”-diameter holes got clogged by the algae in the pond water.
We purchased the 2-inch PVC ball valves and CPVC cement locally. Just purchasing the items was a cultural experience; the first store wanted $15 for one ball valve, the next store wanted $25, and the third wanted $35. American students are not used to bartering.

B. Solar Rechargeable Lights
As its service project for the 2006-07 school year, the students in SEAM chose to help Liberian pastors who live in the bush to read and study at night. We learned of this need while en route to the Liberia bush during the 2006 survey trip. Seeing villages first-hand at night made this need obvious.

While the entire nation of Liberia feels the effects of the conflict, the people who feel those effects the greatest are the rural-dwellers. ELWA Ministries is located near the capital city Monrovia, the hub of the nation, the place where the greatest help from the U.N. peace-keeper and economic development programs as well as the services from many NGOs is available. But the people who live the rural areas do not have as much access to the benefits these Christian and other philanthropic organizations can provide. But they can listen to radio programs. They are served primarily by ECU (The Evangelical Church Union of Liberia), which is a loose association of over 100 like-minded churches scattered primarily over western Liberia.

Liberian hunting and farming villages are small, tight-knit communities without easy transportation access to neighboring villages. Many do not have pastors, but having spiritual guidance and solid biblical teaching is vital to the spiritual health of the Liberian Church. Those congregations that do not have pastors are much more susceptible to discouragement and false teaching. Pastors who are committed to helping meet the spiritual needs of these congregations face huge challenges. Rustic accommodations and lack of employment are among them. In addition to these, lacking basic services such as electricity and water add to the burden of staying upcountry and shepherding their flock.

Liberian pastors can meet spiritual needs of villagers using fewer resources than foreign missionaries, but they need help, training, and encouragement. They typically farm during the day, so any study and preparation time is forced to the evening hours. However, because of its location near the equator, the Liberian sunset consistently occurs around 7:30 P.M. Fuel to power kerosene or propane lights is expensive, but there are usually a few
hours of daily sunlight during the rainy season. These factors made a solar-rechargeable reading lamp technically feasible and culturally strategic.

SEAM designers found a circuit design on the Internet, performed tests, and made modifications so that the user would gradually become aware of the fading batteries. They fabricated their own enclosure design, which was approximately 13” x 7.5” x 4” and featured an inner enclosure for the battery. There were three separate variations for the door and light head position.

Once in the country, we tested the recharging circuits. After the lamps were left “on” for 30 hours, the lamps were placed in the sun to recharge. As was hoped, the recharge rate was at least as fast as the discharge rate. A Liberian ELWA technician was able to troubleshoot and repair two lamps that malfunctioned due to assembly errors.

The lamps were received enthusiastically by the Liberians. The solar lights allow these rural pastors to stretch their days so they can prepare to feed spiritual food to their flocks. The solar light project also provides the potential in the future for some of these men to support themselves and families by building, selling and maintaining these solar units for others to purchase. This would be a great incentive for pastors to remain in the rural areas to serve their churches rather than migrate to the capital city where there are more opportunities for employment.

Not only rural dwellers, but also those who lived around Monrovia saw the value of the lamps—and offered reasons why they could use one. They gave informal feedback about the lamps’ function. The light’s intensity was more than sufficient considering the dark nights in rural Liberia. Concerning the configuration of the light head, one national leader felt that simplicity trumped convenience, so the in-box LED configuration was as good as any.

C. Medical Waste Incinerator

After the survey trip in 2006, we recognized the immediate need for a medical waste incinerator. The hospital, like others in Africa, deals with the AIDS virus and has sharps and infectious waste that needs safe disposal. From our literature survey we learned that D. J. Picken had developed a low-cost but effective incinerator. After evaluating the design using the criteria mentioned above, we chose the DeMontfort Incinerator design. We proposed the design to the ELWA administrators and the hospital staff. They agreed that the Mark 8a or Mark 9 model would be a good solution.

The DeMontfort design has been used in many developing countries and has been shown to be a good moderate-temperature incinerator. These incinerators were designed specifically to be built in almost any developing country, can be made from readily available materials, are effective, and can meet the criteria of a temperature above 800 °C with a residence time of over 1 second. They require a fire to be started using some combustible materials, such as paper or wood, which are readily available in Liberia.

One feature of this design that makes it particularly suitable for Africa is that with this design, the loading door can be out of tolerance by almost an inch and still provide a good air-tight seal. The seal around the loading door is accomplished by placing sand in a “U”-channel; the loading door has a knife edge around the sides that cuts into the sand about an inch. Since ELWA is right on the ocean, sand is plentiful and
cheap. The only way combustion air can enter is through the air inlet opening above the ash door, and that location provides an air blast that fans the fire and helps to increase the incinerator temperature.

Two students were interested in building the hospital incinerator. The Liberians were able to obtain fire brick from an abandoned iron ore furnace, so the students prepared CAD construction drawings of the incinerator design using their exact brick sizes, showing each layer step by step. The students also prepared drawings of the steel work which was fabricated by a Liberian metal worker in their metal shop. The dimensions were specified on the drawings prepared by the students. The steel stock purchased in Monrovia consisted of angle iron, steel plate, and steel reinforcing bar. The parts made of steel were the ash clean-out door, the loading door, and the chimney. The angle iron was cut by hand with a hacksaw, and the plate steel was cut by chisel.

One question in our minds was whether or not the African workers would hold tolerance on the steel work, which had to precisely fit the openings on the brick incinerator. We chose to communicate with the Africans with technical drawings prepared beforehand, and then with additional sketches in the field. We stressed the importance of being square and uniform, and within tolerance. One African made the comment that “precision is only important when making a piano!”

In our case, the steel door had to fit inside the opening in the brick liner, and the top frame had to fit in its precise opening—it could not be too large or too small. When the steel parts were made, the dimensions of the steel work were held to within a 1/32 of an inch; we were quite impressed and pleased.

The students helped to scrounge around the scrap pile looking for suitable chimney stock. Several steel pipes, presumably light poles at one time, were welded together to make a chimney. Eyes were welded onto the chimney near the top to attach stabilizing cables. Since the chimney was not installed until after we left, we were unable to actually start a fire to see it in operation.

D. Water System Assessment and Upgrade - Phase I
During our 2006 survey trip, we noticed that the water pressure dropped off sharply when the generators were shut down at midnight. Because of the high cost of power generation and low water pressure, the ELWA managers asked us to help them improve their water system.

The purpose of the water system assessment project was to measure the performance of the water distribution system on the ELWA campus in order to evaluate it during the following year and recommend improvements. The obvious problems were very low system pressure and no systematic water treatment program. The water pressure overall was low, and there was a variation around campus—caused by the 30-foot elevation change around campus. At some points air was sucked into the system when a faucet was opened. Negative pressure anywhere is serious because it provides an easy source of system contamination. The service technicians would occasionally (maybe once a month) pours
bleach (sodium hypochlorite) into a well to treat the water. Considering that many nearby villagers come to ELWA to get free water at the public access faucet, the very low pressure and randomly-treated water affected a large population.

During the 2007 trip, the students mapped the ELWA compound and searched for distribution boxes containing water meters which marked branches from the water mains into buildings. They measured and recorded pressures and flow rates at each of these branches. They used surveying equipment to measure locations and elevations. They also examined the 5000-gallon pressure tank and observed the pressure fluctuation during shutdown, and also noted the corrosion (i.e., rust). The students measured the flow rate at the only working public faucet which ELWA provides for local villagers. The faucet is open non-stop because locals are continuously filling their vessels—and because the shut-off valve is broken. The students measured pressure and timed vessels filling to measure flow rate.

The students also observed the pumps in operation. The pumps ran continuously during the 18 hours when power was on. They seemed to be operating chronically below their rated pressure. The students noticed and repaired a leak in the high-pressure line between the pump and the sand filter located in the pump house.

For their 2007-08 capstone senior design project, a group of five mechanical engineering students modeled the entire ELWA campus water system so they could understand operational problems and simulate the effects of specific improvements. Their model solved over 500 equations. They also designed and built an automatic injection system for disinfecting the water using sodium hypochlorite or calcium hypochlorite (chlorine).

E. Facilities Survey and CAD Documentation
The purposes of the grounds survey and CAD documentation were to supply ELWA with an up-to-date facilities map; the map was also needed to record the location of the water lines so we could document the water distribution network for next year's senior capstone project.

First, the appropriate software was sought out. To be economically feasible for ELWA, it had to be very low cost and have moderate computer system requirements, since most of the ELWA computers were of the older vintage. It also had to be easy to learn so that someone with a high-school education could learn and use the software. It had to have the functionality that makes features like buildings, roads, and electrical and water lines easy to represent, and
layers so unnecessary information could be turned off. After examining several different codes, the 
software package Cadvance was chosen. There was an older version of the software available free of 
charge.

The ELWA leadership was very pleased with the resulting map, and when they saw how easy it was to 
use, they were eager to learn. We gave them several copies of the revised site map and installed the 
Cadvance source code on their computers. We have updated the map and posted it on our website for 
them to download.\textsuperscript{14}

**Ministry Excursions to the Bush**

To enhance immersion exposure and participate in the spiritual ministry amongst Liberians, we worked 
into the itinerary an opportunity for each student to participate in an upcountry overnight trip to the bush. 
These trips were also great opportunities for team members to understand rural life and learn how 
engineering projects might improve it. On each trip, one professor and four students accompanied a 
church leadership training team that included our liaison going to remote locations in Liberia. Rural 
villagers showed us their farms, cooking methods, food drying, and construction materials and techniques 
for erecting buildings. The students ate locally prepared food and lodged in rural dweller's homes. A 
typical rural dweller's home is made from bamboo-reinforced mud-filled walls covered by thatched 
and/or corrugated galvanized steel or aluminum roofs. The floors are typically packed dirt. There is no 
electricity or running water. The towns we visited had wells, but half of the wells were not producing 
water because they were either dry or inoperative. Wells that were dry were typically dug in the rainy 
season. Future project ideas such as solar cooking were discussed. Due to time constraints, this informal 
process was not as comprehensive as a full participatory rural appraisal.\textsuperscript{15}

One team took a three-hour hike into the jungle to check out a 
potential site for a mini-hydro electric power plant. Our guide 
was an education victim of the civil war—he was 22 years old 
but had a 5th grade education. He worked as a diamond miner 
and on the return trip took us by way of the site they were 
mining; he seemed honored to introduce us to his coworkers. 
We passed through his village and asked to see their well. It 
was 75 feet deep and was drilled by an NGO and capped with 
concrete. A robust manual pump drew the water.

This team drove further to the border of Sierra Leone and spent 
a second night in another village. The drive over treacherous 
dirt roads, through deep mud puddles, and over log bridges was 
an experience none of them will ever forget. When offered a 
chance to return to Monrovia on the second day with the other 
vehicle, none of the students wanted to return—they all wanted 
to venture further into the bush, knowing that they would be 
traveling in very cramped conditions. The reception the 
villagers gave Ray, who had lived among them 20 years ago, is 
something none of us will ever forget.

These excursions were not only for adventure and fact-finding. The Lord has gifted Ray Hutchison in the 
area of providing training for rural church leaders in conjunction with the leaders of ECUL. It is very 
effective for Ray to team teach the faithful ECUL rural church leaders in 1-2 day conferences. Taking 
students from the Cedarville- Liberia connection along on these trips is strategic for several reasons:

- It encourages the Liberian Christians who attend the conferences. Liberians are very hospitable 
  people and they feel greatly honored to entertain guests – especially guests from the West.
• It helps the students better understand the transportation challenges in Liberia.

• It affords the students the opportunity to gain a different perspective concerning life in Liberia. While staying on the ELWA compound they stay in accommodations that are similar to what they are used to in the United States. Rural areas are more rustic and the amenities are much more Spartan. This experience enables the students to “rub shoulders” more closely with Liberians and experience the way most of them live, and affords the potential of discovering simple solutions to help improve the quality of life for Liberian people.

• It enhances the opportunity for the students to experience the culture of Liberia through conversing with Liberians and observing rural life during the “after conference” hours.

• It provides the opportunity for building relationships between Cedarville students and Liberians.

Unexpected Dessert

During our stay in Africa, the team of students, professors, and liaison were invited for meals into the homes of Africans, typically the administrators and workers at ELWA. We were served typical African meals — which means lots of pepper. After dinner, we interacted with the Africans, hearing presentations on topics such as AIDS in Africa. Some evenings we heard first-hand reports of survival during the 14 years of civil war that ravaged their country. It was difficult to fathom what it was like during those times when more than 200,000 people in a country of three million lost their lives. Shortages of food and fuel were rampant, as were accounts of barbaric raids by ruthless young men with guns. At one point in the war, rebel soldiers occupied the ELWA campus and looted at will. Many people were forced to flee on foot with nothing but the clothes on their backs. These first-hand accounts of survivors of the war had a sobering effect on the students — and professors!

Resulting Global Perspectives

This trip and the design experience leading up to it had a significant effect on the student perspectives regarding both ministry and engineering in the global context. Four of the eight students responded to a survey distributed 11 months after return from Liberia. For questions 1 – 3, the scale of 1 (very little) through 5 (profoundly) was used.

1. How has this trip affected the way you look at the world? The student responses averaged 4.3.

2. How has this trip affected the way you think about engineering design? The student responses averaged 3.8.

3. How has the trip affected the way you pray? The student responses averaged 2.8.

4. How much have you communicated with friends made in Liberia? The student responses averaged 2.0 on a scale of 1 (once or twice), 2 (from time to time), 3 (monthly), 4 (weekly), and 5 (daily).

5. Has this trip increased your interest in serving overseas in the future? The student responses averaged 4.8 on a scale of 1 (much less likely) to 3 (the same) to 5 (much more likely). The only student who did not answer “5” had made a prior decision to do so.

Ministry Perspective

[from R. Hutchison] It was a thrill for me to be a part of the Cedarville-Liberia connection. To serve the church and people of Liberia in a more effective way has been a dream for a long time. The partnership between SIM (the mission agency with which I serve), the Engineering Department at Cedarville University, and ELWA Ministries and ECUL in Liberia has been that dream becoming a reality.

I am excited to be a part of this joint venture because it brings hope and help to a nation and to a Church
that has suffered a great deal as a result of a long and horrific war. Through this arrangement very
competent professors and students of engineering brought to bear their knowledge and experience on
wide spread problems. Their completed projects brought a great deal of encouragement and hope to our
partners in Liberia.

I very much enjoyed being a member of the first installment of this partnership. While I was able to use
my expertise in bringing cultural insight to the other team members, I was thoroughly impressed with the
magnitude of preparation each had put into this two-week venture. Each of my fellow team members
worked very hard at accomplishing his projects but equally demonstrated his desire to build relationships
with and learn from his new Liberia friends. Working side by side with Liberians as opposed to just by
himself promoted mutual learning. Each one did his work well and used joint experience to foster mutual
understanding and respect. My Cedarville partners did their best to stay within cultural parameters so as
to not offend the people they came to serve. They readily accepted invitations to enjoy meals and
hospitality in the homes of their new Liberian friends. They were respectful of one another, as well as
their Liberian and expatriate hosts. They listened attentively as Liberians shared their stories of hardship
during the years of war.

The projects that were chosen were strategic. Some were designed to meet felt needs in a land with many
felt needs. Others focused on addressing real needs behind the felt needs. Some have the potential of
being turned into micro-enterprise ventures which could train and employ Liberians who are currently
suffering with an 85% unemployment rate. All the projects were pursued with appropriate technology
and the availability and affordability of local materials in mind.

I enjoyed traveling with my Cedarville partners and our ECUL hosts in our excursions into the interior
part of the country for pastor’s training conferences and for a trip back to a village where my family and I
lived and ministered during our days as missionaries in Liberia. Although the accommodations were
sparse, my Cedarville partners graciously accepted the warm hospitality offered by our Liberian hosts.
They took time to play with children. They asked good questions and did their best not to offend their
hosts. They showed appreciation for all that was graciously offered to them and did not complain when
hungry, tired and uncomfortable. Our trip into the rural areas provided the richest opportunity for culture
learning for my Cedarville partners.

It was a great privilege to serve the people of Liberia with this first team from Cedarville University. I
look forward to accompanying many more teams in future years in the Cedarville-Liberia connection.

Summary

[from L. Zavodney and T. Thompson] In this paper we have provided details of how we developed a
program to give engineering students, as part of their engineering education, a cross-cultural ministry and
engineering design experience that immersed them into an African developing-country culture. We have
identified the necessary infrastructure and resources at the home institution and the receiving institution
abroad. We have summarized the major logistical details of making such a program a success and have
provided a criteria for choosing projects. We have also documented the results of our survey trip and our
pilot program, which from our assessment, the student feedback, the response of the institution abroad,
and our liaison, was very successful. The SIM host missionaries' nontechnical assessment of our work
and the overall impression we made has been posted on their June 3, 2007 blog.17

The team of eight students and two faculty advisors, along with African co-workers, completed the
following engineering design and service projects:

- designed and installed a power station cooling system, including a catwalk,
- designed, fabricated, and delivered 10 solar-rechargeable reading lights,
- chose a design and built a medical waste incinerator and dismantled the old one,
- evaluated and selected an appropriate CAD system for Liberia,
• transferred existing engineering drawings to CAD and updated them,
• surveyed and mapped the water system on the 134-acre campus (6+ miles of pipes),
• delivered the first laptop computer to the school principal, and
• conducted a hands-on seminar for high school students promoting engineering as a profession.

We had only 10 working days to complete these projects. Our schedule was further complicated by the weather — we were there during the rainy season, and most of our work was outside. Each student and one professor was gone for at least two working days for a trip to the bush. We were asked to build the catwalk for the cooling system and conduct the “What is Engineering” workshop and live call-in radio show after we arrived. We also had eight group meals that included extended cultural or historical presentations and discussions.

[from R. Hutchison] The Cedarville-Liberia connection has provided a greatly needed shot in the arm of encouragement to the ELWA Ministries, the Christian organization with which SIM partners in their institutional work (radio station, hospital and school) in Liberia. The team from Cedarville provided much needed technological expertise in the areas of power generation, hospital waste disposal and water distribution. The team also brought along some much needed resources used in carrying out the projects. While competent in many areas and fully committed to the Christian purposes of Radio ELWA, ELWA Hospital and ELWA Academy, the leaders and workers face huge challenges in repairing, maintaining and expanding the infrastructure undergirding these ministries — ministries in Liberia which have a have a long history of providing excellent spiritual, medical and academic service to the people of that nation. Delivering messages of hope and salvation, and providing solid biblical teaching as well as public service announcements has been an important role for Radio ELWA. The ELWA Hospital has had a reputation of being one of the finest providers of medical care in the entire nation. And ELWA Academy is providing a great service to the nation of restoring the opportunity of education from a Christian perspective to a people which suffered the loss of the best and brightest and the disruption of the educational system due to many years of war.

In addition to supporting these ministries, the team from Cedarville provided something else that is at least as important. The members went to Liberia with open hearts and minds. While anxious to implement the projects they had worked on for an entire academic year they wanted to do so in a way that afforded them the opportunity to value and learn from ELWA ministries personnel. The students worked wonderfulely side by side with their counterparts to learn from them and to listen to their stories of great trial through the years of war. The Liberian leaders and workers greatly appreciated the servant/learner posture of the Cedarville team while they, themselves, also obtained new knowledge and skills to better enable them to carry out their tasks.

Future Work

The model we have presented here lends itself to annual trips to Liberia. The intention is that each year the team will identify new projects for future teams. The survey trip in 2006 identified 14 projects; during our 2007 trip we started on six of them and completed five. During the 2007 trip we discussed new projects to put on the list and also identified the most urgent needs in their eyes. Two of the eight students who went in 2007 also went in 2008 and provided some continuity.

During the 2007-08 school year, a team of five seniors worked on the water system, including modeling the system, designing an automatic passive chlorine injection system, and investigated the feasibility of generating sodium hypochlorite electrolytically from the abundant supply of ocean water available to ELWA. Other students designed and built the next generation of solar rechargeable night reading lights for rural pastors enabling us to take over 50 lights this year. We also assembled and installed a computer network for the ELWA Academy and began working on a solar oven.
The 2008 team took over supplies to upgrade the water system; this included two deep-well submersible water pumps, controllers, most of the plumbing supplies, and strain gages to perform a stress test on their water storage tanks. They installed one new pump in an unused well, installed new plumbing, installed new electrical service in one pump house, and provided some much needed maintenance on the main water storage tank that was rusting and leaking. They patched over a dozen holes, pressured washed the inside, removed a lot of rust, and painted the support areas. The 2008 team also upgraded the incinerator and provided some training on how to use it, and performed some maintenance on the generator cooling system by removing the algae and unlogged some of the small holes on the spray heads. Overall, the system is working extremely well. We also met with the ELWA Administrative Team to discuss projects for next summer and after. The intent is to continue this wonderful relationship every summer working on projects suited for students.

Conclusion

In conclusion, we have provided our engineering students with an immersion cross-cultural ministry and engineering design experience as part of their undergraduate engineering education. The design experiences ranged from an upper-level (curricular) senior design capstone project to underclass (extracurricular) design projects. Unique to this design experience was that the engineering had to be put into a majority-world developing-country cultural context. Probably the most obvious constraint was the limited choice of raw materials and very little in the way of funding for the projects. Also, the education level of the end user and maintenance personnel constrained our many design options. What may have been the obvious choice based on technical merits alone played second fiddle to cultural considerations. (The recommended cooling system was not selected, nor was the recommended design of that cooling system.) If a design's operation is unclear to the recipients, or if it needs repairs they cannot perform, it will soon fall into disuse.

We also requested that Liberian workers work alongside the students, assisting them and helping them find resources to complete their projects. The Liberians also taught them many things, such as how to mix concrete—without a mixing container. They taught one of our students how to stick weld. During those working hours, they talked about many things.

The students were motivated to go. They attended the weekly meetings to prepare for the trip, completed their projects in a timely manner, and helped each other. The planning that went into the trip was necessary to scope the projects, organize the work and schedule, and was crucial to satisfactorily completing all of the projects.

On the return trip home the students filled out an evaluation survey of their experience, including their assessment and recommendations. The unanimous highlight of their two-week experience in Africa was the overnight trip to the bush!

When asked if, knowing what they knew after the trip was completed, would they do it again, they all said yes emphatically! Two of the students returned in the summer of 2008. When asked what they would
change, the answer also surprised us; they did not want to split up the group on the out-of-town trips. Further probing revealed what they really meant was that the group that spent two nights in the bush seemed to have had more adventure, and they wished that the other team members could have had a similar experience driving over the treacherous unimproved dirt roads and log bridges. There certainly was a sense of adventure.

We were extremely pleased with how well the students behaved on this trip—there was no a single complaint. There was a wonderful spirit of helpfulness and self-sacrifice that characterized the manner in which the team members conducted themselves. They went out of their way to interact with their Liberian co-workers, not only to teach them new things, but also to learn from them. Even though the food was often very spicy, they still received it with gratitude.

