ASEE AMERICAN SOCIETY FOR ENGINEERING EDUCATION

Paper ID #35732

Engineers and Accountability

Dr. Kenneth W. Van Treuren, Baylor University

Ken Van Treuren is an Associate Professor in the Department of Engineering at Baylor University. He received his B. S. in Aeronautical Engineering from the USAF Academy in Colorado Springs, Colorado and his M. S. in Engineering from Princeton University in Princeton, New Jersey. After serving as USAF pilot in KC-135 and KC-10 aircraft, he completed his DPhil in Engineering Sciences at the University of Oxford, United Kingdom and returned to the USAF Academy to teach heat transfer and propulsion systems. At Baylor University, he teaches courses in laboratory techniques, fluid mechanics, energy systems, and propulsion systems, as well as freshman engineering. Research interests include renewable energy to include small wind turbine aerodynamics and experimental convective heat transfer as applied to HVAC and gas turbine systems.

Session XXXX

Engineers and Accountability

Kenneth Van Treuren
Mechanical Engineering Department
Baylor University

Abstract

Engineers are important to society. They solve problems and develop technologies which improve peoples' quality of life. With that comes tremendous responsibility and trust on the part of the public. Engineering students preparing to enter the workplace need to understand this aspect of engineering. How do we ensure engineers maintain this accountability? Most engineering programs are monitored by the Accreditation Board for Engineering and Technology (ABET) which provides and assurance (accountability) that a college or university meets the standards of the profession. Many engineers, upon graduation, go through the rigorous process of professional registration. Another level of accountability in engineering are codes and standards which provide accountability for a given task, especially for engineers not professionally registered. If engineers do not follow these guidelines or topics and the result is a failure that causes loss of property and/or life, the legal system is always ready to hold engineers accountable. In addition to the external accountability that exists for engineers, there is also an internal, personal accountability that exists. Internalizing the professional code of ethics is a start. Many people have other systems by which they live as well. Religion plays a big part in this role, whether it be Hinduism, Buddhism, Islam, Confucianism, Christianity, Taoism, and Judaism. All religions tend to have a higher calling by which to live. At Baylor, a religiously affiliated Christian university, our students sense a higher standard of accountability which helps them in life. It is a matter of character which becomes increasingly important and develops as a natural extension of who they are. This gives them joy in their work. Students should be taught throughout the curriculum about the importance of accountability in an engineering career.

Introduction

Accountability is an acceptance of responsibility for honest and ethical conduct towards others[1]. It implies a willingness to be judged on performance. Wong has studied accountability in the engineering context and has this to say[2]:

> "Accountability comes up a lot when talking about engineering organizations. Everyone wants to know how to hold engineers accountable. And, in my exploration of this topic with folks, I've found that the term accountability means something different to everyone. There are some folks who use accountability to mean an ability to explain. There's a slightly larger set of people who use accountability when they really mean ownership. And then, there are many organizations that use accountability to mean a mechanism to blame and punish people

when they "don't perform."

Accountability can be confusing however, all agree that accountability is necessary for engineers. All my life I have been accountable to someone other than myself so being held accountable is nothing new. Growing up we are all accountable to our parents as they are trying to instill their values into our lives. There were always consequences for not following their "suggestions" and rewards for lessons learned. This helped shape our early years. At some point we transitioned to elementary, middle, and high school where we were held accountable to our teachers to learn skills and tools that would help with life and possibly a college education.

A college education, especially for engineering students, is a difficult path. Studies show in the U.S. that each year approximately 4 million students enter the STEM pipeline however only approximately 60,000 engineers graduate from the University[3]. My own university engineering education held me accountable. I entered the United States Air Force (USAF) Academy in 1973, graduating with a B.S. in Aeronautics in 1977. The diploma I received was a symbol that I had mastered the requirements for the degree. In fact, typically words such as "You have satisfied all University degree requirements that were in effect when you started your degree program" are mentioned when degrees are conferred at graduation. Some of us went on to more advanced degrees. For me it was a Master's in Engineering at Princeton University (diploma was written in Latin) and eventually a D.Phil. in Engineering Science at the University of Oxford, UK (this graduation ceremony was entirely done in Latin!). For advanced degrees, there were examinations and a research project ending with a thesis. There was a "defense" of the thesis by graduate committees to ensure that an acceptable standard of competence had been achieved prior to graduation. This was a form of accountability to the engineering profession.