Acknowledgments

This experience would not have been possible without the encouragement over the past eight years of our liaison Mr. Ray Hutchison, who lived in Liberia working with SIM during the 1980s before the civil wars. He provided the preliminary cross-cultural orientation for the team and lead the team excursion to the bush. SIM provided the people to serve as our hosts in Africa—Dr. Rick Sacra and his wife Debbie—coordinating our schedule, meals, after-dinner team meetings and cultural discussions, and transportation in Africa. The ELWA management team, headed by Mr. James Kesselly, also welcomed us warmly as they did during our survey trip in 2006. Mr. Augustine Kollie, the Services Manager, provided all of the Liberian helpers who assisted and worked with us.

Logistical help with passports, visas, travel arrangements and tickets, immunizations, and travel to and from the airport were provided by the MIS and UMS offices. This trip could not have been possible without our graduates Earl Girouard and Alan McIver, our students Nathanael Barham, David Bennett, Greg Briggs, Tyler Ruegsegger, Scott VanDyke, Mordecai Veldt, and the generous support of many individual donors who provided the $32,000 to fund this trip. Specific answers to supporter's prayers were felt on many occasions.

References


[16] See, for example, the Confession of a Warlord at http://www.foxnews.com/story/0,2933,324195,00.html.

Lessons Learned: Developing Flight Tracking and Messaging Systems for Christian Nonprofit Organizations

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Abstract

Since the dawn of missionary aviation in the late 1940s, missionary pilot’s spouses have kept track of an airplane’s safe progress during flight by listening to the crackle and hiss of a high frequency radio. They would wait by the radio all day long for voice position reports made by the pilot en route. While visual reckoning of the pilot’s position sufficed for decades, technologies like the Global Positioning System (GPS) and radio data links now promise more reliable information on flight status.

Commercial aircraft have used a sophisticated digital data link system for years, but a Christian missionary organization named JAARS, sending small planes into remote locations for Bible translation work, has more recently developed a simpler, lower-cost solution. Nevertheless, this system has failed to attract investment by the broader aviation community. Thus, for the past three years, senior students at Messiah College have developed alternative solutions for Mission Aviation Fellowship (MAF) and United Indian Mission (UIM), under the counsel of Mission Safety International (MSI), by taking into account the specific needs and policies of each organization in the field. MAF replicated one of the prototypes for further testing, but a version that completely satisfies field requirements has yet to be achieved.

Currently, Messiah is cooperating with JAARS to adapt their low-cost system to the specific needs and policies of MAF. Faculty and students have been motivated, beyond the academic requirement, to invest and develop technical talents so as to serve organizations that spread the gospel of Jesus Christ, in word and deed, and specifically to support pilots who put their lives at risk.

This paper reviews the previous flight tracking and text messaging projects at Messiah College, and emphasizes how 1) current project continuity has been enhanced by the Integrated Projects Curriculum (IPC) implemented in the Messiah College engineering curriculum, 2) cooperating across multiple organizations using field-proven technology retains broader satisfaction among users while engineering adaptations to meet specific organizational needs, and 3) designing for broader marketability gives engineering students realistic experience that better serves the wider missionary aviation community. In conclusion, the concepts illustrated here may serve other Christian engineering educators attempting to establish or maintain projects involving faculty and student participation, especially those that meet needs overlooked by the secular marketplace.
Introduction

This paper documents the authors’ joint experiences with a collaborative relationship between missionary aviation organizations and an academic engineering institution for the purpose of reducing operational risk in fulfilling the Great Commission. In section II, Cary Cupka provides a briefing on the history, motivation and particular need for this missionary aviation work. Then in section III, he identifies some of the complexities and simplification strategies behind such collaboration. In section IV, Harold Underwood reviews projects on flight tracking and messaging undertaken by Messiah College students. In section V he highlights some key aspects of the institutional structures that enable this collaboration and help address real-world problems encountered in the course of the work. In section VI, he summarizes and draws conclusions about collaborating between a Christian engineering school, and a partner, and offers some suggestions.

History, Motivation and Need

The projects on which this author has worked with Messiah College Department of Engineering have been for the benefit of missionary aviation. Missionary aviation serves to connect emerging churches in developing countries with established churches in developed countries. Missionary aviation also includes a humanitarian relief and community development facet connecting relatively affluent donors with needy recipients. These connections generally cross geographical barriers using air transportation and wireless communication technologies.¹ ²

Historically, missionary aviation technology consisted of surplus military and recreational airplanes (two – six seats typical) and radios adapted for use on the mission field. More recently, purpose-built aircraft have been developed for missionary aviation, and the venerable High Frequency radio of WWII vintage is being modernized and integrated with commercial telecommunication networks. Additionally, the application of Global Positioning System (GPS) technology to missionary aviation made significant improvements to navigation and flight tracking.

Flight tracking is necessary because missionary airplanes routinely operate in uncontrolled airspace not monitored by civil aviation radar or commercial radio systems. (For the significance of this risk, please refer to the Steve Fossett story.²) Flight tracking serves two general purposes. First is a safety purpose to facilitate search and rescue operations should an airplane fail to arrive at the planned destination. The safety purpose is a service normally provided by civil aviation authorities. Second is an efficiency purpose to coordinate changes to the flight itinerary while an airplane is en route. The efficiency purpose is a service normally provided to airlines by commercial companies organized by a global standard known as Aircraft Communications Addressing and Reporting System (ACARS).³ The safety purpose is known as the “flight following” function and the efficiency purpose is known as the “dispatch” function.

Provisional flight-following and dispatch functions in remote airspace have been historically performed by missionary aviation operators using voice over High Frequency (HF) radio. Before GPS, the missionary pilot would fly over a landmark en route, plot a current position using an aeronautical map in the cockpit, and then report that position using the HF radio to another radio operator located at home base. After GPS became standard equipment, the pilot would periodically (e.g. every 15 minutes) read the coordinates off the GPS navigator in the instrument panel. Because of the “pilot in command” aviation principle,⁴ an essential part of this tracking process is the read-back of the coordinates from home base to the pilot to confirm that the flight track was being accurately logged. HF radio (which can “bounce” a radio wave between the ionosphere and the earth’s surface to propagate literally around the globe) has been preferred because of its relatively low operating costs (compared to satellite telephony) and low
infrastructure requirements (compared to more modern line-of-site radios which require remote repeater stations to transmit over the horizon).

Over a decade ago, a missionary aviation organization named JAARS\(^5\) launched a project that integrated the HF radio’s which they were already using with wireless modems.\(^6\) This integration allowed data or voice transmission from the same HF radio and made a giant step toward crudely imitating ACARS at a fraction of the cost. The JAARS Automatic Flight Following System (AFFS) added two basic components to the new HF radio data link: a pilot interface unit located in the airplane’s instrument panel near the GPS navigator and a software program for the home base radio operator’s personal computer. Inside the airplane, a data output from the GPS navigator to the pilot interface unit is transmitted over the HF data link. On the home base computer, the airplane’s flight track is automatically generated on a moving map graphic display. Not only can the current aircraft coordinates be automatically logged at home base and acknowledged to the pilot at a specifiable periodic rate, but other GPS navigation information from the flight log will now be available to a search and rescue coordinator should the need arise. This flight following information (such as the intended destination, the next waypoint, altitude, speed, ETA, etc.) greatly increased the chances of finding a downed aircraft in a timely manner. Additionally, dispatch communication was augmented with short text messaging to expedite operational protocol.

AFFS was fielded by JAARS in 1999 to several bases of operation, and subsequently found its way into a few other organizations’ flight operations. While the JAARS AFFS set a new standard for flight tracking, the lack of widespread adoption by the missionary aviation community has been disappointing. Mission Safety International (MSI)\(^7\) moved in 2006 to create a project that would promote both the awareness of risks and AFFS benefits in the missionary aviation community.\(^8\)

**Complexities of and Simplification Strategies for Collaboration**

The present partnership between MSI and Messiah College remains an informal one coordinated by the authors of this paper. Our collaboration includes the Messiah College engineering students and the missionary aviation organizations we are seeking to benefit.

MSI’s purpose in this project is both to promote the flight following enhancements AFFS provides and to promote the safety benefits of purpose-built equipment. Our hypothesis is that tools tailored to intrinsically fit the missionary aviation environment will more adequately manage operational risks.

Further complicating this project is the fact that some of the equipment being developed resides in one of the most regulated industrial sites in the world—an aircraft cockpit. While the equipment in this project does not require certification by the civil aviation regulator, the form and function of the equipment must “do no harm” to either the aircraft systems or the pilot’s workload in operating the airplane. AFFS has already been approved by the regulator and proven acceptable in the field environment.

There have been several distinct simplification strategies in our approach. The first is logistical. We require the internal hardware and software changes made by the students to strictly emulate the original equipment. The second is structural. We are exchanging the traditional technology pipeline approach\(^9\) represented by e.g. the GA Tech venture lab\(^10\) for a practice-centered design approach\(^11\) represented by e.g. the Ohio State Cognitive Systems Engineering Lab.\(^12\) Third is a strategy to align this iterative, distributed, asynchronous process of human-system design. We are using the Incremental Commitment Model proposed by the National Research Council\(^13\) to manage project risks. The fourth strategy is legal. We are at least delaying some of the problems\(^14\) associated with university intellectual property (IP) by working under a non-disclosure agreement
of the original AFFS IP. MSI is proposing that the modified AFFS IP be registered under the GNU General Public License which might best fit the spirit of our collaboration while protecting our individual interests.

These strategies promise to harness the technical expertise of a laboratory environment while keeping focused on the field and the artifacts with which missionary aviators accomplish their work.

Overview of Messiah College Project Contributions

For over a decade, Engineering educators at Messiah College have sought to form, and follow up on relationships in the local and broader worldwide community, so as to identify technical needs not otherwise being met by a partnering organization. Such projects have helped both faculty and students engage in opportunities to address real engineering problems, in a service-learning and experiential mode that goes beyond textbook exercises. The advent of a schools structure at Messiah has facilitated the networking of certain interdisciplinary resources toward this goal, by combining the Mathematics, Engineering and Business Departments into one unit known as the School of MEB. Dr. Ray Norman, formerly national director for World Vision International in Mauritania, has served as the first Dean of this MEB School, having filled the position since Fall of 2002. Thanks to Ray Norman, Engineering Department faculty at Messiah College established contact with Partners in Aviation and Communications Technology, International (PACTEC). This partnership eventually led to involvement with Mission Aviation Fellowship (MAF), MSI, JAARS and UIM International, related to their need to develop communication technology for aviation in remote locations. In January 2005, an author of this paper, Harold Underwood, partnered with PACTEC on a short term basis, to observe how they are working with technology at home and in the field. While on the field in Kabul, Afghanistan, conversation with a PACTEC pilot revealed his need and significant desire to more fully realize the benefits of existing GPS-based flight tracking technology, and the hope that students at Messiah College could help make this happen. Cary Cupka, Research and Development Coordinator for MSI, also contacted Harold Underwood during this time, suggesting that a need existed to bench-test such technology, and Messiah Engineering agreed to serve by offering its resources to help fulfill that need. Thus, in the interest of promoting pilot safety and satisfying concerns of pilot families, the prospect of making contributions to flight tracking and messaging technology was brought home to student senior project groups at Messiah College, who, over the past three years, have strived to address such needs, as communicated by contacts with MAF, UIM, JAARS and MSI.

The first project team, working during the 2005-06 academic year, consisted of four engineering seniors, advised by Carl Erikson, with consulting input from Cary Cupka. This group became known as Alternate Aviations Solutions (AAS), a name that has stayed with successive teams following up on work in this area. One of the student team members held an Amateur Radio Extra-Class license, and significant prior experience, which became an asset to AAS 06, helping it “get off the ground” by developing a system to meet expressed needs of MAF, related to the High Frequency (HF) Codan NGT radios recently installed in many MAF planes. AAS 06 focused on building an inexpensive module that translates GPS coordinates transmitted by the Codan radios, into a format more readily displayed by inexpensive mapping software on the ground. It also designed a request feature into the dispatch (ground monitor) unit, for an automatic transmission of GPS data from the aircraft. A working prototype has since been replicated and is the process of being field-tested by MAF personnel, in Sentani, Papua, Indonesia (based on a 2007 email from Tim Dyk of MAF; unreferenced, see “Acknowledgments”).

The AAS 06 succeeded in meeting its main objectives for the project by producing the prototype of a translator module at a cost of $72 per dispatcher station. This cost covers two Atmel
ATmega16 microcontrollers, PC board expenses, connecting cables and instrument case. The instrument case measures approximately 6 x 6 x 3 inches, and includes buttons for position request and reset, LED status lights, and external RS-232 ports for connection to computer (for position display) and the Codan NGT. The device is powered from an external 6-12 volt AC input through an on-board 5-volt regulated DC power supply. While AAS 06 demonstrated functionality of the translator system for plotting the position of a remote NGT transceiver, using available mapping software, it had several suggestions for future work: internet connectivity to provide pilot location access to family and friends, and a flight-deck interface for the pilot directly; the multiple aircraft tracking capability typically needed by a dispatcher; batter power for full portability; data logging and a simpler display (e.g., LCD) option. It was thought that these improvements would make the device more useful to MAF in the field.

During the 2006-07 academic year, a second team of three engineering seniors formed, known as Continuing Alternate Aviation Solutions (CAAS, a.k.a. AAS 07), under the supervision of Harold Underwood, with continued input from Cary Cupka. Given the options, AAS 07 eventually decided to address the slightly different expressed needs of UIM, while MAF replicated and field-tested the prototype contributed by AAS 06. Since HF radio is prohibited in Mexico, where UIM works, a satellite approach links the pilot to the dispatcher on the ground. Thus, AAS 07 focused on the design and construction of a Pilot Interface Module (PIM), capable of adding one of several preset text messages by a pilot to the transmission of GPS and other flight data, through a satellite modem, and an enhanced display of tracking information for the dispatcher. 

Although the AAS 07 team achieved modest success on its main objectives, producing a functional PIM unit, it ran into certain difficulties on the sending and receiving ends. The message format turned out to be incompatible with third party software required to run the modem, and the location and message information on the website of the satellite service provider proved difficult to access for continuous tracking. The PIM designed and constructed by AAS 07 consists of a plastic case, 6 bicolor LEDs with associated toggle switches to select among preset messages, clear and send switches, a confirmed indicator, RS-232 connectors and other associated electronics. The PIM interfaces with the existing satellite modem, including its built-in GPS unit, on-board the aircraft. The PIM’s plastic case measures approximately 8 x 6 x 2.5 inches in size, powered by the 12 volts available from the satellite modem. Although it might be refined much further, the biggest drawback of the PIM in this design, as an on-board aircraft application, is that it does not build upon existing, tested, aircraft technology or flight-deck specifications. Thus, this version of the PIM lacked the form-factor, indicator visibility, and ease of use to meet pilot user-interface safety standards, desired by MSI or UIM. Thus, while this team’s main objectives were achieved, the PIM did not fully satisfy our partner or client.

Learning a lesson from past AAS project experience, the most recent team of engineering seniors, AAS 08, turned to modifying the AFFS, as encouraged by the authors of this paper. While the AFFS represents a pilot-tested and fully functional system, with display panel and form factor compatible with aircraft standards, its rigidity has kept it from being adopted more fully by the mission aviation community. Interoperability with Codan radios would make the AFFS more flexible, broadening its marketability, due to widespread usage of Codan radios by MAF in its fleet. Although it currently owns intellectual property (IP) rights of the AFFS, JAARS has cooperated generously to advance such work. Thus, while Messiah College itself is still formalizing general policies about nondisclosure agreements (NDAs), a specialized NDA reached between JAARS and Messiah College during Fall 2007 allowed AAS 08 to modify the AFFS, under certain conditions. The NDA as established allows JAARS to retain its IP rights, while AAS 08 at Messiah College adapts it to the needs of MAF. AAS 08 has replaced the PACTOR modem with functionality through the Codan command set, with an option to transmit voice and
data on separate frequencies. However, for new units of JAARS AFFS to be manufactured and marketed, beyond the number currently owned and used by JAARS, the now obsolete BL1500 microcomputer must also be upgraded. This upgrade turned out to lie beyond the scope of AAS 08 due to its time limitations; thus, upgrading the JAARS AFFS remains left for the future work of upcoming students.  

Students and faculty working on the aforementioned AAS projects have prayed that their work will help spread the good news of Jesus Christ in word and deed on the remote fields where these organization work, by contributing to improved safety via enhanced tracking and messaging capability of pilots. Thus, the teams have dedicated their efforts not only to satisfying the academic requirements of the senior project, but to the broader goal of supporting the missions of PACTEC, MAF, UIM, JAARS and MSI, in spite of the difficulties presented by variations in organizational policy, realities of practice on the field and the changing face of technology itself. However, the preceding account of project work related to flight tracking and messaging reveals inherent difficulties, not only in designing the technical product to meet the need of a client, but also in artificially limiting the solutions of such a real world problem to the cycle of the academic calendar, and surviving “brain-drain” related to turnover of graduating seniors.

A focused treatment over a three year period on flight tracking and messaging would not even have been likely, were it not for the development of the Collaboratory for Strategic Partnerships and Applied Research, at Messiah College. This new organization became reality when, “In 2000 the Provost of Messiah College authorized the formation of the Collaboratory to organize longstanding co-curricular service projects under the leadership of several faculty members in the Department of Engineering. Haresco Corporation awarded a lead grant to form the organization.” Currently, the Collaboratory is centered in the School of MEB, with the intention of enhancing “classroom instruction by providing students and educators with opportunities for service in the context of scholarly engagement.” Participants in the Collaboratory “apply academic knowledge and express value commitments through creative, hands-on problem solving that meets needs brought...by client organizations, businesses and communities.” Vision for the Collaboratory involves “Increasing hope and transforming lives through education, collaboration, innovation and service,” supported by other foundational statements related to the Collaboratory mission, identity, core values, and program strategies. To more closely tie Collaboratory activities of students and faculty into the formal engineering curriculum, and alleviate the aforementioned problems (limitations of the academic calendar and brain-drain due to graduation) inherent in the traditional senior project approach, an engineering curriculum innovation has recently been implemented as described in the next section. It is hoped that this curriculum development will further enhance future work on the flight tracking and messaging project reviewed in this paper, other ongoing projects like it at Messiah College, and serves as a model for other schools.

**Messiah College Engineering Department Curriculum Development**

Following inception of the Collaboratory in 2000, plans for curriculum innovation in the Engineering Department at Messiah College emerged, enabling faculty and students to take better advantage of Collaboratory resources. To foster continuity and focus attention, faculty formed specific groups, including Communications, within which project work would occur, under the supervision of a qualified advisor. Each group uses a wiki page to describe its mission, vision and particular project opportunities. Plans for the curriculum development known as the Integrated Projects Curriculum (IPC) matured, and finally received department approval. After approval, IPC began to be implemented over a 3-year transition period, beginning with the Fall 2006-07 academic year. For students, the IPC begins with a preparatory 1 credit course known as Group Orientation, taken by most students during the second semester of their sophomore year,
when they must commit to a Collaboratory Group, and get introduced to basic issues related to its focus and project work. Following Group Orientation, the students enroll in a sequence of four successive one-semester, one-credit courses known as Project I, II, III and IV. Each of these Project courses function as a once per week, 3-hour lab. This four semester Project sequence effectively replaces the traditional two-semester Senior Project courses, and allows students to spread out work on a real world project to two years or more before graduation, rather than just one. Although a more detailed description of IPC may be found on its wiki page, a few key features of this work in progress are described here. IPC enhances continuity and longevity of projects, by the overlapping and tiered nature of student work, enabling student leadership at the upper levels to pass down knowledge and expertise to students at lower levels. Upper level students also practice project management skills by helping define and assign tasks to the lower level students, under supervision of the faculty advisor. During the transition period, traditional senior projects have continued to operate within a $500 budget from the department. However, expenses of project work within groups of the Collaboratory have been being increasingly funded by specific donors and funding sources cultivated by individual groups themselves. Structures of the IPC are still under development, and experience too limited for a complete report at this time.

The Collaboratory and IPC work together to increase project continuity and longevity, while limiting the negative impact that the academic calendar and graduating student turnover may have on the quality of service rendered. Both clients and partners on the flight tracking and messaging projects stand to benefit. For example, sophomore students following up on upgrades and modifications to the AFF, for manufacturability and broader marketability, will have at least two years to address the necessary phases of this project work, rather than being artificially driven by the creative design requirements of the traditional one-year, two-semester Senior Project course. Thus, a better match between the project phase associated with client need, and flexibility of students to address that need, should benefit all parties involved; yet partners and clients alike who recognize the educational mission of the Collaboratory and IPC, will need to accept the slower progress of this kind of voluntary work than that which occurs in the marketplace.

Summary and Conclusions

Toward the goal of spreading the love of Jesus Christ in word and deed to the broader worldwide community, the authors of this paper, sharing a common concern for pilot safety issues, have found an informal partnership between MSI and Messiah College a profitable one, to enhance project work conducted by engineering students and faculty over the past three years at Messiah College, on developing flight tracking and messaging technology for the specific needs of MAF and UIM. In a recent development, Messiah College has entered into a Non-Disclosure Agreement with JAARS, in an attempt to adapt AFFS for interoperability with the Codan NGT radios used in many MAF planes. In general, such an agreement is necessary and practical to protect and/or arrange for the IP rights of interested parties. While AAS 08 has demonstrated interoperability through its modifications to AFFS, it has left an upgrade of the obsolete microprocessor for the follow-up work of upcoming students. An upgrade of the AFFS microprocessor will be necessary in order to make new units of this device available to the broader aviation community or at least of marketable interest to MAF beyond JAARS. Certain aspects of developing our informal partnership may be generalized for consideration by other schools who wish to establish similar project partnerships (not necessarily in this order): networking with contacts among Christian missionary and humanitarian aid organizations helps identify needs that might be met by engineering technology, and communicates what the engineering school may have to offer; selecting an opportunity requires prayerful consideration, patient persistence, a mutual agreement with a representative of the organization and a match been the need and resources available at the engineering school; planning a site survey to personally visit the field and meet workers on the forefront increases motivation and provides
pictures and information to present to potential participants; changing organizational and curricular structures on the academic campus may be necessary to help foster continuity and focus attention by faculty and students, facilitate funding by donors, and encourage a long term partnering relationship.

Inception of the Collaboratory for Strategic Partnerships and Applied Research at Messiah College, along with the development of the Integrated Projects Curriculum (IPC) in the Engineering Department, has already enhanced project continuity and longevity, although IPC is still in initial transitional stages of implementation. We believe these developments will increase the quality of service students and faculty render to their clients, by lessening restrictions of the academic calendar, and mitigating turnover-loss of graduating students, as suggested in the example of the flight tracking and messaging projects reviewed in this paper. The Collaboratory facilitates continuity of specialized Groups such as Communications, and the IPC enables upper class students to exercise leadership and project management skills, while passing down accumulated project knowledge to lower-class students, beginning project work at an earlier stage in their engineering curriculum than under the traditional senior project plan. A complete assessment of experience with the changes, including student feedback, is not yet available for this work in progress, but initial feedback on major aspects is positive. Other engineering schools may consider whether aspects this model fit their institution.