My accountability didn't stop when I graduated with my degrees. After my Master's degree, I entered the USAF and became a pilot. As I gained in experience, I rose through the ranks of Pilot, Senior Pilot, and Command Pilot. Just as with engineering, being a pilot is a profession that demands an element of accountability to keep people safe. Annually, a USAF pilot would be held accountable with a "notice" checkride and often a "no-notice" checkride as well. The checkride is where a Standardization/Evaluation pilot (VERY experienced) would fly along and watch the examinee pilot for an entire flight, which could last as many as 4-5 hours. While not a pleasurable experience, this was necessary to ensure the high standards necessary for a pilot. Eventually I was able to become part of the Standardization/Evaluation Branch, an important responsibility, holding pilots to the required standards of excellence.

Now as a Professor of Mechanical Engineering with 31 years of experience and having taught at both the USAF Academy and Baylor University, I am held accountable to graduate my students with the skills and tools they need to be successful in life and their future occupations, either graduate school or the workplace. I am tenured but that does not mean that I am not accountable. Tenure is the ultimate accountability. It is granted based on your accomplishments and the requirements of the university in which you work. While this is an important milestone in an academic career, the expectation is that you will continue to perform at a high level all the things you have done previously. Tenure is not automatic. Harvard has a 70 % success rate for granting tenue[4]. Tenure depends on the institution and success rates can be as high as 90% to lower than 50% at other

institutions. One can argue the merits of tenure but it still exists and is another means of accountability, to reach and obtain tenure.

Figure 1. Train Engineer (Alamy.com)

What about our students? How are they accountable? We have just come through a difficult time in academia. Students were online and remote for most of 2020 and into 2021. Freshmen entering in 2022 will not have a clear indication of what a "normal" school experience would be. To some extent, standards have been relaxed due to the pandemic. Students in the pandemic have not been held as accountable as they have in the past. For some students Zoom (or similar) online classes were the norm but many students muted their microphones and turned off their video minimizing interactions. Anecdotal information suggests that if someone who was not using video is called on by the professor and there is no answer, classmates would call/text the individual to get them back to the computer so they could answer the question. Attendance itself was relaxed in many cases. Hybrid classes were an excellent opportunity to not attend class and to "attend" online. Because of the students' mental health during this time, taking attendance was relaxed and assignments/due dates were very flexible. This created a lax atmosphere for the students. As we are now transitioning back to more on campus classes, students have come to expect the relaxed accountability to continue. Students need to be reminded of why they are engineers and the responsibilities that come with the vocation. As engineers, they will assume a life of accountability on many levels. If these expectations are known, students can then enter the profession understanding the requirements. This paper will describe ways engineers are held accountable in their profession. It is hoped that during a student's academic career that many of these concepts will be communicated.

What is Engineering?

Engineers and the profession of engineering have a profound impact on society today. Just what is Engineering? Ask the average person and you might get the response that engineering is what a "train engineer" does in their profession, as seen in Figure 1. Other people who might know an engineer or be familiar with STEM will answer "Engineering is the application of science and math to solve problems[3]". This is a common response. Each semester at the beginning of my classes I ask the same question, "What is Engineering?" and most of my students, who are seniors, answer the same way. They are missing an important aspect of engineering. Engineers make things that improve peoples' quality of life. Another way to express this concept is found in the following quote:

> "The role of an engineer is to tackle some of the world's biggest problems; helping to save lives and create fantastic new technological advancements that can improve the way we live.[6]"

Just how can engineers make a difference? The National Academy for Engineering (NAE) has 14 grand challenges that engineers will be involved with in the future. Engineers have a responsibility to society to address these topics. These are the problems that need technical solutions which can impact how we live:

Figure 2. NAE Grand Challenges[7]

Every day engineers are involved in designing and manufacturing items that have great impact on society. The potential result is that of great good for society but there also exists the possibility of causing harm to those who use these items or services. How does the public have the confidence that the car they drive or the plane they fly on or the bridge that they cross is safe? Everyone uses these things nearly every day. The general public has the confidence that the items are safe and they generally don't give it a second thought. Why? It is because engineering is a profession and those in engineering are held to higher standards. They are respected by the general population

Program Certification

The high standards come with accountability in many forms. To start, most engineers have come through a program that has been fully accredited by an accrediting body, such as the Accreditation Board for Engineering and Technology (ABET). Periodic engineering program evaluations by this group of experienced engineers assures the public that anyone who graduates from an accredited institution has the necessary foundational knowledge to be engineer in that discipline. Students often do not realize the work that is done on the part of the engineering department to prepare for and to satisfy an ABET visit. ABET states:

> "Accreditation Adds Value. ABET accreditation assures confidence that a collegiate program has met standards essential to prepare graduates to enter critical STEM fields in the global workforce.[8]"

The new outcomes required for each program describe the skills and tools that engineering students must achieve[8]:

> 1. an ability to identify, formulate, and **solve complex engineering problems** by applying principles of engineering, science, and mathematics
> 2. an ability to **apply engineering design to produce solutions** that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
> 3. an ability to **communicate effectively** with a range of audiences
> 4. an ability to **recognize ethical and professional responsibilities** in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
> 5. an ability to **function effectively on a team** whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
> 6. an ability to **develop and conduct appropriate experimentation**, analyze and interpret data, and use engineering judgment to draw conclusions
> 7. an ability to **acquire and apply new knowledge** as needed, using appropriate learning strategies.

ABET makes recommendations concerning improvements that are necessary for the engineering programs. These can fall into one of three categories[6]:

> **Concern -** A statement that a program currently satisfies a criterion, policy, or procedure, but the potential exists for the situation to change such that the criterion, policy, or procedure may not be satisfied.
> **Deficiency -** A statement that a criterion, policy, or procedure is not satisfied. The program is not in compliance with the criterion, policy, or procedure.
> **Weakness -** A statement that a program lacks the strength of compliance with a criterion, policy, or procedure to ensure that the quality of the program will not be compromised.

Remedial action is required to strengthen compliance with the criterion, policy, or procedure prior to the next review.

Making these visits and evaluations of engineering programs keeps programs accountable to the profession and prepares students to make a difference in their next employment. Any discrepancies highlighted by the ABET visit must be addressed to receive accreditation. Engineering students should benefit by attending and graduating from an accredited engineering program. They should appreciate the efforts taken on their behalf to keep a program's accreditation status.

ABET outcomes are tracked as part of any accredited engineering program and should be assessed on a periodic basis. This allows sufficient time for a program to determine its effectiveness of including the outcomes in their curriculum and, if there is a problem, to develop a plan to address the findings and improve the program.

Professional Certification

A professional license is required for some engineering disciplines, such as those engineers involved with construction or heating-ventilation and air conditioning (HVAC). The requirements for licensing are controlled by the state, district, or country in which the engineer practices. Thus, engineers are held accountable by the governing bodies where they work. In the United States this is handled by the National Council of Examiners for Engineering and Surveying (NCEES) which represents the state boards. Only a licensed engineer can sign off on blueprints or building plans. Their signature assures that the plans have been certified to follow any US Codes or Regulations. While there are areas where a license is required, there are many engineering disciplines, such as the auto or aviation industry, where licensing is not required. Any unlicensed engineers working in an industry where a license may be required must work under a licensed engineer's supervision. Being a Registered Professional Engineer has its benefits[9]:

1. To a client, it means you've got the credentials to earn their trust.
2. To an employer, it signals your ability to take on a higher level of responsibility.
3. Among your colleagues, it demands respect.
4. To yourself, it's a symbol of pride and measure of your own hard-won achievement