An engineering school that partners with a non-profit organization to meet a technical need has benefits for all parties involved. The engineering school gains expertise that the organization has to offer based on experience and real ongoing field work. The non-profit organization benefits from the human resources and innovative ideas brought by students focused on project-work, as a part of their academic degree, and the bench-testing students can do using lab facilities and equipment, on-campus. Engineering students benefit from the motivation and experience of working on a real-world engineering project, in a service-learning mode, addressing issues that go beyond textbook exercises. Difficulties do arise in making sure each party fully realizes their benefit, and in maintaining a harmonious balance of concerns. However, the Collaboratory Communications Group at Messiah College has enjoyed partnering with PACTEC, MAF, UIM, JAARS and MSI, over the past three years, and by learning from and correcting past mistakes, hopes to continue a productive working relationship. Other engineering schools and/or faculty not already engaged in such a partnership are encouraged to try the suggestions given here, and/or contact the authors.

ACKNOWLEDGMENTS

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Enhancing International Humanitarian Design Projects: 
a Contextual Needs Assessment Case Study of Remote Power for Faith-Based Organizations

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Abstract

Although the global market allocates relatively few resources to the most needy on our planet, Christians have a special concern for the disadvantaged. Since many charitable opportunities are in environments unfamiliar or “frontier” to engineers in industrialized nations, a special opportunity-challenge awaits those determined to serve these needs. International humanitarian organizations are routinely confronted with needs in environments not commonly encountered by main-stream engineering practice. One example is the micro-power project at HCJB World Radio, with active interest from Steve Saint’s organization, Indigenous People’s Technology and Education Center (I-TEC). One portion of the micro-power project seeks to generate electricity from rivers in remote areas “beyond roads,” without requiring dams or other civil works.

In collaboration with the HCJB micro-power project, a student team designed, prototyped, and tested a zero-head hydroelectric system ultimately intended to provide 2kW-hr/day of electric power. The team applied a recently published design method created specifically for frontier-design projects, a project beyond the experience and expertise of the designers. The team applied the steps of the “Contextual Needs Assessment” method while conducting customer interviews.

The results of the contextual needs assessment were profoundly important for correct need definition and design decisions. A parallel ASEE paper covers general-interest aspects of the project such as project partners and goals, an overview of the new design method, project results, and how the new method specifically impacted design decisions. This CEEC paper briefly references these general interest aspects, and adds to the case study a discussion of several additional factors which played a major role in the case study outcomes. Some of these topics are especially appropriate for discussion in the context of Christian faith and practice: servant priorities for a “successful” project, humbly engaging reality through prototyping and failure, and faithfully documenting failures as well as successes.

1 Introduction

An ASEE recruiting publication sports the title “Engineering, Go for It! Make a Difference, Change the World.” Can a handful of engineers have a world-changing impact? Can senior design projects make a real difference? God used fishermen, tax collectors, political activists, and religious scholars for the work of the original disciples. Examples of vocational service include Adam and Eve tending the garden, Noah building the ark, and Solomon building the temple.

It is reasonable to believe God can and will use engineers (even engineering professors) as part of His divine plan. Christian faculty and students may ask, “Does God desire to impact the world through this particular senior design project? And if so, what does He intend and what is the path to bring it about?” What enhances -or derails- the world-changing chances of a senior design project? Are there actions and attitudes the faculty sponsor and students can choose in order to enhance success in the deepest sense of the word?

This paper asserts that human nature is in many ways contrary to good design practice. Student design teams (and sometimes faculty as well) have a natural inclination to not plan carefully, document responsibly, or seek advice appropriately; yet all of these steps are very strong factors for project success.
Overcoming and “redeeming” human nature is a core part of Christian faith and practice, and it is reasonable that good Christian practice should synergize with good engineering design practice. This of course does not imply that Christians have a monopoly on virtue, but simply an additional source of guidance, motivation, and power for inner transformation. Individuals not embracing Christian faith have achieved wonderful and virtuous things by choosing, through self-discipline, to suppress impulse and invoke internal motivation. In his book “Mere Christianity,” C.S. Lewis addresses the topic of why some atheists exhibit a better “Christian” lifestyle than some professing Christians (because Christian growth is a process of improvement from a starting point, and individuals begin at different points.)

Table 1 explores aspects of human nature (listed as common sentiments) contrasted with good design practice. The lists may broadly be categorized as prideful thinking contrasted with humble thinking. The following section addresses the question of “what is success,” followed by discussion of a number of non-human-nature principles for design project success. These ideas were largely developed from the first author’s own design project failures, followed by reflective musings with others.

### Table 1: Contrasting Human Nature with Good Design Practice

<table>
<thead>
<tr>
<th>Nature of Human Beings</th>
<th>Nature of Good Design Practice</th>
</tr>
</thead>
<tbody>
<tr>
<td>I don’t need to plan ahead</td>
<td>Planning ahead ab</td>
</tr>
<tr>
<td>My plan will work the first time</td>
<td>Planned iterations of testing and revision</td>
</tr>
<tr>
<td>I already know what the client needs</td>
<td>Thorough customer needs assessment</td>
</tr>
<tr>
<td>I already know the best solution</td>
<td>Serious concept generation and selection</td>
</tr>
<tr>
<td>I already have an idea how I want to do it</td>
<td></td>
</tr>
<tr>
<td>I can do it [all] (over-complexity)</td>
<td>Limited (realistic) scope</td>
</tr>
<tr>
<td>My design will be the best and the flashiest</td>
<td>Contentment with a job well done</td>
</tr>
<tr>
<td>I’d rather add ___ [glitz] than ___ [quality]</td>
<td>Fulfill design requirements effectively</td>
</tr>
<tr>
<td>I think it’d be cool to do ___ [bells &amp; whistles]</td>
<td>Simplicity (only value-added features)</td>
</tr>
<tr>
<td>I don’t need to draw/calculate it</td>
<td>Analyze and evaluate design solution</td>
</tr>
<tr>
<td>I’ll “just do it”; I’ll “just build it”</td>
<td>Sketch or draw before physical embodiment</td>
</tr>
<tr>
<td>My work is fine as it is</td>
<td>Seek technical review (counsel) of others c</td>
</tr>
<tr>
<td>When I’m 80% done … I’m done</td>
<td>Follow-through to completion</td>
</tr>
<tr>
<td>The rest is just details …</td>
<td>Attention to detail</td>
</tr>
<tr>
<td>Partially document final success</td>
<td>Document failures and success</td>
</tr>
<tr>
<td>My design doesn’t really have problems</td>
<td>Seek, identify, fix and learn from failures</td>
</tr>
</tbody>
</table>

2 What is Success? (Prioritizing People and Programs)

Many faculty and students share a strong desire to be world-changers, to participate in the “grand scheme of things” and feel they are making a real difference. Possibly everyone feels this search for significance

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\[a\] All scripture used is the New International Version ©1995, [http://www.biblegateway.com/](http://www.biblegateway.com/)

\[b\] Lk. 14:28-29 “Suppose one of you wants to build a tower. Will he not first sit down and estimate the cost to see if he has enough money to complete it? 29For if he lays the foundation and is not able to finish it, everyone who sees it will ridicule him, …”

\[c\] Prov. 15:22 “Plans fail for lack of counsel, but with many advisers they succeed.”
at some level. At many research-driven universities an approach to success involves the first two steps in List #1 below, and exceptional teachers may include the third step as well:

**List #1: An Approach to Successful Projects**

1. Build a “program” of projects with a common, promotable theme
2. Provide meaningful deliverables for each project
3. Inspire and equip students for great technical achievements

List #1 may indicate a natural order of priorities. In a competitive research environment, it seems it is not possible to train students if deliverable aren’t meaningful, and the lack of a successful “program” means there will be no more opportunity when the faculty member “perishes” for lack of “publishing.” In this approach, the program is the first priority, and everything else (hopefully) flows from that.

God often has a way of turning things “upside down” in very counter-intuitive ways. For example, Jesus said many who are last will be first, and that the widow who gave a few cents was more generous than the rich who gave much more. Jesus taught (and showed) that leaders are to be servants. God humbled himself by becoming a man. God made a priceless redemptive sacrifice for his rebellious and ungrateful creation. Is it possible that List #1 should also be turned upside down … making students the top priority with projects flowing from that? Such a list could look like this:

**List #2: “Upside-down” Approach to Successful Projects**

1. *Model Christian service: humble diligence and technical excellence*
2. *Inspire and equip students for humble and diligent Christ-like service*
3. Inspire and equip students for great technical achievements
4. Provide meaningful deliverables for a given project
5. Build a “program” of projects with a common, promotable theme

List #1 seeks impact through a program, with the hopeful outcome of successful students. List #2 seeks impact through relationships, with the hopeful outcome of successful deliverables and, ultimately, a successful program. These two lists are extremes for illustration … many other combinations are possible and do exist in practice. None of the items listed are unimportant. However, faculty do make daily choices of which items are the driving priorities. Does the program drive relationships? Or do relationships drive the program? Both are important, and one or the other will take priority, similar to Jesus’ words on choosing to serve either God or money (Mt. 6:24). God and money are both important (Mt. 6:32-33), but only one can take first place. Scripture commends us to do our work “as unto Christ” (Col. 3:23), and to be servants (Phil. 2:3-7; Mk. 9:35a.) These scriptures seem to support List #2.

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*a 1 Co. 3:18-19 “… If any one of you thinks he is wise by the standards of this age, he should become a ‘fool’ so that he may become wise. 19For the wisdom of this world is foolishness in God's sight.”

*b Mt. 6:24 “No one can serve two masters. Either he will hate the one and love the other, or he will be devoted to the one and despise the other. You cannot serve both God and Money.”

*c Mt. 6:32-33 “For the pagans run after all these things, and your heavenly Father knows that you need them. 33But seek first his kingdom and his righteousness, and all these things will be given to you as well.”

*d Col. 3:23 “Whatever you do, work at it with all your heart, as working for the Lord, not for men, …”

*e Phil 2:3 “Do nothing out of selfish ambition or vain conceit, but in humility consider others better than yourselves.”*
The choice of priorities contrasted in List #1 and List #2 may have profound effects on long-term project success. There is no guarantee that equipped students (#2.3) and meaningful deliverables (#2.4) alone will necessarily produce good effects. Skilled students may make selfish and destructive career choices. Further, much has been written on the topic of whether technology is value-neutral, and many would agree that even good technologies have the potential to be perverted for evil. Remote jungle transportation could be used to control and exploit indigenous peoples, to transport recreational drugs, or profit from illicit arms trade. Remote power generation technologies could be used to facilitate similarly harmful activities. Even if a program involves deliverables specifically tailored to Christian missions, there is no guarantee the long-term impacts will be entirely positive. Modeling and transmitting Christ-like service (List #2.1 and #2.2) minimizes the risk that trained students and deliverables could, in fact, ultimately produce harm.

Bob Beihl’s visioning booklet “Asking to Win” suggests the focusing self-reflective question, “Where was my greatest unexpected success last year? [Why? How] could I take full advantage of this ‘Window of Opportunity’ next year?” This question was clearly answered in a recent design project which had been minimally successful. One of the design students went on to intern with the customer and developed a revolutionary, patent-pending solution to the original design problem. This anecdotal event also seems to support the order of the second list.

3 “Flearning”: Fail Early and Fail Often

Failure is an important topic throughout the design process. Henry Petroski’s book and documentary “To Engineer is Human” suggests the “cycle of success and failure” is an inevitable part of advancing engineering frontiers. Failure Modes and Effects Analysis (FMEA) techniques attempt to prioritize resources towards minimizing failure effects in a final product or process. A form of failure widely recognized as part of the design process is covertly labeled “iteration.”

If failure is an inevitable part of progress, it makes sense that it can and should be planned for and managed, not only for the final product, but within the design process itself. Failure is not the worst thing that can happen, especially if it results in learning and change. (The Bible, for example, can provide inspirational models of recovered failures such as Jacob, Moses, David, and Peter.) Petroski addresses this theme in his latest book, “Success through Failure: The Paradox of Design.” A summary from one of the lectures in the book is based on states, “Understanding failure is essential to success. Failure, rather than success, is a more reliable guide to better design. Success-based improvement does not succeed.” (emphasis added.)

Failure is often how students realize that some things work better than others, and some do not work at all. Failure clearly and eloquently demonstrates the real-world phenomena computer simulations or pencil-and-paper calculations fail to capture. Milestone-driven prototyping with specific goals in mind encourages “Flearning,” learning catalyzed by failure, which is critical to the design process.

4 A Handshake with Reality: Prototype and Test

Prototyping is a “handshake with reality” widely recognized as a critical part of the product realization process. Experienced engineers recognize that almost no complex physical system performs exactly as analysis predicts. Failed prototypes are often how students realize the distinction between a “video game” simulation and a real, physical engineering system governed by natural laws. Students must prototype early in the design process to inform decision-making before it is too late. Tragically, scarcity of time and finances often pressure student design teams to delay prototyping until the end of a project, leaving no time for the inevitably necessary design changes.

a Mk, 9:35 “‘If anyone wants to be first, he must be the very last, and the servant of all.’”
Concurrent prototyping throughout the design process (as opposed to only an ending demonstration) enables multiple cycles around Kolb’s learning model (Figure 1). Information gleaned from the sensory experience of prototype testing (steps 4 and 1) provides insight and motivation for the next re-design iteration (steps 2 and 3). Moe et al. as well as Otto and Wood’s design text address planning prototyping throughout the design process, with particular attention to student projects.

![Figure 1: Diagram of Kolb’s “Wheel”](http://www.infed.org/biblio/b-explrn.htm)

The cultural inventor stereotype is too often an eccentric dreamer with outlandish inventions creating perpetual havoc, such as in “The Absent Minded Professor,” “Honey I Shrank the Kids,” or “A Bug’s Life.” A review of “A Bug’s Life” describes the inventor-ant caricature as “… an inventor who is always getting the other ants in trouble with his hair-brained schemes … they never expect to see him again, which would please most of them.” Due to insufficient prototyping and testing throughout the design process, many student design projects run the very real risk of perpetuating this incompetent inventor stereotype.

An excerpt from the NASA “Lesson’s Learned” database underscores the importance of physical testing for learning:

> “There seems to be insufficient awareness that information or knowledge obtained from [canceled X-vehicle] programs has … never been verified through actual flight-testing … [and is] suspect. … Programs which complete but are unsuccessful contribute more to the knowledge base than those that are cancelled. However, many of the younger scientist and engineers in the Agency have not had the opportunity to experience a failed flight (or a successful one).” (emphasis added.)

A challenge of prototyping is to address enough breadth of the design problem to give meaningful results, and yet maintain a feasible scope. Prototype planning requires a clear understanding of what characteristics (specifications or requirements) a system must have to satisfy the design need, and which are to be tested. This testing phase inevitably involves trouble-shooting: mentally or physically segmenting the device into modules which can be grasped enough to efficiently conceive, execute, and measure the results of experimental changes. Students often struggle to effectively identify modules appropriate for troubleshooting. These modules must be small enough to efficiently conceive, test, and refine until ready for integration into the complete system. The modules must also not create excessive physical or information interfaces, thereby creating inefficiencies. Significant research exists on the practice of dividing a system into modules, although unfortunately most is on a level too advanced for application by an undergraduate design team.

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a [http://www.infed.org/biblio/b-explrn.htm](http://www.infed.org/biblio/b-explrn.htm)
5 Documenting Mistakes (and Successes)

Unlike most autobiographies, the Bible enumerates as many or more bad examples as good. Since design is inherently iterative (filled with “Flearning”), it makes sense to mark the trail for those who follow. While it is much easier (in both time and pride) to simply present final design result on a pedestal (with good lighting and at an angle such that the flaws don’t show), presenting the reality of the process is much more helpful to posterity. Documenting design work is critical to having a lasting impact. Passing on only an end product, which may or may not work completely, discards most of the work that went into the long, winding journey of bringing about a physical solution addressing a conceptual need. The third frame of Figure 2 below illustrates the engineer’s natural inclination towards documentation.

![Figure 2: Caricature of the Design Process](http://www.projectcartoon.com/ProjectCartoon.pdf)

In the article “Learning for the Mars Rover Mission: …” Linde\(^\text{12}\) describes one of NASA’s database strategies to institutionalize learning from failure through a format which “encourages recording problems rather than positive learning.” The database homepage gives the following description:

“The NASA Lessons Learned database system is the official, reviewed learned lessons from NASA program and projects. The information provided is a summary of the original driving event, as well as recommendations, which in turn, feed into NASA’s continual improvement via training, best practices, policies and procedures\(^\text{13}\).”

6 Understanding Frontier Needs – Applying the Contextual Needs Assessment Method

Needs assessment is a humbling, servant-like step in which the design team says to the customer, “tell us what you need, and we will seek to do it.” A parallel ASEE paper\(^\text{14}\) details the case study of the “SPARC” (Supplying Power Alternatives for Remote Communities) design team developing a kinetic-energy water wheel. In collaboration with the HCJB micro-power project, a student team designed, prototyped, and tested a zero-head hydroelectric system ultimately intended to provide 2kW-hr/day of electric power (Figure 3 and Figure 4). The SPARC design team faced the challenge of thoroughly understanding the design needs and context, which were both foreign to the team’s experience and expertise as well as inaccessible and widely variable among the target sites. Additionally, the team had no experience with, or access to, existing micro-hydro installations. The project scope and goal needed to be appropriately clarified through phone calls and research. This daunting task-clarification phase was facilitated through the application of the contextual needs assessment method, which dramatically increased effectiveness while decreasing person-hours and frustration. Section 6.2 describes how the

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\(^\text{a}\) [http://www.projectcartoon.com/ProjectCartoon.pdf](http://www.projectcartoon.com/ProjectCartoon.pdf)
team customized the method for the micro-hydro project and Section 6.3 provides sample results, including an interview summary and select specifications.

![Diagram of %Stream Kinetic Energy Harvested vs. Blade Slip Ratio](image)

**Figure 3:** Calculated %Stream Kinetic Energy Harvested vs. Blade Slip Ratio

![SPARC Wheel Feasibility Testing Prototype](image)

**Figure 4:** SPARC Wheel Feasibility Testing Prototype

### 6.2 Customizing Contextual Needs Assessment for the Micro-Power Project

The published Contextual Needs Assessment Method\textsuperscript{15,16} improves task clarification through a new focus on context. The contextual focus is especially critical for needs which are “frontier” or foreign to the designer. Testing under both laboratory and normal classroom conditions shows the new method is extremely effective, easy to use, and well received by students\textsuperscript{17}. The contextual needs assessment method facilitates and directs the process of discovering, documenting, and applying contextual information and is easily adaptable to a variety of design needs. The straightforward method provides valuable structure and insight for organizing and driving the needs assessment process, and the templates place the power of contextual assessment in the hands of even novice engineers who are tackling a design
need outside of their experience and expertise. The latest version of the needs assessment templates are available electronically from the first author.

For the SPARC micro-hydro project, no site visit or articulated-use customer interviews were possible. Thankfully, the two project customers are lead users with unusual insight into the design need context. This combination of an inaccessible context along with knowledgeable customers made the contextual needs assessment method even more instrumental to project success. The team customized the method and templates to fit the project.

The Contextual Needs Assessment Method was customized as shown in Table 2. In the customized version of the method, step (1) involved adding a few contextual factors to the template. Step (2) involved modifying the generic template questions to fit the project. Step (3) was completed by answering the questions generated in Step two primarily through customer phone interviews augmented with research. Step (4) involved inferring customer needs from the interview transcript (rather than an articulated use interview or a like/dislike method.) Step (5) involved translating the needs identified from the interview into quantifiable specifications.

Table 2: The Customized Contextual Needs Assessment Method

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Add additional contextual factors to template (brainstorming)</td>
</tr>
<tr>
<td>2.</td>
<td>Modify and add contextual questions in template</td>
</tr>
<tr>
<td>3.</td>
<td>Answer contextual questions (phone interviews)</td>
</tr>
<tr>
<td>4.</td>
<td>Develop customer needs list from interview transcript</td>
</tr>
<tr>
<td>5.</td>
<td>Develop specifications from interview transcript and customer needs</td>
</tr>
</tbody>
</table>

6.3 Sample Results: Interview Summary and Specifications

Four phone interviews (two with each customer) yielded a large amount of information which was classified according to contextual factors. Table 3 shows example summary statements from the interview consolidation. The parallel ASEE paper\textsuperscript{14} lists the complete set of contextual questions.
### Table 3: Snapshot - Template with Sample Interview Notes

<table>
<thead>
<tr>
<th>#</th>
<th>Context Factor</th>
<th>KEY:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Plain type: Template CNA Questions v3.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Bold Italics:</strong> customized question for SPARC project</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bulleted: Interview response summary statements</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>#</th>
<th>Context Factor</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>a0</td>
<td>task application</td>
<td>How specific purpose(s) will product be used? How will the product be used?</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>What equipment/purpose(s) will need power?</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Lights, dry rooms, small refrigerator for medicine, small office</td>
</tr>
<tr>
<td></td>
<td></td>
<td>equipment, misc. shop equipment, and 2-way radio</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• AM &amp; FM, mainly FM, computer or two, light or two, audio console</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Low power means DC would be first choice</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• DC by itself would not be a useful system (would eventually need AC)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Long term could be medical clinic (all in remote locations)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Power Should be scalable</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Should work with low water pressure (but compatible with high head)</td>
</tr>
</tbody>
</table>

| a2 | task quality         | What quality of the primary function is needed? What are the output power requirements? What voltage/current (w/tolerances) must the product provide? Will it need "bursts" of power? |
|    |                      | • DC stores better, AC transfers better                            |
|    |                      | • Power transport from gen site to load will have to be higher voltage AC - makes most sense to integrate raft to w/ converters |
|    |                      | • Total Harmonic distortion of sine wave should be no more than 5%, preferably 2-3% |
|    |                      | • Prefer 440V 3-phase generator & rectify at end of distribution lines |
|    |                      | • Absolute maximum on efficiency not great concern - high reliability, low cost, ease of maintenance far more important (would rather double size than sacrifice reliability; ease of maintenance) |

| a6 | task quantity        | How much quantity of the product's output is needed? How much energy is needed for a day? What is the peak power need? Will several forms of power be needed simultaneously? |
|    |                      | • 5kW is a daydream (we'll take all we can get and build on that)    |
|    |                      | • Don't want to go below 100W - wouldn't be useful                  |

| a9 | transportation type & amount | How often, how far, in what way will product be transported? How often, how far, and in what way will product be transported? Will it be moved after initial install? How important is transportation? |
|    |                                | • What a single man can manage in tough terrain                    |
|    |                                | • Thinking of hauling up river as barge w/ motor boat               |
|    |                                | • If you can pack it in we have no objection                       |
|    |                                | • Wouldn't be moving it at all from the initial installation site   |

The customer interviews and needs served as the basis for developing the customer-driven specifications outlined in Table 4.
### Table 4: Snapshot – Sample Specifications

<table>
<thead>
<tr>
<th>Specification</th>
<th>Description</th>
<th>Target value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Easy to carry</td>
<td>Total weight of each component when broken down</td>
<td>≤ 50 lbs</td>
</tr>
<tr>
<td>2. Output voltage</td>
<td>Output voltage from generation system</td>
<td>a) 120 VAC 60 Hz OR b) 12 VDC</td>
</tr>
<tr>
<td>3. Average power</td>
<td>The average power from the generation system</td>
<td>&gt; 100W</td>
</tr>
<tr>
<td>4. Min. stream velocity</td>
<td>Minimum river velocity required to achieve average power</td>
<td>3 mph</td>
</tr>
<tr>
<td>5. Min. stream depth</td>
<td>Minimum operating depth required</td>
<td>2 ft</td>
</tr>
<tr>
<td>6. Min. stream width</td>
<td>Minimum operating width required</td>
<td>5 ft</td>
</tr>
</tbody>
</table>

### 6.4 Key Design Considerations Revealed Through Contextual Needs Assessment

The contextual needs assessment templates provided the basis for a thorough, flexible, and iterative dialog with the two partner organizations. The templates facilitated recording expectations in an efficient, organized way and built a relationship with mutual understanding. The four contextual phone interviews revealed the clear design driver: provide continuous electricity ranging from 100W to 5kW to charge a battery bank, generated from a level stream with virtually no civil works. A successful design would be a rugged, easily maintainable micro-hydro solution of reasonable size and cost. Installation sites would need a minimum river speed and width for the design solution cost-competitive with solar photo-voltaic or fossil fuel generators. The relationships among stream speed, cost, and product size would need to be determined by the design team. Table 5 itemizes a sampling of key design considerations along with the letter-number identification of the prompt which elicited the information.