How do these professional engineers assure that there is adequate accountability in their work? The process to be registered is long and demanding. Often, upon graduation, engineering students will take the Fundamentals of Engineering (FE) Exam which, if passed, also indicates that the individual has achieved an acceptable level of basic and applied knowledge. The next step towards licensing would be to gain job experience and eventually take another test, the Principles and Practice of Engineering (PR) Exam which shows proficiency in an engineering discipline. Most engineers never take this step of either the FE or PR test and licensing. So, in summary the following is the pathway to registrations:

1. Earn a four-year degree in engineering from an accredited engineering program
2. Pass the Fundamentals of Engineering (FE) exam
3. Complete four years of progressive engineering experience under a PE

4. Pass the Principles and Practice of Engineering (PE) exam

Engineering students should be encouraged to take the FE exam upon graduation.

Codes and Standards

If an unlicensed engineer goes to work for a company, then the company usually holds the engineering work done by that engineer to the codes and standard that the company culture requires. What then assures the public that engineers are competent and have the best interest of the public in mind? One such topic is that of codes and standards that assure the quality of something being designed or made. A code is a set of rules and specifications for the correct methods and materials used in a certain product, building or process[10]. Codes can be approved by local, state or federal governments and can carry the force of law. The main purpose of codes is to protect the public by setting up the minimum acceptable level of safety for buildings, products and processes. A technical standard is an established norm or requirement. It is usually a formal document that establishes uniform engineering or technical criteria, methods, processes and practices. Standards allow for interchangeability of parts, system interoperability, and they ensure quality, reliability and safety[10]. These standards are published by an engineering discipline and outline procedures that should be followed when something is being designed or made. If one follows the standards then, if something could go wrong, charges of negligence might be dismissed, but that might not clear the engineer of other charges.

Professional Code of Ethics

One topic that influences an engineer and holds them accountable is the code of professional ethics. Most engineering professional societies have a series of statements that engineers must follow if they are to uphold the profession. These are minimum standards that are agreed to by engineers to cover their professional behavior. The Fundamental Cannons of the NSPE Code of Ethics for Engineers are[11]:

1. Hold paramount the safety, health, and welfare of the public.
2. Perform services only in areas of their competence.
3. Issue public statements only in an objective and truthful manner.
4. Act for each employer or client as faithful agents or trustees.
5. Avoid deceptive acts.
6. Conduct themselves honorably, responsibly, ethically, and lawfully so as to enhance the honor, reputation, and usefulness of the profession.

Engineering ethics are first addressed in Baylor's Introduction to Engineering course taught in the freshman year. Ethics are reinforced in the junior year by taking the course Social and Ethical Issues in Engineering taught by the Mechanical Engineering Department. Ideally, professional ethics is a topic that is reinforced throughout the curriculum.

Legal Accountability

If engineers do not follow these guidelines or topics, the accountability is always something for which the courts can make a ruling. This brings up the issues of accountably vs responsibility. How much responsibility must engineers take for their actions? What is the right thing to do as opposed to what is legally required? Engineers can be personally liable through tort law theories even when practicing for an employer. As a result, engineers place their assets at risk in the practice of their profession—as do many practicing professionals in fields other than engineering. A practicing engineer can face personal liability for mistakes, errors, or omissions made in the course of their work. For latent property damages, the statute of limitations for design professionals in California is 10 years from completion of their work on the project[12]. There are exceptions to the statutes of limitations, which would suspend the running of the time period. Engineers who design buildings for commercial and/or residential use should have professional and general liability insurance to protect themselves from claims and lawsuits brought by clients, vendors or even employees.