### Table 5: Key Information Elicited by Context Questions

<table>
<thead>
<tr>
<th>Context Question Prompt#</th>
<th>Key Design Information Elicited by Application Context Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>A0</td>
<td>Strongly desire no civil works (no head)</td>
</tr>
<tr>
<td>A2, A6</td>
<td>Needed power output (100W min, up to 5kW)</td>
</tr>
<tr>
<td>A2</td>
<td>Power needs – AC &amp; DC</td>
</tr>
<tr>
<td>A2</td>
<td>Reliability &amp; cost more important than efficiency (could make it bigger, or more)</td>
</tr>
<tr>
<td>A5</td>
<td>Energy storage needed (usage is 4-24 hr/day)</td>
</tr>
<tr>
<td>A7</td>
<td>Theft issue (disagreement between two customers)</td>
</tr>
<tr>
<td>A7</td>
<td>Tree barreling down stream (protect? Pull out?)</td>
</tr>
<tr>
<td>A8</td>
<td>Installation – river transport vs. one man pack down side of river (e.g. 50lbs) Doesn’t need to be move-able</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Context Question Prompt#</th>
<th>Key Design Information Elicited by Environment Context Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>E0</td>
<td>Theft (high price of copper), bug nest proof</td>
</tr>
<tr>
<td>E3</td>
<td>100% humidity</td>
</tr>
</tbody>
</table>
No idea of stream speeds, depends on how much power they can get

<table>
<thead>
<tr>
<th></th>
<th>Key Design Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>E8</td>
<td>Elicited by Customer Context Questions</td>
</tr>
</tbody>
</table>

| C0 | Setup by semi-skilled technician, clarified “throw it in the river” really means easy installation |
| C1 | Operation super-simple, repair part needs must be minimal |
| C5 | Don’t know cost (assumption must be value-proposition) |
| C8 | Clarified – it doesn’t need to be move-able |
| C9 | Kids jumping off, less visible is better |
| C10 | Durability 5 years |

6.5 Assessment of the Contextual Needs Assessment Method: Strengths and Limitations

Rigorous assessment of the contextual needs assessment method has been reported in previous work, providing strong quantitative and qualitative support for the usability, usefulness, and designer acceptance of the proposed method.

Limitations of the contextual needs assessment method fall into two major categories: (1) projects which do not rely heavily on needs assessment and therefore do not make full use of the method, and (2) projects which rely heavily on needs assessment and therefore include the normal associated risks that the method can not completely eliminate. The first category includes projects which are not frontier to the designer, and therefore prior knowledge significantly reduces (but does not eliminate) the importance of investing resources into needs assessment. In these cases the contextual needs assessment method is still useful, but not as critical to success since the need may already be well understood.

The second category of method limitations involves projects which are heavily frontier to the designer. These projects rely heavily on needs assessment in order to correctly formulate and guide problem definition and the design process. These projects necessarily entail a risk that “something will be missed.” The contextual needs assessment method reduces, but does not eliminate, this possibility. Needs assessment of any type is enhanced if the designers experience the actual context of use. However, in the SPARC micro-hydro design project, no access was available to the actual end-user, environment, or application (Table 6). The application of the method greatly increases the chance of success of the SPARC project, but of course does not guarantee that no oversights occurred.

| Table 6: Map of Frontier Contexts with Dimensions of “User” and “Environment” Accessibility |
| Environment Accessibility |
|---|---|---|
| Low | High |
| User Accessibility | |
| SPARC Micro-Hydro | Low | High |
7 Conclusions and Future Plans

Several factors important to outcomes from senior design projects, and design projects in general, appear contrary to human nature. Factors enhancing the chances of a truly “successful” outcome include servant-like project management, humbly engaging reality through prototyping and failure, faithfully documenting failures as well as successes, and conducting contextual needs assessment interviews when appropriate. These factors (or the lack of them) are believed to have played an important role in the successes (and failures) of the SPARC design case study and the author’s other design experiences. For example, application of the modified contextual needs assessment method enabled the SPARC team to move in a few weeks from a sparse, poorly defined idea to a set of specifications accompanied with valuable contextual information. The positive impacts are apparent from the vast amount of contextual information that was efficiently and effectively gathered with the modified contextual needs assessment method.

The sponsoring customers are extremely pleased with the progress and contributions of the SPARC design project. Project results indicate a large scale wheel is required to extract sufficient kinetic energy from flowing water, and have prompted the lead customer (HCJB) to re-consider the possibility of using civil works and pressure head-based hydro solutions. However, the 2007-08 SPARC project scope remained focused on developing the theory and empirical data required to scale and optimize the design of water wheels which do not require civil works.

References


What Faculty Wish First-Year Students Understood About
Calling and Vocation: The Genesis of a New Textbook

Murat Tanyel and David W. Shaw
Geneva College

ABSTRACT

The mission statement of the Geneva College Engineering Department calls for “developing engineering professionals [to see] their careers as a calling from God in which they may glorify him and love their neighbors…” The Introduction to Engineering (EGR 101) course for incoming freshmen has presented a Biblical view of calling as applied to the engineering profession. A previous paper compared available textbooks and varying degrees of emphasis, highlighting the effectiveness of increased focus on calling. In 2007, the readings and discussion were relocated to the Learning & Transition (L&T) seminar, where calling could be better integrated with career exploration. Course surveys and evaluation of final papers from previous offerings of EGR 101 will be compared to those from the recent offering of L&T to assess the efficacy of this move. Initial feedback indicates that this relocation of course content makes it more difficult for students to see the connection between general texts on calling and the engineering profession. This deficiency in integration reemphasizes the need for a textbook on calling and vocation with a specific engineering focus.

We envision this text to be a self-supporting introduction to the concepts of calling and vocation in engineering. The text must include the Biblical foundations of a Christian worldview illustrated with modern engineering examples. It should introduce the specific vocation of engineering and address the question incoming engineering students need to ask themselves: Am I called to be an engineer? More importantly, they need to ponder if they are called to be engineering students. The text should provide a means for students to consider these questions as well as advice for academic success.

The first author has initiated the project, and in this paper presents an outline and structure together with a process for the completion of this text. Currently, we propose the following chapters for the text:

Chapter 1: Why We Do What We Do: Creation, Fall, Redemption, Consummation
Chapter 2: Christian Understanding of Vocation
Chapter 3: Engineering as a Christian Vocation
Chapter 4: Reality Check: Am I Called to Be an Engineer Or an Engineering Student?
Chapter 5: What Does It Take to Be a Faithful Engineering Student?

The process will include departmental, student, and peer review of the text, ultimately leading to publication in a form which could be used in Christian colleges or by the Christian engineering student seeking a better understanding of his/her place in God’s world.

INTRODUCTION

The concept of calling and vocation is central to our valuing of education and professional practice. The topic is not a new one, with books written for various audiences, ranging from the popular\(^1\) to the technical/philosophical\(^2\). Introducing and illustrating this relationship to the typical 18 year old American college student is particularly challenging, given the varying levels of interest and maturity. The Through the Eyes of Faith series\(^3\) provides a good example of this effort for selected disciplines, however, Engineering is not part of that series.
In a previous paper the authors have discussed effective methods of teaching concepts of calling and vocation in a freshman Introduction to Engineering course. This included discussion of content and emphasis, textbook selection and availability, and assessment of student learning. Significant conclusions of this work were that such a course should allow time for reading and reflection in the area of calling and vocation, require students to write in response to those readings, and that, lacking an ideal textbook, instructors will need to develop materials or exercises to emphasize the relevance of these topics to the field of engineering.

Application of these conclusions to the Introduction to Engineering course at Geneva College has led to a series of changes during the 2006 and 2007 academic years. The first change was to use a different text in the calling and vocation portions of EGR101, Introduction to Engineering. Texts previously used or considered had lacked clear connections to engineering (except for selected essays used to supplement the texts) and were not well received by the typical 18 year old freshman student.

The first change was to select the text *Here I Am: Now What on Earth Should I Be Doing* by Quentin Schultze for use in EGR101 during the fall 2006 semester. This text was written in a style which seemed to be much better suited to the average freshman than the previously used text by Plantinga. This text was used in much the same manner as described previously, with students reading, writing journal responses, discussion during multiple lecture periods, and exam questions. End of course surveys showed positive changes in student response to the text and lecture material, which had already been generally favorable. This was seen in consistent responses to multiple questions.

The second change was made in fall 2007. Rather than continuing to teach the concepts of calling and vocation within EGR101, which is essentially an introduction to engineering design course, the material was relocated to Learning and Transition (SSC101), a freshman seminar course designed to facilitate the transition to college life. This course had already included emphasis on calling and vocation, career planning, and study skills, which were beginning to significantly overlap with content of EGR101. Student comments along the lines of “…but we already did that in L&T”, along with a new openness to departmental ownership of SSC101 sections led to this significant shift. This shift included the change to engineering faculty leadership of the SSC101 course.

The third change was brought about by the second author’s work on a paper written by each new faculty member at Geneva College addressing some important faith/learning integration topic within his/her discipline. His desire to produce a product which would do more than gather dust on the shelves of the College library led to a focus on a textbook project.

The interaction of the three changes noted above is significant in providing context for the main project described in this paper, which is the creation of a textbook for engineering freshman addressing the topics of calling and vocation. One of the most valuable lessons learned in the most recent change (moving the calling/vocation content to SSC101) is that the same text (Schulze) was perceived in very different ways when read and discussed in a course without engineering design content. It seems that students had been able to provide some of their own practical connections/applications of the material when the topics were at least within the same course. When calling and vocation were addressed in a course where the main purpose was seen as transition to college, the students were less likely to believe in the connections to engineering.

**RESULTS OF SUBJECT MIGRATION**

End of course surveys were used to solicit student feedback in both EGR101 and SSC101. The survey questions were somewhat different for the two courses, mainly because of somewhat
different goals, implementation, and administrative structures. Nevertheless, responses to certain questions can give an indication of student response to the text and its use in the course.

The text by Schultze was first used in EGR101 in fall 2006, then again in SSC101 in fall 2007. When used in EGR101, the readings and associated lectures were focused toward the middle of the course (lectures 8-13 of 28 lecture periods), after the students had been introduced to the general engineering design method and its application to a semester-long design project. When used in SSC101, the readings began with distribution of the books during the summer orientation session (mid-July), with an assignment to read the Introduction and first chapter before freshman orientation week (late August). The remainder of the readings were distributed throughout the semester, with reading assignments/lectures/discussions during weeks 1, 4, 7, and 9. Other topics covered in SSC101 included time management, stress management, and “Hot Topics” lectures and discussions related to the various engineering disciplines.

29 of 40 students in SSC101 wrote comments on the surveys in response to the question, “How could we better deal with the topics of calling and vocation, as presented in Here I Am, and in the “God’s Call” essay?” These comments were classified as either positive or negative, with a typical negative comments being “Don’t do it”, “waste of time”, and typical positive comments including “go more in depth with the book”. Of the 29 comments, 18 were classified as positive and 8 as negative, with the remainder not clearly defined. When compared to the more extensive data from EGR101, the comments show less overall satisfaction with and connection to the material on vocation and calling. We believe this may be a result of the lack of engineering design context, leading many students to perceive the topics as irrelevant when presented from a broad, philosophical point of view.

THE PROPOSED TEXT – AUDIENCE

This text is intended to reach the typical freshman engineering student who is a Christian or who is enrolled at a Christian college. This book could be used in a course, by individual students for personal study, or even as the basis for a small group study run by a church or parachurch group.

We recognize that these typical students can come from a variety of educational and faith backgrounds. For example, a typical freshman class at Geneva will include those who have read widely in this area, with entire high school curricula centered around the topics of faith/learning integration, to those who have no idea what that might mean. We will also have students from reformed, evangelical, and Roman Catholic backgrounds, with faith commitments ranging from nonexistent/nominal to deep and mature.

These students will also come from a wide range of technical backgrounds, ranging from those who have invested a great deal of time learning about engineering by job shadowing, involvement in design competitions, etc., to those who are trying engineering because they are “good at math and science”.

This wide range of backgrounds will drive the content, organization, and style for the text. Key issues will be providing significant, well-organized, Biblical support for the general approach to vocation and calling, and providing well-documented real-world illustrations relevant to students at this stage of life.

THE PROPOSED TEXT – OUTLINE

Currently, we propose the following chapters for the text:

Chapter 1: Why We Do What We Do: Creation, Fall, Redemption, Consummation

To quote from the opening paragraph of the first chapter: “Our cultural heritages influence how we deal with life. The technological tools we currently have will shape the types of technological
solutions we will furnish. Our assumptions about life, death and happiness will determine what kinds of problems we will tackle. Even at a more fundamental level, our assumptions and expectations will prescribe what aspects of life are problems to deal with and what are to be left alone. In other words, our worldview will influence how we practice engineering.” Therefore, we start out with a summary of the Christian worldview for the engineering student. One of the main goals in this book is to convey to the students that the practice of engineering is a response to a Divine call as opposed to a pursuit of technological interest or a means to livelihood. To this end, chapter one establishes engineering in relation to the cultural mandate (Gen. 1:28-29).

Chapter 2: Christian Understanding of Vocation
Much of Christian culture has established a distinction between “ministry” and “profession.” Pastors are called to churches, missionaries are called to the field, but lawyers, physicians and engineers “practice.” However, this distinction is unrealistic given “There is not a square inch in the whole domain of our human existence over which Christ, who is Sovereign over all, does not cry: ’Mine!’”9 Although the authors would lean toward a reformed view of work and service, we acknowledge that there are valuable contributions from many faith traditions in this area. For example, there are valuable lessons on work and leisure to be learned from the monastic tradition. This chapter will establish the Christian understanding of vocation, and engineering as one of the “good works, which God prepared in advance for us to do.”10

Chapter 3: Engineering as a Christian Vocation
This chapter will describe engineering and the world of engineering for students who have very vague ideas about the profession. Content will include summaries of the engineering disciplines and engineering job functions, emerging fields and opportunities, and typical work experiences for engineers. Here, we will also prescribe what engineering practice should look like, given Christ’s claim on it. This will be supplemented with biographical information from a variety of engineering professionals.

Chapter 4: Reality Check: Am I Called to Be an Engineer Or an Engineering Student?
Now that we have introduced engineering as a worthy calling and have described what it is and what it should be, it is time for the student to reflect: What will it take to become an engineer? Do I have the motivation for pursuing an engineering education? What will a successful completion of engineering education achieve? What if, 2 years into my education, I do not like the corporate world in which engineers work? What if, 3 years into my career, I am alienated from the corporate world? Do I really want to go through with this endeavor?

Chapter 5: What Does It Take to Be a Faithful Engineering Student?
This final chapter will provide words of wisdom/advice to prepare students for the rigorous 4 years they are expected to spend for engineering education. This chapter is intended to be a guide for success as an engineering student, noting the proper motivations and measures for such success. It could be seen as an explicitly Christian complement to texts such as Studying Engineering11 by Ray Landis.

Where possible, the chapters will be designed as modules which could be covered in almost any order. This will allow flexibility in the use of the text in various contexts. For example, if a school already has a course addressing the Biblical and philosophical basis of calling and vocation, then it should be possible to move directly to Chapter 3. Or, if a course addresses career issues early in the outline, then Chapter 3 could be covered in parallel with earlier chapters. Chapter summaries and clear chapter introductions, clearly listing presuppositions, will be designed to assist in this task.
THE PROPOSED TEXT – AUTHORS
A task of this magnitude requires time well beyond that typically available to those teaching a full course load, and requires a great breadth of knowledge and experience. In an effort to move toward a complete and high quality text in a timely manner, we prayerfully considered the gifts and experience of faculty within the engineering department at Geneva College and asked individual faculty members to be the lead authors for the various chapters. It will be especially important to both connect the chapters, but also provide sufficient summary and background information to allow instructors or readers to use chapters in an order that best suits their situation.

Chapter 1 already exists in draft form, as a result of the first author’s integration paper. He will revise this within the framework of its connection to the other chapters and the general flow of the text. This has been an area of interest for him throughout his Christian life.

The current department chair, James Gidley, has written a variety of articles on the Biblical view of vocation, in the context of engineering and other fields. He also was the main instructor for EGR101 in the early years of the present engineering curriculum. He has consented to be the lead author for Chapter 2.

The third chapter is intended to make the clear connection to engineering as presently practiced. The second author has done significant work over the past eight years in helping students make these connections in EGR101 and SSC101, so he was selected as the lead author for this chapter.

The fourth chapter involves the practical application of the material from chapters one and two in the lives of students. The author of the first chapter will be the lead author.

The lead author for the fifth chapter will be Robe Liljestrand, who has historically taught the Computer Aided Engineering course and the first Solid Mechanics (Statics/SOM) course, since he can provide direct guidance in areas critical to first-year students. He has a wealth of experience, and great success, in helping students make the adjustment to college-level engineering studies.

THE PROPOSED TEXT – PROCESS/REVIEW
Recognizing the hazards present in a multi-author text, we are including several steps in the process to help lead toward a coherent, easy to read manuscript. We have adopted a set of general guiding principles to help in this task, as well as processes to provide feedback at various points.

Those guiding principles include

- A preference for direct quotation, rather than extensive footnotes or endnotes. This is particularly important for scripture references which support main points or arguments, since we have found that students seldom follow up on such references when reading, either assuming that they already know what the verses say, or accepting conclusions uncritically.
- A voice and style well-suited to the typical 18 year old. This includes both word and sentence length, as well as use of clear, current, and relevant pictures and illustrations.
- The use of clear introductory and summary sections in each chapter, providing a clear basis for what will be said and a summary of main points.
- Direct connections made to the topic of engineering education and practice in each chapter.

The first author (Tanyel) will act as copy editor, working with individual chapter authors to ensure consistent style, and that the content from various chapters is well integrated. The copy
editor will also be seeking assistance from other faculty in the English and Communication departments.

Reviewers will include selected students (this is already in progress for Chapter 1), faculty within the engineering department, and selected faculty and administrators within the college. These faculty will be drawn from the other professional fields (business, education), English, and the Higher Education program. External reviewers will also be used for selected chapters.

The first draft of this text will be used in the fall 2008 section of SSC101, with approximately 40 students (2 sections of 20). Especially valuable insight will come from the four student assistants for this course, who will be drawn from students who had used other texts (mainly Schulze).

Upon completion of the fall 2008 semester, the chapter authors will meet to review the results and make revisions based on feedback from students and from internal and external reviewers. This revised text will then be circulated to selected students and to reviewers within the college. The text will also be made available to other interested individuals (external reviewers) at this point. We will be especially interested in others who might be willing to use and review the text, or portions of the text, in other settings, whether college classes or book studies.

CONCLUSION

Several years of experience and student data indicate the need for an engineering oriented textbook on vocation and calling for use by students in the early college years. This book could be valuable both within Christian colleges and for Christian students in other settings.

The engineering faculty members at Geneva College are in the process of writing such a text. Feedback from and cooperation with other interested individuals and institutions will be a valuable asset to this project.

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Career Choice in Light of the Kingdom of God:
An Engineer’s Perspective

Max Deffenbaugh

ABSTRACT

The question “What does God want me to do with my life?” is the subject of considerable contemplation and prayer among Christian young people when deciding on a major in college or choosing a job. The Bible says a great deal about what God wants people to do with their lives, but often it is hard to see how Biblical principles apply to career decisions like “should I major in engineering, pre-med, or Bible?” We consider Jesus’ teaching about the Kingdom of God. Based on the themes which emerge, we suggest a criterion for career selection and evaluate engineering as a career option. Jesus taught that the Kingdom of God must be the central concern of His followers. To many this means that Christians who are able or willing should choose vocational Christian ministry over the so-called secular professions, as the former allows a full-time commitment to advancing the Kingdom by fulfilling the Great Commission. Others see advancing the Kingdom as transforming culture in any of its myriad expressions and so value all careers as service to Christ. More than advancing external causes, we suggest that the call of Jesus is to an internal transformation of values in response to the Kingdom of God. Accordingly, the measure of a career is the opportunity it affords to live out the values of the Kingdom. By this measure, a broad spectrum of careers can be good choices. We look specifically at engineering. Engineering jobs offer differing opportunities to express Kingdom values through creating responsible technologies. They also present situations where Kingdom values require the engineer to transcend the engineering mindset and engineering methods. Particular assignments and employers may enhance or hinder our ability to live out Kingdom values in church and family relationships. Although we have proposed a measure for the value of a career and suggested factors that influence value, in the end the contingencies of life preclude career selection as a global optimization over likely outcomes. We propose that career selection is better viewed as an act of worship—an expression of what we value and a response to God’s gift of abilities, desires, and circumstances.

INTRODUCTION

Next to decisions about faith and marriage, the choice of career is one of life’s most significant decisions. It is one of those decisions we make that in turn make us. In Christians naturally want to know how God would want them to decide on these matters, but the Bible doesn’t provide direct, personalized answers. Within the Christian community there are various approaches to determining the will of God with regard to life decisions. Most books on that topic recommend elements of biblical study, consultation with trusted advisors, prayer, and personal reflection. However, sincere attempts at the application of these principles often do not lead to a satisfying level of clarity. Even when the right basis for the decision can be determined, unknown and even unknowable factors can make it impossible to compare the relative merits of some options.

In this paper we attempt to gain a Biblical perspective on career selection from one particular body of material: Jesus’ teaching about the Kingdom of God (or equivalently Kingdom of Heaven) as found in the Synoptic Gospels (Matthew, Mark, and Luke). We note how differing theological perspectives on the Kingdom of God lead to differing values in career selection. We propose a particular interpretation of the Kingdom and consider the implications for career selection. Then we discuss some aspects of engineering that play into its evaluation as a career. Finally, we offer some perspectives about the “unknowable” factors in any such evaluation.
THE KINGDOM IN JESUS’ TEACHING

The central theme of Jesus’ teaching was the “Kingdom of God.” (Mark 1:14-15; Matthew 4:17; Luke 4:43) Jesus taught that the Kingdom of God must be the central concern of His followers (Matthew 6:33). It was a hidden treasure, a pearl of great price (Matt 13:44-46), a discovery so great as to be worth any degree of personal sacrifice. Better to enter the Kingdom blind or mutilated than not to enter (Mark 9:47). Indeed blessedness must be reckoned not by prosperity, comfort, and satisfaction, but instead by whether one has part in this Kingdom, (Matt 5:1-12; Luke 6:20-26). Clearly a response to the Kingdom which involves only an avocational, spare-time engagement is not envisioned here. But what exactly did Jesus mean by the Kingdom of God?

THE KINGDOM IN THE OLD TESTAMENT

When Jesus spoke of the Kingdom of God, he was not defining a new concept but rather correcting a spectrum of misconceptions around a familiar and deeply cherished hope in first century Judaism. While the phrase “Kingdom of God” is not found in the Old Testament and appears only occasionally in the apocalyptic literature of the intertestamental period, the hope it expresses has its roots deep in the early faith of Israel. Israel believed themselves to stand in a special relationship to God as His people. God had made certain promises to them, had acted in history to fulfill those promises, and would act again in the future on their behalf.

In first century Palestine, Roman oppression brought a deep longing for the Kingdom of God. The devastation of Israel by foreign powers was viewed by the prophets as God’s judgment upon the moral failure of His people, so the Pharisees (as religious descendents of the Hasidim) pursued careful adherence to the Law in the hope that a return to righteousness would lead to God’s intervention to restore the political fortunes of the people. The Essenes lived in ascetic communities practicing rigorous law-keeping while awaiting the imminent arrival of God’s Kingdom. The Zealots instigated military rebellion, waging a guerilla war against Rome in the hope that God would act on their behalf to overthrow Roman dominion and restore Israel’s fortunes and prominence among the nations. While the Zealots ultimately succeeded in inciting military rebellions, these did not precipitate the Kingdom of God, but only brutal retaliation from Rome in 70 A.D. and finally in 135 A.D.

MODERN VIEWS ON THE KINGDOM

Christians recognize two senses to the Kingdom of God. God, who created all things, has continued to sustain and rule them according to his sovereign power so that nothing can happen that He does not allow. In this first sense, God has always been and will always be King. However, at the present time many aspects of Creation have not been made subject to His rule. The second sense of the Kingdom of God is a still-future rule of God over a new creation in perfect order and submission. This latter sense was the hope of national Israel in the 1st century and is what Jesus means when he speaks of the “Kingdom of God”.

Christians differ over what, if any, aspects of that future Kingdom have become present reality for us today, and what, if any, role people play in advancing that Kingdom. Since all would agree that the Kingdom of God should be in some sense the defining concept in how Christians live (Matthew 6:33), each viewpoint regarding the present nature of the Kingdom of God leads to a particular way of assigning relative value to career options. We present three viewpoints which are labeled “Evangelical”, “Reformed”, and “Pietistic”. These viewpoints are not polar opposites. Even within churches that identify strongly with one viewpoint, most people embrace some aspects of each view.
**Evangelical Perspective**

In the evangelical perspective, the Kingdom in the current age is God’s rule in the hearts and lives of those people who receive it. The Kingdom grows as evangelism increases the number of people who accept God’s rule and as discipleship expands the extent of God’s rule in their lives. Building the Kingdom is equivalent to fulfilling the Great Commission of Matthew 28:18-19 and is the highest calling of every believer. Some fulfill the Great Commission by serving as missionaries, pastors, or other forms of professional Christian ministry. Others pursue “kingdom careers” where they apply the skills of “secular” professions to the advancement of the Kingdom by assisting those who are directly fulfilling the Great Commission, for example, as an accountant for a mission organization. Secular careers have value because of the opportunities they afford for evangelism and discipleship in the course of interacting with people on the job—many of whom would never have occasion to interact with someone in “full-time” ministry. Secular careers also find their value in the opportunities they afford to participate part-time in volunteer activities and to financially support ministries. In all cases, the measure of a career is the opportunity it affords to advance the Kingdom of God by fulfilling the Great Commission, either directly or indirectly.

This view is expressed, for example, by Friesen,

Yes, The missionary task is difficult, but rather than waiting for some kind of mystical call from God, every believer should respond to the revealed will of God by giving serious consideration to becoming a cross-cultural missionary…

Obedience to the command to be faithful stewards requires all believers to evaluate whether they have the God-given capability to best fulfill the great commission by personally taking the gospel to unreached peoples. Those who do should go. Those who don’t should send [others].

To be fair, this quote is lifted from Friesen’s chapter on evaluating missions as a career option. However, there is no corresponding chapter with an impassioned plea for Christians to respond to the revealed will of God by considering personally becoming engineers.

**Discussion**

One difficulty with this evangelical view is that the Kingdom of God in Scripture does not seem to be restricted to the hearts and minds of people. The Old Testament expectation regarding the Kingdom was at least a political transformation, and by the time of the later prophets, a complete transformation of the created order. In Christ’s miracles, evidence of the Kingdom was manifested through his dominion over spiritual realms, medical conditions, and even the forces of nature, not just in his calling of people to repentance and faith. It is hard to find a New Testament basis for an exclusively internal kingdom, even in the interim between the first and second coming of Christ. An internal kingdom is sometimes posited based on Luke 17:20-21 (with entos translated “within” as in KJV, NKJV, NIV), but this translation is problematic as it places the supposed internal Kingdom in the hearts and minds of Jesus’ opponents, the Pharisees. A better sense for entos is “in the midst of” (as NASB, RSV), which is consistent with the context. The Pharisees were on the lookout for signs that the Kingdom was coming, but the Kingdom was already present in the person and ministry of Christ.

More to the point, no matter what stage of the NT tradition is being considered, the idea of the kingdom of God as a purely interior, invisible, present spiritual state of individual hearts is a foreign intrusion. It is at home in 2d-century Christian Gnosticism … 19th-century German liberal Protestantism, and some 20th-century American quests for the historical Jesus, but not in the canonical Gospels in general or Luke in particular.

If this evangelical view of the Kingdom is too narrow, then it naturally follows that the view of how to value career options is correspondingly narrow. To be sure, evangelism and discipleship
are vital roles of the Church. The Great Commission of Matthew 28:18-20 is predicated on the universal authority given to the post-resurrection Christ (vs. 18), and therefore closely connected with the notion of the Kingdom of God. However, within the context of Matthew’s gospel, 28:18-20 does not primarily function as a call for all believers to take up cross-cultural missions. There are two commissionings of the disciples as apostles in Matthew: 10:1-42 and 28:18-20. In the first of these, they are explicitly told not to go to the Gentiles or to the Samaritans (Matthew 10:5). The second time, they are sent to all nations (Matthew 28:19). The second commissioning has noteworthy parallels to Daniel 7:13-14 and seems to be presented by Matthew as the fulfillment of the Daniel prophecy. The central feature of the Daniel prophecy is a kingdom which includes “all peoples, nations, and languages” parallel to Matthew 28:19, and is “an everlasting dominion which shall not pass away” parallel to Matthew 28:20. The transcendence of the Kingdom of God across ethnic divisions is a major theme of Matthew’s gospel (Matthew 8:11-12), and establishing this as a necessary consequence of Old Testament prophecy is an important goal of Matthew as he writes to an audience of Jewish Christians faced with rejection and persecution in their synagogues. To its first readers, Matthew 28:18-20 was probably heard as an explanation and defense of the increasingly Gentile makeup of the early Christian communities. This change in ethnic composition is presented as a fulfillment of Old Testament prophecy and a consequence of the universal power and authority of the resurrected Christ.

If the Great Commission is understood primarily as a call to cross-cultural missions, then we must admit that the Great Commission is not the Greatest Commandment. (cf. Matt 22:34-40; Mark 12:28-34) However if the goal of the Great Commission is universal discipleship to Christ in light of the universal scope of His Kingdom, and that discipleship applies not just to others but to ourselves, then we have a solid basis for career decisions: In what career can I best express discipleship to Christ in myself and promote it in other people?

Reformed Perspective

In the reformed perspective, the Kingdom is God’s rule over the entire created order and is present now in all dimensions but to limited degree. Those people who submit to His rule become the agents and stewards of that rule as they use their skills and influence to see the whole created order restored and functioning according to God’s principles. The Kingdom grows as the influence of Godly principles is extended by His people to increasing degree in all dimensions of creation. Within the reformed tradition there are differing perspectives on how successful this endeavor will be. Some expect upward progress with the church becoming at least the dominant influence in society while others expect a deterioration of conditions up until the return of Christ. Either way, most careers can be valid expressions of faith as we fulfill the Cultural Mandate (Genesis 1:28) by ruling as God would have us to rule. The measure of a career is the opportunity it presents to cause God’s will to be done on earth.

Swearengen explains,

…”God’s present work is redemption and reconciliation, the results of which expand his present-and-future Kingdom…” If technology can help restore some lost dominion, it can also help advance God’s kingdom. A Bible-based science and technology ‘should consciously try to see nature substantially healed, while waiting for the future complete healing at Christ’s return’. 11

Discussion

This viewpoint seems to blur the distinction between the Kingdom of God and the dominion of mankind. Genesis 1:28 describes the latter. Man’s dominion began with the first humans and is part and parcel of man’s role. It was growing prior to Christ (fire, agriculture, transportation, construction, metal working, etc.). It grows by man’s initiative, through his power, and in many
respects is advanced as effectively by those who recognize God’s Kingdom as by those who do not. It fell with mankind and bears the ambivalent moral character of mankind.

The Old Testament expectation was that the Kingdom of God would be a divine act and a manifestation of God’s power. The preliminary Old Testament rumblings of the Kingdom (deliverance from Egypt, deliverance from Babylon, various theophanies and “Day of the Lord”s) were pictured as divine acts. Indeed, the entrance of the Kingdom of God into history with the incarnation of Christ, can only be considered a divine act. The miracles Christ performed were evidence of the Kingdom of God not in their outcome, but rather in the way they were accomplished: by the power of God. (Matthew 12:28; Luke 11:19) The mechanism of Kingdom growth is not human effort (Daniel 2:34, 8:25; Mark 4:26-29). Ladd observes,

The supernatural character of the present Kingdom is confirmed by the words found in association with it… Men can enter the Kingdom (Matt. 5:20; 7:21; Mark 9:47; 10:23; etc.), but they are never said to erect it or to build it. Men can receive the Kingdom (Mark 10:15; Luke 18:17), inherit it (Matt 25:34), and possess it (Matt 5:4), but they are never said to establish it… They can look for it (Luke 23:51), pray for its coming (Matt. 6:10), and seek it (Matt. 6:33; Luke 12:31), but they cannot bring it.

Monsma says,

God’s kingdom of shalom—whether in its current fragmentary form or in its glorious fullness in the culmination of human history—is God’s gift to us, not something we wrench out of a fallen culture by our own efforts.

In Hebrews 2:5-9 we find a typological link between the dominion of mankind celebrated in Psalm 8 and the Kingdom of God, but these links nowhere suggest that the Kingdom of God is equivalent to or initiated and consummated in the same way as the dominion of mankind. The Kingdom of God unfolds according to God’s plan, by his initiative, and in His own good time. The Pharisees could not hurry it along by meticulous law-keeping, nor could the Zealots precipitate it by military rebellion, nor indeed can we hasten God’s timeframe today by the evangelism of all “people groups” or by the transformation of our culture according to Christian values, as noble as these goals may be.

The New Testament references to the Cultural Mandate are typological in nature. The familiar dominion of mankind is a type and imperfect foreshadowing of the coming Kingdom of God. The Second Adam can and will accomplish what the first Adam and his descendents are unable to do: exercise Godly dominion over all Creation. The teaching of Jesus about the Kingdom of God is a call to live and to value in light of this future certainty. The Cultural Mandate applies to career selection not just as a call to improve the dominion of mankind now, but moreover as a reminder that a new and perfect dominion is coming, one not formed by human hands.

Pietistic Perspective

In the pietistic perspective, the Kingdom is the final, perfect state of creation, initiated by a supernatural act of God and characterized by universal and perfect relationship with God as well as an end to sin, suffering, and death. Christ demonstrated that the power to bring that very Kingdom was His and called his followers to live even now in light of the certainty of that future Kingdom. That living involves expressing the values of the Kingdom through loving God and people, following Christ’s model of sacrificial service, as well as evangelism and seeking to see God’s will carried out in every sphere of life. These actions are all part of the response to Christ’s message about that future Kingdom, but do not bring, advance, build, or hasten that future Kingdom. The measure of a career is the opportunity it provides to express the values of the Kingdom.
Discussion

The current work of the Holy Spirit in restoring creation through the dominion of mankind and in transforming hearts and minds is a real and active phenomenon. However, the product of this work does not seem to be what Jesus has in mind when he speaks of the “Kingdom of God”. Our issue with the evangelical and reformed perspectives as described above is largely semantic, however it becomes substantive if the Great Commission or the Cultural Mandate is elevated to the only or primary mandate of the Kingdom of God. It is often observed that our Western culture emphasizes “doing” over “being” and achievement over relationship. The Western notion that “the value of a life is measured by what a person achieves” is not fully Christianized by saying that “the value of a life is measured by what a person achieves for God”. In the Synoptic Gospels, Jesus does not relate greatness in the Kingdom to achievement in global evangelism or transformation of culture, but rather to humility (Matthew 18:1-5; Mark 9:33-37), service (Matthew 25:31-46), and sharing in the suffering of Christ (Mark 10:35-45). In fact, the Kingdom of God requires a profound reversal of our notions of greatness—even spiritual greatness (Luke 9:46-48; Matthew 23:11-12; Luke 22:24-27). The heroes of our faith are not primarily the notable spiritual leaders or political reformers. The heroes of our faith are those who over the broadest spectrum of life situations have embraced the promises of God (Hebrews 11:13-16.)

If the call of Christ is primarily to advance his Kingdom through the application of our wealth, intelligence, power, and influence, then what of those who have physical or mental disabilities that prevent them from being missionaries in foreign countries or even contributing much money to missions. What of those who are born into places and life situations where they have so much less possibility of transforming technology or culture on a global scale than we do. Are those who are so profoundly limited in their capacity to impact society, proportionally limited in their capacity to fulfill God’s great purpose for mankind?

THE KINGDOM AND ENGINEERING

Choosing engineering as a profession is not just choosing to practice a certain activity for a third of the day, but also to be part of a professional community. This community has a certain culture, and membership brings a certain set of life experiences. Although there are individual differences, there are significant commonalities. After all, why do we all relate to Dilbert? This broader picture needs to be evaluated from a Christian perspective. How does the practice of engineering itself as well as the culture and experiences that surround it either help or hinder the Christian as he/she tries to live in response to the Good News of the Kingdom. We consider four ways: 1) the technical problems you solve, 2) the way you work, 3) church involvement, and 4) relationships with people.

Which technical problems you solve

As an expression of love to neighbors, Christian engineers solve practical technical problems by applying science and math. The values that an engineering design should reflect have been discussed both from a Christian perspective and from a more general ethical perspective. It should be noted, however, that very few engineers actually control design decisions at the high level of most ethical discussions. For example, as an engineer, you might decide how the electronic control system for a DNA sequencing device will be implemented, but you will not be consulted by your employer about whether genetic engineering as a technology should exist. Decisions about technology policy are generally made by public officials and the upper management of corporations. The decision point on these issues occurs when you accept a job with a particular employer. It is important to consider the values of potential employers. They are unlikely to change these in response to your convictions, though they may accommodate your
convictions as far as you continue to serve their goals. Are their goals ones which you can fully support as you seek to express Kingdom values through the work you do? Are you willing to devote a substantial portion of your life to accomplishing their goals? Is that good stewardship of your time and abilities?

As a response to the profound reversal of values required by the Kingdom of God, Christian engineers value differently from the world. However, alliances of convenience are often found. Your employer’s explicit goal probably has something to do with “enhancing shareholder value”. This may not be enough to daily inspire and motivate you, but it is important to evaluate the broader impacts of helping your employer accomplish their goal. Could your work for them be an avenue to make an important technology available to many people? Could it meet basic human needs and improve life conditions? Because of the interrelatedness of our economy, there are many ways to meet the needs of people. If a remote village suffers disease due to a lack of clean water, who has greater impact for the well-being of the village, a doctor who diagnoses and dispenses medication or a driller who makes a well to provide clean water? And how does the impact of the driller compare to that of the aid agency which sent her to the village. What about the wealthy businessman who endowed the agency, the engineer who designed the product that made the businessman wealthy, or even the petroleum geologist who provided the dependable, inexpensive source of energy that supported the economic prosperity needed for consumers to buy the product. Clearly, it is difficult to say which of those individuals had the greatest impact on that hypothetical village. There may be a greater sense of personal satisfaction when you can directly observe the human impact of your work, but for most of us, our indirect impacts are far more significant and lasting. The potential for impact, both direct and indirect, should be carefully considered in choosing jobs or assignments. An artificial distinction is sometimes made between “kingdom careers” and other careers. In the chain of people who played a role in improving circumstances in the village, where do you draw the line between those who have a “kingdom career” and those who do not? The line can only be drawn based on the values that motivate the individuals, not the consequences of their work.

One of the highlights of engineering research and development is the enormous multiplication of impact that comes from developing and communicating ideas. A new technology that you may develop can impact the lives of far more people than you will ever meet, and the chain of indirect consequences of the technology can be greater still.

How you do your work

In response to the ethical demands of the Kingdom, Christian engineers uphold the ethical standards of their profession regarding honesty, safety, environmental responsibility and protecting the interests of their employers and customers. They also uphold the constraints of business ethics, such as honoring systems of management controls, even when these seem inefficient or onerous.

Relationship with the church

Christian engineers live and value in reference to the Kingdom of God. While certain aspects of the Kingdom of God were present in Christ, he taught that there would be a period of time before the consummation of the full eschatological Kingdom. This tension between the “already” and the “not yet” is felt in many aspects of Christian faith and life. Disappointment with the “already” has presented a faith struggle from the earliest days (Matthew 11:4-6; Luke 7:22-23; Matthew 13:31-33; Mark 4:30-32; Luke 13:18-21). This disappointment combined with the “loner” tendencies of many engineers leads some to disengage from the life of the church. While the church is not to be equated with the Kingdom of God, we must bear in mind
No one can pray (the Lord’s prayer) wholeheartedly who does not give God first place in all speaking and doing, and not as an exercise in heroic individualism but as a member of the people called to reflect the holy otherness of God in their daily living.17

Relationships with people

Christian engineers value people over things and achievements because of the Kingdom of God. Science and math are enormously effective for solving technical problems. However, many of the problems we encounter in life are not technical. They involve people, relationships, and ultimately sin in human hearts (and not always the hearts of others). These problems are not subject to solution by engineering methods. There is a tendency for engineers to retreat into the world of technical problem solving where they feel successful and the problems can be overcome with familiar tools. An important aspect of testifying to the Kingdom of God is in valuing the people around you, whether co-workers, family, or friends (Matthew 5:14-16). This requires transcending the engineering mindset to see them as Christ does rather than as system components that may or may not be within spec.

Employers and assignments differ in the opportunity they provide to value people. Frequent or extended travel can be exciting professionally but devastating to family relationships and church involvement. Some employers are more flexible than others in allowing employees the time they need to deal with emergent family situations. Some organizations have a culture of healthy work / life balance while others do not.

THE PROBLEM OF UNCERTAINTY

We have laid out a criterion for career choice and evaluated some aspects of an engineering career in light of the criterion. However, the contingencies of life make it impossible to select a career as an optimization over likely outcomes. We simply do not know what the future will hold, and this is what the Creator intended. We have maintained in this article that God’s will for us centers not so much in the things we achieve as in the values we express. Accordingly, we recommend viewing career selection (and all decisions) as an act of worship: an expression to God and those around us of what we value, of where we assign worth. We value above all the Kingdom of God and His righteousness (Matthew 6:33). Intimately connected to this, we value people and resolve to make their needs our own. We also value our abilities, circumstances, and resources as gifts from God to be returned to Him in worship.

CONCLUSION

The concepts discussed in this paper could be useful in advising and informal discussions with students and could be incorporated in an engineering ethics class taught from a Christian perspective. The main topics were:

1) Jesus taught that the Kingdom of God must be our primary concern, therefore what we believe about the Kingdom of God determines (or should determine) how we make decisions.

2) There are various interpretations of what Jesus meant by the Kingdom of God. Each one translates into a particular way to evaluate career options.

3) Jesus does not call people to attempt to advance, build, or establish his Kingdom. Rather he calls them to live and value in light of the certainty that His Kingdom will come.

4) Career selection (and decision making generally) is best approached as an expression of present Kingdom values rather than an optimization over future predicted Kingdom impact.
5) Engineers express Kingdom values in a variety of ways, not just by their design decisions. Accordingly, the discussion around the value of an engineering career needs to expand beyond the value of technology to encompass the broader personal, family, and church implications of that career choice.

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[6] I call this view “Pietistic” because it emphasizes internal transformation over external action as the primary response to the Kingdom. The choice of name is problematic. I don’t mean to include the 17th to 18th century religious movement called Pietism in this group or those denominations (e.g., Methodist) that trace their heritage to that movement. While this group also emphasizes personal piety, their perspective on the Kingdom of God is not the one I describe as “Pietistic”, but more like the “Evangelical” perspective.
Integrating Faith into the Academic Environment at Baylor University

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Abstract

At universities today, including Christian universities, the integration of faith and Christian principles into the academic environment is left to the individual faculty member, depending on the academic environment. Integrating Christian faith should be an important topic when developing our teaching skills but it is quite often overlooked and not discussed as it should be. While religiously affiliated universities may have a core set of beliefs and may even have classroom requirements, such as an opening devotional, again, it is often left to the individual professor to develop a “style” of integration. Many engineering faculty find it very difficult to integrate faith into the academic environment. Most faculty have come through an educational system where integrating faith was either not modeled or not modeled well. This paper will examine what is being done by engineering faculty members in the School of Engineering and Computer Science at Baylor University in the context of Baylor’s academic environment. A wide spectrum of activities will be addressed. Topics covered include what Baylor professors do on a personal/spiritual level, in the classroom, and outside the classroom to emphasize Christian faith and its significance, especially to the profession of engineering. It is important to document these activities to give new faculty encouragement to integrating faith and learning. For experienced faculty, knowing what others are doing should also provide encouragement to more effectively integrate faith into their vocation.

Introduction

There is too much at stake in our educational system to not address the integration of faith and learning. History is replete with examples of once proud universities which were founded in the Christian tradition that are now just proud and somewhat arrogant. James T. Burtchael in his book “The Dying of the Light” chronicles how universities such as Harvard and Princeton to name two, have lost their first love1. The potential danger is that other universities with a religious affiliation might do the same. Integration of faith and learning must be intentional, purposeful, and effective. Development of students is the main focus of this integration effort, preparing them to face a world that is not “Christian friendly”. But students are not the only benefactors in this integration. Faculty grow both professionally and spiritually through the process of integrating faith and learning. The purpose of such efforts is to honor God and, if done with this attitude, God will surely bless. Undergraduate and graduate experiences by the authors did not prepare them to operate in a Christian university. Working at a religiously affiliated university, such as Baylor, began with the naive belief that this was going to be the perfect job and that expressing faith in this academic environment would be a very natural process. After arriving on campus it was obvious that integrating faith and learning was a topic not often discussed. The environment at Baylor has changed over the last ten years but not as much as is needed. As we reflect on new faculty arriving in the engineering departments and after becoming mentors for new faculty, we have a distinct burden to help these new faculty take the first steps toward integration of faith into the classroom. We want new faculty to be more than just Christians teaching at a university, but to be faculty who inspire students to excellence in their faith and in their vocation. Most everyone at Baylor seems to agree that faith must be integrated into the academic environment. How this is to be done is not exactly clear. Putting this subject
into perspective and then outlining ways that current faculty are integrating faith and learning might give not just new faculty, but all faculty, an opportunity to reflect and to take this responsibility more seriously. After all, the consequences of not integrating faith with learning would be devastating.

The Case for Integration of Faith and Learning

Integration of faith and learning is an important topic for religiously affiliated universities. Most websites at religious institutions, such as those at Baylor, Union, Wheaton, Calvin and LeTourneau, have references for faith and learning. While this is important, the concept of faith and learning seems more of a concept than a reality. Michael Duduit in his article “The Challenge for Christian Higher Education” sees the secularized environment at today’s universities eroding the religious heritage of truth that was an important part of attending a Christian university. He sees five steps that must be taken to stem this trend.

1. The church must learn the difference between “church-related” schools and “Christian Universities.” – A Christian university is founded on Christ and His principles.
2. Denominations and boards of trust must reclaim responsibility for the direction of their schools.
3. Presidents must be elected who will set a vision for Christ-centered education.
4. Faculties must be taught to integrate faith and learning. – Secular universities integrate their worldview into the classroom. Christ-centered universities should do the same. Christian faculty must be hired at Christian universities and be taught to integrate their faith.
5. Students must be drawn to the mission of Christian universities.

Obviously, the integration of faith and learning by the faculty is one of the key concepts needed in Christian Higher Education to prepare our students to face the world with a Christian perspective.

The integration of faith and learning depends heavily upon one’s own faith and worldview. Everyone has a worldview whether they realize it or not. Worldview is used to filter what we learn and to decide what truths are important. Van Treuren and Eisenbarth have written previously about “The Christian Worldview in the Engineering Context” and the difficulty of trying to decide on a common worldview at Baylor University. Richard Harris outlines several assumptions concerning worldview and the integration of faith and learning:

1. All truth is God’s truth – Christian knowledge is not separate from but part of the whole database of knowledge.
2. There is no conflict between God’s truth and other truth – Conflicts usually arise from conflicting interpretation rather than conflicting facts.
3. Secular learning is incomplete and often distorted – All worldviews except the Christian worldview are unable to explain all of existence.
4. Christian interpretation is based on the Biblical framework of reality – Biblical authority is the starting point.
5. Truth is the most important goal of learning – Truth is more important than any personal or worldly influences.

Harris sums this up with the following:

“…successful integration of faith and learning depends on a thorough, accurate, and careful thought through interpretation of the Bible with a good understanding of the Bible, together with a good understanding of how academic knowledge claims are made
and the worldviews underlying those claims. Skillful interpretation in both areas is a key factor."

Sadly, most students do not come to Baylor with this type of understanding. It is not taught in the public schools and it is not often found in the private schools either. Students at Baylor are required to take two religion classes, usually in their freshman year, however, these classes are usually taught from an academic perspective and do not teach the essence of what Harris is advocating. The first class, REL 1310 The Christian Scriptures, is “An introduction to the Old and New Testaments (their contents, historical backgrounds, and major themes), and to appropriate strategies for interpretation of the Bible.” The other class, REL 1350 The Christian Heritage, is “An introduction to Christian life and thought, from the early church to the present, through an examination of great texts with an emphasis on Christian doctrine, ethics, witness and institutions.”

David Dockery, President of Union University, is an advocate of religious education courses and says:

“We need to understand the central place a school or department of Christian studies must play in a Christian college in carrying on this tradition by offering courses required of all students in both biblical studies and the various areas of Christian thought. Such courses are not merely exercises in spiritual devotion or professional preparation, as important as these may be, but they provide the framework for serious intellectual wrestling with literary philosophical, scientific, technological, and worldview issues.”

Students should have a class in worldviews and how that integrates into their academic environment. This training would ideally occur prior to attending a university or college. Organizations such as Worldview Academy or Summit Ministries run summer camps for high school students to give them a solid biblical foundation upon which to build their life. The Worldview Academy states that they are a “…non-denominational organization dedicated to helping Christians to think and live in accord with a biblical worldview so that they will serve Christ and lead the culture.” The Summit Ministries has summer student conferences that are “…two-week educational conferences that analyze the major worldviews of our day, contrasting them with the Christian worldview.” Focus on the Family offers the Focus on the Family Institute for college students to spend time in a program that will “…challenge you to discover God in a deeper way and live out his calling and purpose in your life. It's a hands-on, action packed, life-altering experience that will give you the tools and inspiration to change your world by living the Christian worldview in your family, church and society.”

For Baylor, either an additional course in worldview or modification of the existing two religion courses would be appropriate; however, the engineering departments have no control of the content of the religion courses as they are part of the university requirements. Perhaps this could be integrated more completely into the freshman introductory engineering class. Learning about the prevailing worldviews (such as scientific naturalism and postmodernism in addition to the Christian worldviews) would prepare students to face the academic learning environment at any school and prepare them for a life of learning.

The key to integrating faith and learning is to develop the life of the mind. Several Bible verses support this ideal. The first states that we have a responsibility to learn so that we can explain God’s truths and be able to discuss these truths in light of our faith and knowledge:

Always being ready to make a defense to everyone who asks you to give an account of the hope that is in you. (NASB I Peter 3:15b)

The second scripture verse clearly indicates that God is all around us, especially in the created world. Thus, the study of engineering is merely an extension of studying God and His truths.
For since the creation of the world His invisible attributes, His eternal power and divine nature, have been clearly seen, being understood through what has been made, so that they are without excuse. (NASB Romans 1:20)

Lastly, the pursuit of truth is at the root of all knowledge.

And you will know the truth, and the truth will make you free (NASB John 8:32)

Richard C. Chewning, Distinguished Scholar in Residence at John Brown University and Emeritus Professor of Christian Ethics at Baylor University, has written on assimilating the mind of Christ in the integration of faith and learning. First, he points out that “there can be no genuine integrations without the help of the Holy Spirit.” Chewning cites three scriptures from John (John 6:7,13; John 15:1-2,4-5; John 15:7) which show that Christians need the Holy Spirit and without the Holy Spirit we can do nothing. Second, the “mind of Christ” is available to those whom He calls into teaching. It is up to each individual to allow Christ to use us more and more and to develop this “mind of Christ”. Having “the mind of Christ” is only limited by our human shortcomings. Third, integration requires cooperation between the Christian and the Holy Spirit. Simply becoming a Christian does not mean that we are always operating in the Spirit. We are flesh and are tempted to still operate in the flesh. We choose and the more mature we become, the more we are open to the leading of the Holy Spirit. As Chewning says “Living by faith, in this context, means that we faithfully acknowledge our absolute dependence upon God who both guides us and strengthens us for his work.” Lastly, Chewning points out that there are varieties of “styles” by which integration may take place. It is up to the individual to develop a “style.”

Integration of Faith and Learning at Baylor University

In the School of Engineering and Computer Science, an attempt was made to define the intentionality of our Christian mission in February of 2006. This document was in response to a request for information from the then new President, John Lilley. A committee was formed to draft this document consisting of one faculty from each of the three departments in the school. It was very clear that a consensus between engineering and computer science could not be reached. The Department of Computer Science chose to draft their own statement. Included as an appendix to this paper is the engineering response, which contains a reference to Christian faith in the academic environment. This document provides the framework within which the engineering faculty can operate.

In all, 20 faculty members were interviewed for this paper (approximately 87% of engineering faculty) including the Dean and Assistant Dean. The faculty members were part of the two engineering departments, the Department of Mechanical Engineering and the Department of Electrical and Computer Engineering. All faculty were asked three distinct questions as part of the interview:

1. What is your personal philosophy with regard to integration of faith and learning?
2. What do you do in the classroom to integrate your faith?
3. What do you do outside the classroom to integrate your faith?

For the most part, faculty were cooperative with these questions, however, an observation was that faculty who make an effort to integrate faith and learning in the classroom were more articulate about their personal philosophy and were more open to discussing questions two and three. The variety of answers distinctly showed that while Baylor talks about integrating faith and learning, and has done so since 1845, the current faculty are not accustomed to discussing this subject. The opportunity exists for more to be done, to truly make Baylor a distinctly Christian university, but the faculty emphasis has recently changed. The current administration has created an environment where faculty at Baylor are more concerned with research and the implications of
becoming a research Tier One institution. The efforts outlined in the following sections are from both tenured and non-tenured faculty. We make no distinction here, as being tenured or tenure track should not influence our Christian witness nor should it keep one from being sensitive to the call of Christ to educate students. As previously mentioned, all Christian academics must find a “style” that suits their personalities. With that caveat, the following discussions on integration of faith and learning at Baylor University are offered as suggestions as to what can be done to integrate faith and learning in an academic setting.

**Personal Philosophy of Faith and Learning**

Most faculty see the integration of faith and learning as an extension of who they already are or what they believe. Most faculty feel called to the vocation of teaching and know this is where God wants them to be. If we are truly Christians, then we are Christian in everything that we do, including teaching at a university. As one faculty member put it, the defining characteristic we bring is our attitude to the profession. Attitude says a lot about an individual. Professors must be able to demonstrate that Christian faith is important in all facets of their lives. To achieve this end encourages each professor to pursue personal growth and maturity in Christ. One cannot be too busy to learn about God or to serve our students. While teaching at a religious institution like Baylor can be considered a ministry, all work that honors God is a ministry and must be treated as such. This also includes the responsibility of being up-to-date professionally by reading journals and attending conferences. Personal philosophy is exactly that, intensely personal, however, our faith and how we live that faith out must not detract from our ability to communicate about engineering in the classroom, it should punctuate it.

Equally important is how one views their students. Students are children of God and worthy of our efforts. This point of view should give us a burden for our students, that they know and love God and that they are prepared to face the world as competent engineers with a Christian worldview. We want our students to graduate with a wonder and awe concerning God’s creation and to see everything that happens through that filter. Several faculty pray regularly for their students in general and pray more specific as requests are made known. One faculty member actually gets the class roster before each semester and prays for his students as a way to get to know the students and to become closer to them. (Baylor’s class rosters also come with photos which makes associating a name and a face much easier).

As has already been seen, faith and learning are not mutually exclusive, but mutually dependent. One must accept with faith that the Bible is truth, not mythical, and that it is consistent with the topics we pursue intellectually. Only then will one be able to begin to see that the technical engineering topics taught as are really an extension of one’s own faith. Some faculty do not feel comfortable discussing their faith either inside or outside the classroom. At Baylor, there is no pressure to conform to any preconceived plan to integrate faith and learning and, while these professors do not feel comfortable discussing their faith, they do not want to limit any efforts by others to integrate faith and learning. These professors are content with being positive role models and treating students with respect, letting their life be their integration of faith in the academic setting. Actions speak louder than words.

Personal development is key to maintaining the “mind of Christ” in all we do. Reading about important technical topics to keep up with what is happening in our field is important. Also, reading about issues facing Christians worldwide is important. Students need to be brought into these conversations to remind them of what is happening outside the sheltered walls of the university. At Baylor, it is sometimes called the “Baylor Bubble” and that bubble needs to be opened every now and then. Several of our faculty participate in conferences such as the Christian Engineering Education Conference (CEEC) or the American Scientific Association (ASA). These associations allow faculty to write papers that are explicitly Christian on topics that are...
important to the issue of integration of faith in what we do. It could be about missions or people and culture, or papers such as this, to integrate our faith in our learning. All these efforts lead to the personal development of the individual and ultimately lead to more intentional integration of Christian principles in our curriculums.

In the area of personal development, some faculty are involved in reading groups across campus. Topics are varied as are the mix of individuals in the groups. Mostly these groups choose a book to study, agreeing to read and discuss on a weekly or bi-weekly basis. Recently, three engineering faculty were involved in a group reading Charles Taylor’s “A Secular Age”. This book looks at Christian faith and traces the history of Christian faith, attempting to understand where faith is today. Taylor is attempting to understand the secularization of the church and Christian faith in light of the decline of religion. This reading group initiated many good discussions leading to a more complete understanding of our culture, the culture that has influenced many of our students as they enter the university. Being more informed helps faculty be more responsive to the needs of the student. It is very healthy to be thinking bigger than the courses one teaches or one’s own department.

Also available through the university are seminars designed to help faculty understand our students more completely. These seminars are a series offered mostly once a year covering topics such as “Understanding the Students We Serve: Helping Students Discover Meaning and Purpose in their Lives” and “Facebook and Online Communities”. The seminars are taught by Student Services and are very popular with both faculty and staff. As with most programs of this sort, the individual faculty must feel the burden and be self-motivated to attend. These seminars (and reading groups) take time, however, the time invested is well worth the result of being more informed and personally challenged to do a better job as a Christian and faculty member.

In any faculty or school meetings, most start with a short devotional message and prayer. This is a constant reminder to the faculty that our mission is a divine one. Keeping that perspective foremost leads to very enjoyable faculty meetings most often with consensus on important issues.

**Integration of Faith in the Classroom**

At Baylor, all faculty agree that it is very difficult to intentionally integrate Christian faith into every lesson and every topic. Science and engineering professors have been taught the scientific method which tends to influence how they approach their topic. Faculty take data that proves or disproves the hypothesis. We are told by the academic world that to include any reference to God is to introduce a bias. This bias, it is thought, would obviously make the data flawed and the work suspect. This pressure is especially true for untenured professors at secular institutions (and some religiously based institutions). In research, everything we do is seeking to understand God’s creation more completely. Therefore, even though there may not be a very specific application of the Christian faith in every lesson, students can be continuously reminded to take a step back and look at the big picture of what God is doing in this world. We will never understand the immensity of the universe that God created. Having this perspective is awe inspiring and humbles us in the presence of the almighty God. This attitude keeps our knowledge and our ego in check.

We were pleasantly surprised at the efforts shown by the faculty to integrate faith and learning in the classroom, however, most of the efforts revolved around either ethics or design. Baylor engineering requires an ethics course as part of its degree requirements. A variety of ethics courses are available to the students from departments across the campus that are taught from a Christian perspective, ranging from biomedical to business. Recently the engineering departments have offered their own ethics elective titled Societal and Ethical Issues in Engineering. The faculty member that teaches this course sees this as an opportunity not just to
teach the “nuts and bolts of ethics”, but to emphasize the “whys and wherefores” and “to do the things that matter most.” The course exposes students to the different theories of ethics and includes a discussion on Christian ethics. It then follows with a discussion of professional ethics and lastly looks at technology and ethics, raising cultural, stewardship and values issues. This challenges students to go beyond knowledge and apply their ethical system to situations they might face. In the area of ethics, the major engineering ethic emphasis at Baylor is through this course; however, ethics is also introduced in the freshman introductory course in the context of professional ethics related to Christian ethics.

Design is the other area that seems to naturally welcome the integration of faith and learning. Design integrates the concepts learned in the ethics classes. As engineers, there are both legal and moral obligations that go with designing an object used by the public. A professional engineer’s pledge presented by one faculty even has a reference to Divine Guidance. Is the design appropriate, especially in the context of the culture and humanity? In design, engineers have a series of intrinsic and extrinsic decisions that must be addressed. While being a Christian engineer does not change the physical principles used to design something, the motivation for the design may be entirely different which may result in a significantly different design. Christians might pay more attention to safety issues or the type of material used in the manufacture. Today it is more common to consider the lifecycle of a product or how green a product might be. This is entirely consistent with the concept of Christian stewardship. Our students should be aware of our responsibility before God to be stewards of the planet and its resources. These concepts are discussed in our freshman, junior and senior design classes, with more emphasis given in the junior and senior classes. Our senior design class completed a project to directly help people who need physical therapy. The class designed a device to place invalid people on horses, as hypotherapy has shown to help people more than some traditional therapies. In addition to design and construction of a project, students were excited that their result had a humanitarian benefit. More projects like this may result in Christian engineers being involved in these humanitarian efforts after they graduate either as a primary vocation or as a part of a mission outreach.

The concept of being an engineer because God has gifted you to serve in this capacity has become accepted at Baylor. Newberry has addressed the challenge and importance of teaching the concept of vocation in engineering education. As early as the introductory freshmen class, the concept of vocation is clearly presented to the students. We are called of God to serve our fellow man as engineers because of our gifts and talents. In this context, in the freshman year it is not uncommon to help students discover that their talent or desire lies in another direction from engineering. While this does not help retention, it satisfies a higher calling of helping students discover their place in the world and, as faculty, we feel successful if this occurs. As faculty, we also model this concept of vocation, making sure that our students know we feel called to teaching and, more specifically, we feel called to teach them at Baylor University. Enjoying what we do and feeling secure in knowing that we are in the place God wants us to be speaks volumes to the students. It also allows us to use this confidence when counseling our students in their career choices.

Discussions with the faculty have shown other ways that faculty display their faith in the classroom. Most faculty introduce themselves on the first day of class to give their students an idea of their academic journey and also a glimpse of their personal self. As such, many faculty at Baylor also talk about their Christian faith on the first day of class, that they attend church, and encourage students on their spiritual journey. Not all students at Baylor are Christians but, as a religiously affiliated university, there should be no hesitation to discuss such matters in class. As faculty, we are to challenge our students to think for themselves and not just to think something because we say they should. Most faculty who do discuss their Christian faith on the first day of class also invite the students to discuss anything, including spiritual matters, with them in private.
Baylor is very student friendly and encourages students to come by the office at any time. Office hours are officially posted but they are not the only time for student interaction.

Building relationships with students is highly important. This means that professors must learn the names of their students. Not being especially good with names, some professors take pictures of students on the very first day of class so they can study the names and put a name with a face. Recently, Baylor University included the freshmen pictures with class rosters. This is a great idea unfortunately, if one only teaches seniors, some of the students look entirely different than they did as freshmen.

One of the authors uses an information sheet to learn about the students on the first day of class. The students are asked to list three things that they would like the professor to know about them and their student activities. These inquiries are most enlightening. Many make overtly Christian statements about themselves and seek to communicate that they are Christian. Looking at their activities also shows that many students are involved in Christian organizations on campus. This information gives the professor insight into the individual student, knowing their motivations. This information can be used in future conversations with the student. On this same information sheet is usually a question the students to comment on a particular topic that may be related to Christian principles. It is a topic that the student may eventually face in their engineering practice, such as cloning or intelligent design. The results of the survey are tabulated and presented to the class. This leads to interesting conversation and lets the professor have another piece of information that might indicate the level of spiritual maturity of the students.

From time to time, it is good to bring up topics in the news that may be controversial. This may be the national news however; more often it is something that is happening on campus. Students bring a different perspective to the conversation and often do not know the whole story on a particular topic. This leads to great discussions in the context of the Christian environment at Baylor and what should be our response. A recent example is the Baylor 2012 initiative that has polarized the campus. Students hear about the controversy but do not understand what is really happening. Having an open and honest discussion, presenting both sides of the argument, is the best policy. In any discussion, the authors do not state their opinions up front so they don’t influence the students’ thoughts. In certain cases where a clear opinion needs to be established consistent with Christian faith, this is usually done after inviting further discussion in the office. Another professor uses vacation times as an opportunity to allow students to discuss what their plans are or what they did on their vacations. At Baylor, it is not uncommon to have students who take mission trips during their vacations. The professor allows these students to describe where they went and what was accomplished. This is a good opportunity to inspire other students to do the same and to have conversations on mission trips outside of class.

Course materials can be given a distinctly Christian flavor. In a course syllabus there is usually a summary of the class and what will be accomplished. One professor uses this to describe the study of the topic as a study of God’s wonders, putting the topic in its proper perspective. Another professor places a Bible verse as a footnote at the bottom of each printed page in the course. Having taught previously at a secular university, this professor does not include the name of God in the verse to not offend anyone. He has never had an objection in all his years at the secular university. Obviously, the name of God can be included at Baylor. Another professor places a Bible verse on the projection screen at the beginning of the class period. The verse does not usually have anything to do with the lesson but provides an opportunity for the students to have a quiet moment of reflection before class. Professors would obviously have the freedom to give a devotion in class or to do something special directly relating to Christian faith, however the prevailing thought is that it should be a natural part of the class and not forced. It is not the culture at Baylor to open the class either with prayer or a devotion however it is encouraged to do so if the situation warrants. This was particularly true last year with the tragic death of a
graduating senior. The faculty felt totally comfortable to address this unfortunate event in class with scripture and prayer.

Another way to integrate faith into the classroom is to profile some of the famous individuals in the discipline who were Christian. Names such as Newton or Farady can be highlighted for their Christian faith. A good example of this is found in an article by Ben Clausen of the Geoscience Research Institute. His paper entitled “Integrating Faith and Learning in the Teaching of Physics” gives several excellent examples of Christian physicists. Even Einstein has some distinctly Christian references to interject into the classroom. It is good to keep this historical heritage alive. This has been used by one of the authors in a freshman course.

In the freshman introductory class, a lesson is devoted to intelligent design to stimulate the students to think about this in the context of their Christian faith. After the presentation, the class discusses the topic in a free exchange of ideas.

In each engineering class, there are usually one or two topics that do lend themselves to intentionally discussing the Christian faith. In the area of thermodynamics, the concept of entropy causing processes to occur in one direction tending toward disorder has a direct application with the creation-evolution debate. The first law of thermodynamics states that energy cannot be created or destroyed but that it can change forms. Where did the energy originate? If one looks at state properties and studies water, why does water expand when frozen? What would be the consequences if water didn’t expand when frozen? These and other topics lend themselves to discussions with a view toward integrating these ideas from a Christian worldview. In heat transfer, if one views the energy spectrum from sunlight, it peaks in the visible wavelengths which allow humans to use this light to see. If one operated with a Christian worldview then this is the marvel of God’s design. If one believes in evolution, then this would be the process by which man evolved over millions of years. Its all about worldview and this is what is emphasized with this particular example. Another topic taught at Baylor deals with biomechanics. Again, the human body is a marvel of God’s creation and example after example can be found in this discipline. Sometimes the handiwork of God so obvious that we miss it.

Integration of Faith Outside the Classroom

It seems far easier for faculty to demonstrate their faith outside the classroom. Many senior faculty see this as the sphere where they have the most influence and feel the most comfortable. While, again, some faculty are not overt in their faith, the way faculty interact and treat their students speaks volumes about their faith. Attitude and approachability are everything to the students. While faculty are all different and have their own styles, this is something that should be common to all faculty.

Much of the student interaction occurs in the office. Many faculty use the office as a safe haven for conversation on many topics. If it is an advising capacity, interest in the student’s progress and well being can be communicated. Helping them find their way is a priority. One faculty asks the question, “If you didn’t have to worry about money what would you do with your life? What are you passionate about?” This leads to discussion on vocation and the student’s future. At times, students come into the office with either personal or academic problems. It is an opportunity to discuss these in a Christian context and to pray with the student. Even if the student is not a Christian, people do not usually refuse the prayer of an interested individual. To reach this point where students feel open and able to share means that over the course of time, a meaningful relationship has to be established. In small schools with low numbers of faculty and a reasonably small student body this is possible. In larger schools one would have to make more of an effort to know the students individually.
By knowing the students’ names, it is possible to engage in conversations with the students as you meet them across campus or in the halls of the engineering building. Just saying “Hello” and using the name of the student communicates their importance. Often engineering students’ friends are amazed that the professor knows the student by name.

Faculty start showing students they are important even before they come to Baylor by giving time to perspective candidates. We work closely with student services to accommodate requests for individual meetings with professors. These meetings usually include about 20-30 minutes of discussion/questions followed by a short tour of the building. All together, these meetings can take 45 minutes to an hour. A Student Success Specialist has been coordinating the student visits which often include a visit to a classroom to observe the student-teacher interaction. For these classroom visits, it is important that a relationship already be established with the students in the class environment. Sometimes when students arrive at Baylor they point to these visits and the personal attention they received. These individual visits are in addition to the regularly scheduled Fall, Winter, and Spring Premieres formally held by the University and supported by the faculty.

Another great way for faculty to show students Christian faith in action is through their involvement in student organizations. At Baylor there is an organization called Engineers with a Mission (EWAM) which involves students in projects that help the developing world. During the school year the students develop the appropriate technology to then take to third world countries during summer mission trips. These projects have included bridge building in Kenya, installation of a wind turbine and lighting for a rural slum in Africa, and a water filtration system for an orphanage. Current projects include micro-hydro electric power to villages in Honduras. The focus of these projects is to provide local villages a sustainable means to bring in revenue and to improve their quality of life. These micro-enterprise types of projects are becoming more popular and it is great for our students to get the exposure during their academic experience. Having been involved in the projects gives the students a sense of accomplishments and a sense of worth, having used their engineering skills to help their fellow man. Faculty have many “teachable” moments as students are often overwhelmed by what they see. This leads to larger questions about God and our purpose in life. Some of the groundwork for these trips is done through special project courses working with the students on an individual basis.

Other organizations, such as ASME, IEEE, SWE, Catholic Student Services, and NSBE on Baylor offer opportunities for professional service. Service can be to the department, school or university by supporting different events. It also can be to the community by organizing groups to participate in Baylor’s Stepping Out Program. This past fall, two organizations sponsored the 3rd Annual Girl Scout Day Camp, working with elementary school young ladies to interest them in engineering. It was widely praised and provided the young ladies great role models. Also, being a faculty sponsor of a student organization allows the students to get to know the sponsor on a more personal level.

Some faculty do invite students to their house for dinners or “movie nights.” This is a very appropriate way for students to see their professors in a different setting and for the students to get to know the professor’s family. Movie nights can be used to stimulate discussions about the larger issues in life. The movies do not necessarily have to have a Christian worldview but should provide a starting point for discussions on deeper life issues. Smaller student groups are better, such as the executive committee for a student organization or a class.

Faculty at Baylor regularly participate in move-in day for incoming freshmen. Baylor has a Living and Learning Center for the School of Engineering and Computer Science so engineering students can live together in a dormitory. When the students find out that one of the professors is actually moving them into their room it is an opportunity to say how important students are to us. Other activities during the Welcome Week include dinner at a faculty home. Freshmen go to a
faculty house in groups of 10 to 20 students. This is an informal atmosphere to ask questions and talk about their new life at Baylor.

Other ways to interact with students occur off campus. Waco is not that large and it is possible to see students around town. It is always good to say hello to the students when you see them. A number of students earn extra money waiting tables around town. When they wait your table, it is great to see them and encourage them (and leave them a big tip). We also see students at church. Again, saying hello or inviting them over for Sunday lunch goes a long way in demonstrating our faith.

Conclusion

A paper such as this cannot be all inclusive but just scratches the surface concerning integration of faith in the academic environment. The Faculty agrees that integration of faith is something that needs to occur, especially at religiously affiliated schools, but it is a subject that always has room for improvement. Not enough discussion is occurring on how to best accomplish integration of faith and learning both in and out of the classroom. Two things are clearly evident. Personally, faculty must be committed to the concept of integrating faith in the academic environment. There is no way to build relationships with students if there is no commitment. This also involves the personal growth aspect of one’s faith to value students as individual human beings. The second thing is the academic culture at schools such as Baylor must recognize that to successfully accomplish this task of integration of faith takes time both to personally develop and to serve our students. At Baylor there is a strong expectation of service, however, in terms of faculty evaluation, service counts for only 10% with research and teaching counting 45% each. Often faculty, such as those at this conference, take valuable time to write papers such as this or to plan conferences with little compensation or recognition. If we as a school or department do not acknowledge that integrating faith and learning is an integral part of who we are and where we are going, then where will this type of dialogue take place? We need to be more intentional and involve all of our faculty in these discussions. The reality is that tenure track faculty, especially at Baylor under the current administration, must operate in a research Tier One university environment to become tenured. This type of professional development will emphasize research over teaching and not allow young faculty time to intentionally develop a spiritual dimension to their vocation. The early years are where habits are formed and priorities placed that will influence a career.

The good news is there are faculty on campus at Baylor University that do value integration of faith into the academic environment. These professors, however, do not talk enough among themselves and do not talk across campus. As an engineering department on a liberal arts campus, the university is ill equipped to address the unique challenges that face an engineering curriculum. It is unfortunate that it takes a conference such as the CEEC or the ASA to stimulate our thinking about how to better integrate our faith or other aspects of Christian engineering education. What can be done to help facilitate this discussion? Schools such as Calvin College or LeTourneau do have websites with some resources (past CEEC papers or other web based materials such as found on the CCU website). Perhaps a website focused on only integration of faith and learning might be a better repository. Along with that, the recent web innovation of blogging might be advantageous for asking information about integration of faith and learning. This means we could be more connected at times other than the conference and for reasons other than the conference. Again, developing these relationships also takes time but our peers can be our greatest resource. Our desire would be to have a website where new faculty could visit and see what has been done before and to eventually be contributors as they develop new and innovative ways to integrate their faith in and out of the classroom. The ability to talk about
spiritual things in the classroom is what attracted the authors to Baylor in the first place and what continues to inspire them on their journey.

We all desire to be servants of Christ and to impart this to our students. The following student comment illustrates what we are trying to do at Baylor:

“I just thought I’d let you know how much I appreciate your place in this department. You have a mysterious way of keeping students attention even for the most boring of lectures. Personally you had me enthralled with most of those …… lectures. I also appreciated your mentions of real world issues and Christian worldviews. As fascinating as engineering is, and obviously is to you, it’s incredible to hear you address things that really matter in this life (and the next, particularly). While you don’t flood the classroom with “religious talk”, you still convey what Christ means to you and the importance of Him in our lives. Profs like that are few and far between. Luckily, we have a few real men like you in this department. You encourage me to be a Christian engineer rather than an engineer who happens to be a Christian. Thanks for all your hard work for your students. It’s obvious how much you care for the student as seen by the way you take care of us by presenting interesting journal articles, job facts and tips, and giving us confidence that someone will want to hire us. I will be honored to graduate for this program having been mentored by you. Thanks again. – One of your blessed students.”

References


The faculty of the Departments of Mechanical Engineering and Electrical and Computer Engineering offers the following thoughts on how the School of Engineering and Computer Science can be intentional in its Christian mission, value both teaching and research and use the increasing quality and quantity of its scholarship to enrich the learning experiences of all its students.

The Christian faith and professional competence of the faculty and staff of the School enable us to provide exceptional educational opportunities in a nurturing Christian environment. We believe that enthusiastic, compassionate and professional teaching fulfills our Christian vocation as educators, role models, and mentors.

It is essential to the future success of the School that faculty who are hired and tenured are able to express their belief in the Triune God and the necessity for personal redemption through Jesus Christ. Also, it is essential that these beliefs be accompanied by Christian charity, especially in relationships with faculty, staff and students. Candidates should also share the commitment to fulfill Baylor’s mission as a Christian university in the Baptist tradition. They should be scholars who have a significant potential for inspiring teaching and high-quality research. To find these candidates, Baylor’s Christian identity should be clearly indicated in advertisements and a statement of faith should be required with each application. In addition, we must proactively seek exceptional candidates by networking with other Christian colleagues and scholars.

The Engineering faculty is committed to fielding the strongest undergraduate programs possible within the limits and bounds set by the School’s mission and resources. In the last six years the School has added two undergraduate engineering programs to enhance and consolidate its educational base. To support all of our undergraduate programs, it is important that we secure resources for curriculum development (e.g., summer sabbaticals, educational conferences and release-time for special projects).

Maintaining a balance between teaching and research is an ongoing challenge that does not have easy or simple solutions. For some faculty, teaching will be their primary task, while others will emphasize research and scholarship. Nonetheless, the School values both high-quality teaching and excellence in research and scholarship. Consequently, the Departments are committed to rewarding excellence in both.

The Engineering faculty believes that educational experiences can be significantly enhanced as we continue to increase the quantity and quality of research and scholarship. This positive interaction between undergraduate education and research can happen in a variety of ways. For example, research projects provide opportunities for both undergraduate and graduate students to apply what they are learning and to experience the adventure of discovery. The Departments have recently expanded their commitment to the undergraduate Honors program, which provides research opportunities for undergraduates. A professor’s research work often injects insights into courses they teach; this is especially true in areas of rapid technical development.

In technology-driven disciplines it is challenging to find distinctive ways to express Christian commitments in research and scholarship. There are obvious opportunities in ethics and the relationship between technology and society, where a Christian perspective can provide significant insight. Several faculty members in Engineering are actively engaged in such scholarly activities. Christian commitment can also influence the problems that we choose to address. For example, developing appropriate and sustainable technologies for third world countries or addressing the “digital divide” are ways to honor the Biblical mandate to serve the
poor. In another example, ECS professors and students participated in Africa ‘05 and will return this coming May, to deploy several projects. Research in traditional fields and topics can also express our Christian commitment to research and scholarship simply by exploring and increasing our knowledge of the natural world, which is God’s creation.

In the last four years the Engineering Departments have added four graduate programs to increase our research and scholarly output. This nearly unprecedented growth has occurred in the face of minimal pre-existing research infrastructure. Despite our continuing need to build and expand research facilities, the Departments are committed to the equitable distribution of resources so that undergraduate programs and lab facilities are not compromised. To increase the quantity and quality of research and scholarship, we must leverage institutional resources and grow our extramural research funding and faculty research capabilities. Although external research funding has grown dramatically in the past two years, this growth must be sustained for the foreseeable future to insure the stability of our research infrastructure and culture. Continued University support must be used wisely to enhance faculty development, i.e. research sabbaticals, and to facilitate external funding.

In summary, the Departments of Mechanical Engineering and Electrical and Computer Engineering will continue our strong commitment to inspiring teaching while simultaneously increasing our research and scholarship, valuing both as essential elements of our educational and Christian mission.

This document was created by a committee with representation from all three departments within the School of Engineering and Computer Science. This document represents a collection of ideas from faculty within these departments to which the committee attempted to provide form and organization.
Heating up the Engineering Curriculum to Include the Science
Behind the Global Warming Debate

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Abstract

The debate about Global Warming has moved from “is the average temperature of the earth rising?” to “what are the causes of the rise in the average temperature of the earth?” Two opposing views have been publicly broadcast, each claiming sufficient scientific soundness so as to presume the correct answers to this second question.

How should the community of Christian engineering educators tackle not simply the scientific findings, but, more importantly, the biblical mandate to be proper stewards of God’s creation? As faculty, we have been asking our students to learn basic concepts and apply these concepts to complex real-world problems. We expect them to succeed at some level of competency before we declare them to be an “engineer”. Should we expect less from ourselves? This paper describes how the following TOPICS can easily be discussed within the confines of some representative Courses: SOLAR RADIATION/Physics, COMBUSTION REACTIONS/Chemistry, CLIMATE CHANGE/Introduction to Engineering, THE CARBON CYCLE/Biology, ENERGIES OF COMBUSTION/Thermodynamics, MEASUREMENT BIAS AND STATISTICS/Any Engineering Laboratory Course, THE STEWARDSHIP MANDATE/Christian Ethics. These TOPICS/Courses, distributed throughout most all engineering curricula, combine to present a complete set of the information required in order to make a reasoned judgment about the causes of Global Warming.

Introduction

Engineers are increasingly becoming employees of global corporations. Many practitioners, including new graduates, travel abroad to help sell or install equipment in manufacturing facilities or act as customer support. Students will have many opportunities to explain their views on issues which affect world markets. Americans should be prepared to engage in conversations with Europeans, Asians, and Africans when the issue of global warming arises.

Additionally, it appears that Christians are increasingly becoming aware of the Biblical stewardship mandate. Public pronouncements from evangelicals have surfaced in newspapers and on the Internet. It is educational to read the diversity of thoughts being put forth by our brothers and sisters in Christ. My concern is not that these issues have come to the fore, but that the majority of the writers of these editorials are not scientists or engineers. Journalists, pastors, lawyers, educators, and politicians do not have the experience to properly collect and analyze the huge amount of data which is required to correctly convey actions which might need to be taken by individuals and governments. It is my hope that Christian engineering educators will see the importance of requiring their engineering students to learn the breadth of information they will need to properly engage our culture in the debate over climate change.

The problem most of us have is that our engineering curricula are already bursting with more credit hours than most other degree programs. Yes, one can develop an elective course which provides the necessary information, but our goal is to enlighten ALL engineering students to see that they will impact their environment, for better or worse, by how they practice engineering. Web-based modules are one way to accomplish this goal.
The objective for this paper is not to present a political perspective of the issues related to global warming, but instead to encourage engineering educators to consider how best to provide the necessary information which engineers will be relying upon as they design and manufacture products for a global community. This necessary information would include the following: (1) insolation, a short-hand way to describe incoming solar radiation which impinges upon the surface of the earth, (2) the chemistry and thermodynamics of combustion, including the production of carbon dioxide and the energy produced during the reaction, (3) greenhouse gases, including what they are and how they are produced, (4) climatology, defined as the study of the prevailing weather conditions and their causes, (5) the correct practice of data collection and analysis, and (6) Biblical and ethical decision-making. I will identify where in current (generic) engineering curricula each of the topics can be inserted by engineering educators.

Relevant Topics

Insolation
I first learned of the concept of insolation in seventh grade in physical science. Our teacher enthusiastically depicted the near-parallel rays from the spherical sun, being 93 million miles from earth. Using the simple concept of ray reflection from the field of optics, he energetically reminded the class that these parallel rays from the sun would bounce from the surface of the earth at varying angles due to both the spherical surface and the 23.5º tilt of the earth's rotation relative to the ecliptic plane. It was easy to convince even seventh graders that the poles would not become as hot as the equatorial surfaces of the earth due to the higher angles of reflection at the poles versus the near-direct insolation experienced at the equator.

Thus, solar radiant energy, earth's supply of heat, becomes the first important parameter in the discussion of “how the earth heats up.” My hope is that any professor teaching introductory physics would be able to incorporate the sun-earth system as an example of parallel rays when discussing Newtonian optics. An example problem can include data which includes the surface temperature of the sun, the average amount of solar radiant energy striking the earth's surface, and the history of sun spots and solar flares to encourage students to think about the cyclical behavior of the energy source for our solar system.

The Chemistry of Combustion
Regardless of whether engineering students are required to take a one- or two-course sequence in Chemistry, balancing chemical reactions is typically included in the content. A chemistry professor could be encouraged to use relevant examples to show how to balance the equations for the “oxidation” process of important fuels used by many of us. Since methane is the primary constituent of natural gas, it would be instructive to show the following:

\[ \text{CH}_4 + 2\text{O}_2 = \text{CO}_2 + 2\text{H}_2\text{O} \]

and then suggest that, for each mole of methane burned, one mole of carbon dioxide is produced. The same could be shown for another important fuel—ethanol:

\[ \text{C}_2\text{H}_5\text{OH} + 3\text{O}_2 = 2\text{CO}_2 + 3\text{H}_2\text{O} \]

which generates twice as many carbon dioxide molecules per consumed mole of fuel. It is easy to generalize this pattern for other familiar hydrocarbon fuels, such as propane and butane. Students may have to wait until they take thermodynamics to gain a complete picture of the products obtained from burning these fuels (i.e., by using the heating value of a fuel to compute heats of combustion) but this should provoke them to be active learners whenever the topic of carbon footprint is evoked in a discussion of global warming.
Climate Science
Our atmosphere plays an important role as it absorbs, distributes, and reflects the thermal energy the earth receives from the sun. The albedo, or local reflectivity, represents the percentage of the sun's insolation which is not absorbed by the surface of the earth but is, rather, reflected back into space as short-wavelength radiation. Current models place this number anywhere from 30 to 40%. Only about 47% of the sun's incoming energy is actually absorbed by the surface of the earth; the remaining 13 to 23% of the sun's incoming radiant energy is absorbed by the atmosphere. Of the 47% of the sun's insolation absorbed by the surface of the earth, about 18% is re-radiated in the form of long-wavelength infrared radiation. Less than one-third of this makes it directly into space; the remainder is absorbed by the atmosphere. In addition, the earth heats the atmosphere by direct convective heating as well as latent heating caused by the condensation of water evaporated from the oceans. Were atmospheric conditions to remain fairly constant, the earth's surface temperature would experience no net heating and thus maintain a constant temperature.

The information shared above can be incorporated into any of the Introduction to Engineering courses being offered to students as an example of review topics such as "representing data in graphical format" or "use of spreadsheets to present data". The variability of atmospheric conditions could then be introduced by altering the content of the atmosphere to reflect current levels of CO₂ and H₂O, the two most important greenhouse gases (i.e. those gases which absorb the infrared radiation re-radiated by the surface of the earth). A simple model could be programmed into the spreadsheet to show how changes in the atmospheric content would result in changes to the percentages of re-radiated heat escaping to space or being trapped by the atmosphere, the latter being described as the greenhouse effect.

The Biology of Consumption
Though some engineering curricula do not (yet) require students to take a general biology course, Cedarville University has required such a course for all students as a means to fulfill its mission. The carbon cycle would be a standard topic found in any freshman-level biology course. Since CO₂ is the most abundant form of carbon found in our atmosphere, understanding its uptake by plants is an important part of the process by which students acquire the information they need to knowledgeably enter the debate about global warming. Quoting from the text:

Photosynthetic organisms lock billions of metric tons of carbon atoms into organic compounds each year.

Though CO₂ is the major greenhouse gas, others are also noted in this text, including chlorofluorocarbons (CFCs), methane, and nitrous oxide. The replacement of CFCs with hydrofluorocarbons (HFCs) in refrigeration systems has stalled the increase in man-made CFC emissions for the sake of the ozone layer. However, the greenhouse effect of the HFCs currently in use is expected to be far greater than that of even CO₂. Engineering students need to be made aware of the trade-offs required when technology is introduced into our ecosystem.

Thermodynamics of Combustion
As alluded to earlier while discussing the balancing of equations for combustion reactions, students must have a correct understanding of the combustion process in order to properly engage in conversations related to alternative energy sources and carbon footprint. This is, perhaps the most difficult component of the entire package for which to find a course that is common to most engineering curricula. While thermodynamics is required of all mechanical engineering (ME) and chemical engineering (ChE) curricula, many electrical engineering (EE) curricula, for example, have forsaken this gem for additional electronics courses. One would hope that selected topics from thermodynamics, such as heat transfer, would still be required for EE students. Certainly any course in thermal systems would include the topic of combustion of fuels.
The critical issue when completing the story of how combustion of fuels increases the amount of CO$_2$ in the atmosphere is to ask the question, "how much energy will be obtained for each mole of CO$_2$ produced?" Of the two example fuels identified above (methane and ethanol), methane generates 890 kJ of heat for each mole of CO$_2$ produced and ethanol generates 705 kJ of heat for each mole of CO$_2$ produced.\textsuperscript{14} Even though the gasoline we use as fuel for our automobiles is not 100\% octane, we can approximate it’s heating value by balancing the reaction for gaseous octane and computing the heat of combustion:

$$C_8H_{18}(g) + 12.5O_2 = 8CO_2 + 9H_2O$$

We find that burning gaseous octane generates 689 kJ of heat for each mole of CO$_2$ produced. Of these three common fuels, it is easily observed that the energy obtained per mole CO$_2$ produced is best for methane.

Measurement Bias and Statistics
Data reduction and analysis are required components in laboratory courses throughout the engineering curriculum. Engineering students must learn how to compute errors associated with measured values, plot data on graphs, compute statistical variances, and use properly sized error bars. Data points far outside the standard deviation are often noted and removed from consideration of correlation fits.

It is certainly appropriate for engineering faculty to use temperature versus time data collected by satellite and calibrated by buoys as an example of how a student’s graphs should look when presented in a report.\textsuperscript{15} Additionally, when error types and combined instrumental errors are being taught, examples of "bias error" and "human error" might be "combined" using examples of how data is being manipulated to further individual agendas.\textsuperscript{16,17,18}

The Stewardship Mandate
In one of the first popular, albeit controversial, books written about how man interacts with his world, the author, while describing how things were in "The Good Old Days," writes the following:

We have been privileged to live through the most extraordinary five decades of expanding knowledge and its use for bettering life that the world has ever known...Our challenge now is to ensure that we be informed and sensible stewards of this planet and all its life.\textsuperscript{19}

The scriptural mandate for Christians to be "sensible stewards of this planet" is based upon our understanding that its creator and owner is God:

The earth is the LORD's, and everything in it, the world, and all who live in it, for he founded it upon the seas and established it upon the waters.\textsuperscript{20}

The scriptures also suggest that God has authorized man to have "dominion" over the earth.\textsuperscript{21,22} The word "dominion" suggests different things to different people. Some equate "dominion" with "domination."

While some translations of the original language use the word "rule," the word "manage" may be used in this context of "having authority over."

Joining the concepts of God as "creator/owner" and man as "manager" is what I will define as the Stewardship Mandate. A clear picture of this can be found in the "parable of the ten minas," where a nobleman traveled to a far land, leaving his servants in charge of investing in his absence.\textsuperscript{23} So, too, God has provided us with a supply of resources and says to us "occupy until I return."

Within any engineering curriculum, a course in Christian Ethics is a natural location for encouraging students to use their critical reasoning skills. Ethical theories present challenges for students as they
consider how best to interpret the data they collect. For example, an adherence to the consequential ethic of Utilitarianism might sway a student in the direction of "whatever makes me happiest" and impart a distinct bias to the presentation of the data. In contrast, a student whose ethic is more closely associated with the theory of Immanuel Kant might consider it her "duty" to be as complete and forthright as possible, and perhaps never feel that an adequate conclusion is even possible.

Case studies which involve environmental impact should be included in class discussions. Two classic examples from history are (1) the 1979 incident at the Three Mile Island nuclear facility and (2) the reviving of Chesapeake Bay resulting from the 1998 Tangier Island Waterman's Stewardship Initiative. A clear contrast in the behavior of community and government leaders can be seen when these two cases are viewed alongside one another.

Summary

The relevant information required for engineering students to knowledgeably enter the debate over global warming must be inserted into engineering curricula. I suggest the following topics along with their respective courses:

- Solar Radiation................................. Physics
- Combustion Reactions......................... Chemistry
- Climate Science................................. Introduction to Engineering
- The Carbon Cycle............................. Biology
- Combustion Energies........................ Thermodynamics
- Measurement Bias/Statistics............. Any Laboratory Course
- Stewardship Mandate......................... Christian Ethics

Clearly, the majority of these topics already exist as content areas in the suggested courses. For these, selecting an appropriate example problem may be all that is necessary to assure that students interact with the information. My hope is that engineering educators will not balk at the opportunity to relinquish some of their course time for the few topics which may not be directly connected to the course content. It should be our goal to help the next generation of engineers become more globally aware than the previous generation. Perhaps the future debate over Global Warming would then involve fresh minds with an accurate and complete data set and minimal bias—components seemingly missing from one of the "hot" topics of the day.

References


[8] The composition of natural gas varies between 70 and 90% methane, according to NaturalGas.org.


[17] In a CBS "60 Minutes" expose', Dr. James Hansen was interviewed concerning the editing of documents by Phillip Cooney, White House chief of staff on the Council on Environmental Quality. The clip can be viewed at http://video.google.com/videosearch?hl=en&q=james%20hansen%20on%2060%20minutes&um=1&ie=UTF-8&sa=N&tab=wv#.


A Christian Approach to Energy and the Environment at Baylor University

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Abstract

This paper outlines some of the curricular advances in the area of energy education at Baylor and the philosophical underpinnings driving these advances that may be of interest to Christian technical educators. In particular, we examine one of the often overlooked facets of the Christian environmental stewardship movement, the problem of sacrifice, by asking four fundamental questions: Why is it necessary to consider sacrifice in the larger context of Christian environmental stewardship? What, or who, are we sacrificing for? What are the practical forms this sacrifice takes? And, is God ultimately worshipped through such acts of sacrifice?

Introduction

The topic of energy has gained a strong footing in the mainstream media over the past three or four years. It is popular to speak about “green” issues and to speculate about future scenarios for the environment, global trade, geo-politics and energy economics. American corporations can’t develop “green” marketing campaigns fast enough. Even to the casual reader, though, it quickly becomes obvious that not only is there a wide spectrum of opinion about energy and the environment, but there is an abundance of contradictory and just plain confusing information. Those knowledgeable in engineering and other technical arts can only assume that much of the United States’ media possesses a shallow understanding of energy-related issues, and especially of the technological and scientific basis behind the issues – an assumption quickly validated with some careful study.

It almost goes without saying that the current generation of college students is highly attuned to messages about energy, energy independence, and the environment. Some of their friends are serving in Iraq, and they ponder (as many Americans do) the extent to which the Iraq conflict is tied to, or at least emblematic of, the politics of oil. We have found that they struggle with important questions such as how much longer will oil be available to process into hydrocarbon-based fuels? What about the use of coal for generating electricity? Does the U.S. have an energy policy that makes sense? Will there be enough energy in the future to sustain our current standards of living and also raise the standards for billions in China and India? What should be the response of Christians, and particularly of Christian engineers?

The circumstances above suggest that educators, especially educators of technical persuasions like engineering and economics, have an important role to play in the national discussion. The authors set out to explore that role two years ago, and developed a vision for energy education that extends beyond the School of Engineering and Computer Science to include students of other majors and even the general population of Central Texas. That work is still in its infancy, as is our understanding of how Christian engineering educators ought to approach subjects like energy. This paper outlines what has been accomplished to date from a curricular point of view, followed by a discussion prompted by our students themselves, about the role and meaning of sacrifice in the context of the global energy problem.

Curricular Developments

One’s understanding of the technical, economic, environmental and political aspects of energy is termed his or her “energy literacy.” Because of the broad-ranging nature of energy and its
foundational place in industrialized life, professionals in the technical arts and sciences do not necessarily have an edge when it comes to energy literacy. One measure of energy literacy is the National Environmental Education Foundation’s “Energy IQ” survey. It asks 10 questions, and NEEF found that only 12% of Americans can answer seven or more correctly. With this in mind, there are three major thrusts underway to address energy education in our community, aimed at three distinct demographics: the area’s general non-university population, Baylor’s non-engineering student population, and Baylor’s engineering students.

**Mayborn Museum Exhibit**

Baylor’s Mayborn museum is an ideal platform from which to address Central Texas’ non-university population. It attracts well over 100,000 visitors a year, spanning a full range of ages. The first major thrust is to build an energy-related interactive exhibit in the museum. This project was funded in 2006 by the Baylor/Waco Foundation and BP Energy. It has several components, including

- A 1.1kW (peak) grid-intertie photovoltaic array on the roof along with a small Sevonius wind turbine;
- An interior exhibit demonstrating the efficacy of various wall insulations and window glazings;
- An interior small-scale wind turbine that invites users to vary wind speed and monitor power output;
- A series of hand-powered generator/alternator sets, to give users a feel for how much effort is required to power everyday loads like light bulbs;
- A graphical display of the power costs of various types of lighting and of a typical household’s phantom loads.

The display is instrumented so that college and high-school students can take and examine real data, and the power output of the rooftop components can be reported over the internet via embedded Ethernet controllers. All of the technical parts of the exhibit are intentionally exposed, including power inverters, disconnects and wiring, wall studs and insulation, etc.

**Engineering Electives**

At the other end of the educational scale are Baylor’s upper-division engineering students. Not surprisingly, this population began to exhibit a sharply increased interest in energy and power topics about two years ago, coinciding with the initial stages of a plan to offer an “energy core” in the ECE and Mechanical Engineering departments. Last fall, the first author taught a senior/graduate elective on Solar Energy, focusing on Sun-earth geometry, the dynamics of thermal flat-plate and photovoltaic collectors, and large-scale solar energy system design in the TRNSYS numerical simulation suite. Currently, the chairman of ECE is teaching a first course in power systems (he brought over 20 years of expertise in this area when he joined the Baylor faculty last year), and next year the second author will inaugurate a course in wind energy and turbine design. To these will soon be added curricula in internal combustion engines, fuel cells, and the increasingly important subject of power electronics. These topic-specific electives are buttressed by an energy-intensive focus in the Engineering Design II capstone course, taught by the first author, and the Mechanical Engineering senior laboratory course, taught by the second. (Students from both of these were primarily responsible for designing the technical components of the Mayborn exhibit.) National Science Foundation grants are supporting the purchase of sophisticated laboratory equipment such as computer-controlled fuel cells and small-scale steam turbines, and research into power system control. We note here that almost all of the current and planned teaching and research activities are open to students of any engineering major, with senior or graduate standing.
The Energy and Society Engaged Learning Group

In between the general public and the Baylor engineering populations is the Baylor non-engineering population. To address this group, the authors took advantage of an innovation driven by Baylor’s Southern Association of Colleges and Schools (SACS) re-accreditation process. All SACS accreditations require the development of a “Quality Enhancement Plan,” a specific program that each school will initiate to improve some aspect of student learning. A committee at Baylor solicited input, and eventually developed two initiatives, one of which is the “Engaged Learning Group” (ELG).

ELGs are designed to enhance student-faculty engagement and to make connections, between subject matter and personal vocation, between classroom teaching and original research, between professors and students and between students themselves. Three ELGs commenced in 2007, including the “Energy and Society” ELG [6]. Each ELG starts with an interdisciplinary group of faculty and incoming freshman. The freshmen are housed together (separated by gender). ELGs meet once per week to discuss an academic topic, while also meeting regularly for social functions and extracurricular activities like field trips. Most importantly, they remain together – with the same faculty – for two years (four consecutive semesters). At the conclusion, they have earned enough credit to substitute their ELG work for a course in their academic major.

The Energy and Society ELG is in its second semester, and its goals can be broken down roughly by semester:

1. **Energy Literacy.** The first semester (already completed) discussed the nature of energy and its importance in the world. Students learned foundational topics like unit conversions, calculations involving different types of energy, and the basic concepts behind energy conservation (i.e. the first law of thermodynamics) and efficiency. Students wrote a major report about some aspect of energy that interested them.

2. **Energy Production.** The second semester (currently in progress) exposes students to energy conversion from petrochemical, nuclear, solar, thermal, hydro and renewable fuel courses. Students explore how energy is used in sectors such as transportation, housing, electronics, agriculture and industry. Students write and research an energy-related scientific hypothesis on their topic of interest.

3. **Energy and Society.** In the third semester, stewardship and worldview will be the thread that is woven throughout the conversation concerning energy, environment and society. Questions about what energy sources may be appropriate for the future will be addressed, with a view toward political, cultural and economic ramifications. Teams of students will develop their previous hypotheses into formal research proposals.

4. **Energy Research.** This semester will feature a seminar-style class, where student research teams investigate a thesis using the university campus as an “energy laboratory.”

It is interesting to note that, despite the technical nature of this ELG, it has drawn a cohort of students from across campus, and across gender lines. There are majors from business, theater arts, nursing, and liberal arts as well as a few from engineering and environmental science. The class is approximately 50% female – a very significant deviation from a typical engineering course. We have found, through informal conversation, that these young ladies are drawn to the subject of energy because they realize that this is an area where knowledge can be applied directly to the use of helping people and improving their world. It is, in fact, this passion and excitement that the ELG structure seeks to encourage and reward. Approved ELGs are given an internal operating budget; and the Energy and Society ELG is further supported by the NSF.

Each of these three educational thrusts – the energy museum exhibit, the engineering “energy core,” and especially the freshman Energy and Society ELG – by their very nature provide fertile
ground for discussion of worldview, and for examination of the subject through the lens of Christianity. In particular, the ELG will spend an entire semester (the third) discussing “soft” subjects that leave room for opinion. In this context, values and beliefs play an explicit role in the discussion, and should arguably be addressed explicitly at a Christian university. We are first to admit that we do not yet know precisely how to approach some environmentally sensitive issues from a faith perspective, and the ensuing sections explore one such issue.

Stewardship and Sacrifice

It is not hard to find examples of mainstream Christian churches and para-church organizations that have recently adopted positions on environmental stewardship\(^{[5,17]}\). A recent book by Tri Robinson\(^{[14]}\) details the overwhelmingly positive response from his church when he suggested that the church, and its individual members, had a spiritual obligation to examine their ecological footprint and begin practicing stewardship of the Creation in tangible and measurable ways. His church experienced a growth surge after that point, finding that the subject of environmental care (including energy conservation) could open doors for evangelism that were previously locked. Undoubtedly, Pastor Robinson’s approach would not be equally well received everywhere, but his experience vividly illustrates how American Christianity is in many ways more than ready to embrace environmental causes, and how people may even be won to Christ.

However, our own observation is that the Christian environmental stewardship movement – though grounded on defensible theological territory – rings hollow on certain points. For one, it is uncertain whether some groups and individuals clinging to this philosophy are truly motivated by concern for God’s creation (to be sure, many are) or if the aims of the movement simply happen to mesh with a deeper concern for the pocketbook. Environmental stewardship theology (a phrase we will not here try to precisely define but which we will use in reference to the belief that caring for the Creation is a way to worship the Creator) is easier to accept if it coincides with cost savings on one’s fuel and electricity bills, or at least does not cost much more than effort. There is certainly nothing inherently wrong with hoping to save money by investing in a fuel efficient vehicle, better insulation for a house, or switching to locally grown produce – this is often good financial stewardship! In Texas, electricity deregulation even gives customers the option to pay a few cents more than the lowest possible price to support renewable energy investment, and many people do. However, these are examples of widespread trends across all industrialized nations that are arguably driven more by economic realities and political agendas than by a sudden surge in heartfelt belief that we are neglecting the Creation and thereby distancing ourselves from the Creator.

The sense that environmental stewardship theology may in fact be more akin to “convenience theology” leads us to consider the question of sacrifice, for it is here that individual motivations become clear. Jesus himself used the sacrifice test on many occasions (e.g. Luke 18:18-23), and is the ultimate exemplar of the goods that flow from sacrifice when (1) it is offered willingly and (2) there is some alternative temptation in view, such as short-term personal gain or power. The very essence of sacrifice indeed demands that something valuable must be given up and its future utility forsaken. Speaking of a different kind of sustainability – economic sustainability – Blackstone Group founder and billionaire Peter G. Peterson commented bluntly on sacrifice \(^{[13]}\):

> These challenges require sacrifice… I’m not sure if we remember how to give up something for the long-term general good. Nor do we hear calls for sacrifice from our leaders. Our lawmakers are enablers, either joining us in the state of denial or trying to anesthetize us.

The question of what sort of sacrifices are demanded of an American billionaire aside, Peterson has a point. In the context of energy and the environment, California governor Arnold Schwarzenegger boldly embodies the dreams of many: that technology and free market forces
will soon be sufficiently incentivized to solve environmental problems instead of creating them, while simultaneously generating scores of new high-tech jobs, all with nary an inconvenience.

The Republican governor is peddling feel-good, consumer-friendly environmentalism that resonates not only with … hybrid drivers, but also with big business and those who think “green” is a synonym for “Chicken Little…” [T]here is concern that his approach places too little emphasis on the need for Americans to reform their consumption habits, from running their air conditioners around the clock to driving (yes) their SUVs. [2]

Fortunately, the Governor’s Hummers run on hydrogen and biodiesel! His stance – one likely shared by a large segment of the American population – begs important questions. If no one is willing to sacrifice for the “long-term general good,” can anything of lasting value be accomplished? More importantly, if little or no sacrifice is demanded, does environmental stewardship theology have any redemptive or worshipful qualities at all?

Is sacrifice really necessary?
Students are remarkably quick to tell you when they sense hypocrisy, and ELG freshman Frank Marquez opened a paper with a scathing commentary on the question of sacrifice. He writes, “Everyone wants the benefits of clean air, water and energy, but everyone is waiting for someone else to be the first to sacrifice for [these things].” A pretty astute observation, actually, that jibes with a comment once made by a personal acquaintance of the first author with years of experience as an environmental lobbyist, “Sacrifice is the ‘third rail’ of environmentalism.” In other words, if you want to have any success advancing an agenda of sustainability or environmental concern, don’t suggest under any circumstances that Americans will have to give something up.

Of course, extolling the virtue of sacrifice and complaining that nobody is truly willing to do it are one thing, but in point of fact, how necessary will it really be to ask serious sacrifices of the citizens of industrialized nations in the future?

Prognostication regarding energy (and food) supply is as old as humanity, and most prognosticators in the energy area have a knack for being wrong. But occasionally, cutting through the noise, come the voices of reasoned and knowledgeable individuals. Two of these are the late geologist M. King Hubbert and energy analyst/investment banker Matthew Simmons. Hubbert became an instant legend in the field of geology when, in the 1970s, his mathematical model of U.S. oil supply was proved correct – a model he developed in the early 1950s, though it was not published till 1962. The time frame between 1970-1975 was the when he predicted, some 20 years earlier, that U.S. oil supplies would peak; it would turn out that a greater volume of oil would never be produced in the U.S. than was produced in 1970. His theory, carefully studied and reproduced by many people over the years (including first author last summer), is complex and nuanced; however, without losing significant accuracy, the theory was recently distilled into more easily digestible form published in the book “Beyond Oil: A View from Hubbert’s Peak,” by one of Hubbert’s younger contemporaries and professional colleagues, geologist Kenneth Deffeyes [4].

The correct prediction of U.S. peak oil was only the most dramatic of Hubbert’s predictions. The Hubbert model also correctly anticipated the symmetry of oil production and decline, described the nature of how oilfields age, and gave good estimates of how long it takes for a declining production curve to reach various milestones like 50% production. It is also stochastically robust and naturally accounts for the steady march of technological progress in the oil industry, and it assumes and even anticipates future large oilfield discoveries. So, the $64,000 question is, what does it say about world oil production? Well, in a nutshell: that we are quite likely to see no more oil produced in the future than will be produced this decade, or early next. Where disagreements arise about the applicability of Hubbert’s theory, they focus on the size of known world oil
reserves or the impact of technology, not on Hubbert’s model per se. But as Matt Simmons painstakingly details in his book [15], “Twilight in the Desert,” most of the “reserves” are in the Middle East, and are likely highly inflated by OPEC nations that refuse to release trustworthy production statistics. Simmons carefully analyzes decades of publications by the Society of Petroleum Engineers (an admirable feat for an investment banker!) to paint a grim picture of Middle Eastern oil production, and argues convincingly – in agreement with Deffeyes – that the Saudis in particular will no longer be willing to “open the tap,” simply because they no longer can. Simmons and others also soundly argue that supply restrictions will eventually induce a high degree of volatility in energy markets, a phenomenon we are already witnessing. (It is tempting to try to superimpose Hubbert’s ingenious model onto the problem of other energy supplies, like natural gas or quality uranium ore. Even Hubbert argued that this would not be appropriate. However, researcher Julian Darley has looked deeply into the question of natural gas supplies, and found more – though less immediately pressing – bad news [3].)

Responses to the dawning, though still nascent, awareness that one of God’s greatest gifts to humanity – a huge store of liquid and gas petrochemical energy – was halfway consumed in only 100 years range across the spectrum. The “dark green” view is that mankind will not react in time, and would prefer to wage war over dwindling resources than to try to adapt. The “bright green” view suggests that new energy sources will be tapped, new technologies discovered, renewables will replace petrochemicals, or all of the above.

Physicist Howard Hayden addresses the bright green viewpoint with hard calculations that suggest renewable energy sources will likely never play more than bit parts on the energy stage, at least as long as demand from industrial (and industrializing) nations continues insatiably upward [8]. His focus is on solar energy, and is required reading in the first author’s Solar Energy technical elective. Further buttressing the view that humanity’s transition out of the “easy petrochemical” era will not be straightforward nor smooth are arguments by authors such as Richard Heinberg [9,10], who point out that modern industrialized economies using debt-based monetary systems must necessarily expand or fail catastrophically. It is no secret that first-world economies, and increasingly, third-world ones as well, have historically consumed ever greater natural resources in order to produce economic prosperity. Countries such as Japan with few natural resources have also managed to induce stunning economic growth (on time scales like 50 years) by importing energy and raw materials. However, less well known may be the incredibly strong correlation that economic growth has with growth in energy availability and supply. Energy economist Peter Tertzakian is arguably a “bright green” optimist, but even he pauses to point out the strength of this correlation: from 1950 to 1979, the U.S. demanded 4 million barrels per day (1.4 billion barrels per year) of additional oil supply for every $1 trillion of additional GPD [18, p.105], with a very high correlation coefficient. Relative to other countries, this was a remarkably large “oil dependency factor,” and was directly responsible for the rapid industrialization of the country during the post-WWII period. The only event in the last 50 years to moderate the U.S. oil dependency factor was the Arab Oil embargo. Tertzakian and author Edwin Black [1] also address the seductive nature of technology, noting that technology has never actually produced more energy, it merely aids in the transition from one energy source to another – what Tertzakian terms a “break point” – assuming that there is another on the horizon with sufficient capacity to drive technological innovation.

Sacrifice for what?
It seems likely to the authors that at some point in our lifetimes, or at the very latest the lifetimes of our children, a significant change in energy consumption patterns will come, along with an attendant change in lifestyle and economic expectations for many in the world. The question presently facing humanity, and asked by virtually every one of the aforementioned authors, is: what can be done today to mitigate the negative effects of this change when it arrives? So we are
now back to the question of sacrifice, with a deepened appreciation that it is not simply the earthly Creation for which sacrifices will be made, but for actual people who will live through the coming economic, environmental and energy-related changes. Yet, as poignantly illustrated by J. Matthew Sleeth in “Serve God, Save the Planet” [16], “it is not only the unseen future which warrants sacrifice, but also the unseen present – the price paid by the worldwide poor in terms of health and economic and agricultural damage because of the industrialized world’s demand for resources, cheap food and endless energy. His text, owing to his extensive international missions work as a physician, reveals a wealth of understanding about the nature and forms of sacrifice that may be called for in the present, for the sake of both people in the present and future.

*Sacrifice as an act of worship?*

There is one last important question that Christians must address. Even if we understand why sacrifice is warranted, and what forms it may assume, and for whom or what we are sacrificing, does the sacrifice in fact please God? Is it, in an appropriate sense, worshipful? Ethicist Michael Northcott addresses the nature of sacrifice in his book, “The environment and Christian Ethics,” pointing out three primary purposes of sacrifice in ancient Israel:

1.) The “expiation of pollution, guilt, death and disease;”

2.) The “re-establishment and affirmation of communion, between God and humans, and between persons;”

3.) The representation of a “fundamental attitude of thanksgiving to God…for the gifts of nature or the created order.” [12, p. 186]

Sacrifices that lead to a restoration of order in the world, he ultimately argues, meet all three of these conditions, especially when one takes the view that the sacrifice is being made to atone for sinful acts. Sleeth would seem to agree, stating,

“I’ve regularly encountered [arguments against Christian environmental stewardship] in discussions with believers and nonbelievers… Unspoken reasons for neglecting our role as stewards can include greed, thoughtlessness, lust, exploitation, and short-term profit. These factors negatively affect our environment as well as our individual walk with God.” [16, p. 34]

Sleeth’s list of sins doesn’t quite sum up to Romans 1:29-32, but certainly would seem to warrant atonement and restoration of order through the practical outworking of sacrifice. Of course, post Dominus, Christians have access to the atoning power of Jesus’ ultimate sacrifice to cover all sin. Yet Jesus himself continued to call for sacrifice, and required it of His apostles. At a minimum, we can deduce that sacrifice remains an important Christian precept even though it is no longer necessary to spill blood for the forgiveness of sin. Aside from the continuing doctrinal importance of sacrifice, Northcott’s reference to the “expiation of pollution” is an antireflection of Paul’s urging to dwell on those things which are “pure” and “lovely” (Phil. 4:8). But the exhortation to dwell, or meditate, is immediately followed by a command to take action, or “do” (Phil 4:9) – a logical couplet if there are to be real, tangible goods that flow from the meditation. In the context of creation stewardship, then, sacrifice may be viewed as one possible action that amends for “pollution and disease,” simultaneously bringing forth the intrinsic goods of purity and loveliness, and ultimately moving us toward a deeper respect and love for the Creator.

**Conclusions**

In summary, this paper poses four basic questions, and dwells on three of them. In answering the question, “Why is sacrifice needed in the context of energy and the environment?” engineering educators may have a particularly important role to play because the nature and foundational importance of energy remain obscure for a great part of the population. (We assert that it is
equally important to address the limits of technology.) The question, “For whom or what are we sacrificing?” is answered in a single word: people, both of present and future generations. God does not need our sacrifice, but asks His followers to strike a thoughtful balance between the provision of the Creation for our needs and our protection and care for it because His people’s well-being hangs in that balance. And lastly, the question, “Is the sacrifice worshipful?” is briefly addressed in the context of atonement for sin.

However, we have left open the question, “What are the appropriate and relevant forms of sacrifice?” Here we must defer to the many writings on what sacrificial steps one may take toward the care and conservation of energy and environment. Not all of these will be appropriate for all individuals, but it is worth noting that this question – the practical methodology for sacrifice – is one that excites and energizes our students more than any other. They want to do something that is important, that helps people, and that is carried out in a spirit of humility and respect for God’s gift of our world.

We conclude by noting that it is still far from clear how to integrate these questions, and the ensuing discussion, into every technical course on which they have bearing. Nevertheless, we believe that interested engineering educators will find students quite open to examining the role of sacrifice in their worldview, and wondering why people don’t speak of it more often. Our ideas, approaches, and avenues for discussion are still forming and we certainly do not claim to have exhaustively addressed the four questions of sacrifice. It is our assertion that students will be better for simply talking about them, and that students researching or learning about engineering-related subjects like energy are often eager to engage on both a technical and spiritual level.

References
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