Internal Accountability

In addition to the external accountability that exists for engineers, there is also an internal, personal accountability that exists. Internalizing the professional code of ethics is a start. Many people have other systems by which they live as well. Religion plays a big part in this role, whether it be Hinduism, Buddhism, Islam, Confucianism, Christianity, Taoism, and Judaism. All have a higher calling by which to live. Olanrewaju et al. describe the accountability of an engineer in the Muslim faith[13]. They state that accountability is an assessment useful for evaluating an achievement or failure in any organization. To a Muslim, faith is a complete way of life and thus a Muslim engineer cannot separate religious ethics from work. A Muslim engineer is accountable to the profession and to Allah. He or she understands from an Islamic point of view that, as an engineer, Islam will be their guide. Qur'an states the following about accountability:

> "And every soul will be paid in full whatever (good or evil) it has done (in the world); and, indeed, He knows best all that they do" (Q39:70)[13]"

Where does accountability fit in the Christian tradition? At Baylor, a religiously affiliated Christian university, our students also have a sense of a higher standard of accountability which helps them in life. As stated in the Bible:

> "Whatever you do, work at it with all of your heart, as working for the Lord, not for men."
> Colossians 3:23

> "Work hard, but not just to please your masters when they are watching. As slaves of Christ, do the will of God with all your heart. Work with enthusiasm, as though you were working for the Lord rather than for people."
> Ephesians 6:6

Baylor students feel called to the profession of engineering because of their natural, God given, skills and talents. The work they do is really a part of their beliefs which hold them to this higher standard. If a student lives up to these standards, given by God, then they naturally satisfy all other standards for accountability. Our accountability to God with our vocation and our lives becomes the foundation for how we live our lives and the legacy we leave for those who come after us. In fact, our Christian foundation might be influential in what areas of engineering we might work. If we have a deep desire to help mankind we might help to find solutions to the grand challenges such as clean water and abundant, clean energy. It is important to have a consistent worldview when considering the work as a Christian engineer. The following worldview was offered by Van Treuren and Eisenbarth[14]:

> "As a Christian, I believe in the Triune God and the personal redemption the individual through the cross of Jesus Christ. God created the universe, of which I am a part, and that these beliefs, coupled with the knowledge and skills developed through the engineering curriculum, motivate me to live the life God would have me live; engaged in the vocation of engineering to make a difference in the world"

The world needs more heroes and champions for these causes. God can use our efforts to have a profound impact on society and the world. It is a matter of character which becomes important. Being an engineer then becomes a natural extension of who engineers are while fulfilling their God given abilities. This gives engineers joy in their work.

Summary and Conclusions

Engineers are vital to society because they solve problems and develop technologies which improve peoples' quality of life. The results of an engineer's work must also have the public safety in mind as well. With that come tremendous responsibility and trust on the part of the public. Engineering students preparing to enter the workplace need to understand about accountability in the engineering profession. Engineering programs must emphasize accountability in engineering to prepare our students for the workplace and beyond.

Why do engineers need accountability? Being accountable and knowing you are doing a good job brings happiness and fulfillment. The ultimate result for accountability is that engineers are successful in what they do. According to the Engineering Management Institute, accountability[15]:

1. Keep us focused on the details – must have discipline
2. Keep on schedule – milestones in place
3. Keep honest – truthful to others
4. Keep us in the trench – working hard, failure not an option
5. Keep doing what is needed even when we don't feel like it.

Engineering students must learn that they will be held to be accountable in their profession. Understanding and accepting this will lead to rewarding career helping society and growing personally as a professional.

References

1. Kenton, W., 2021, "Accountability," Investopedia, https://www.investopedia.com/terms/a/accountability.asp , accessed on 22 Jan 2022.
2. Wong, J., 2021, "On Accountability," JWONGWORKS, https://jwongworks.com/blog/2019/1/17/on-accountability , accessed on 22 Jan 2022.
3. Sturtevant, D. J., 2008, "America Disrupted: Dynamics of the Technical Capability Crisis," Engineering Systems Divisions, Massachusetts Institute of Technology.
4. Nair, M. S. and Wang, A. Z., 2021, "FAS Review Largely Upholds Tenure System Despite Acknowledging 'Mistrust and Low Morale'," The Harvard Crimson, https://www.thecrimson.com/article/2021/10/12/tenure-review-report-2021 accessed on Jan 22, 2022.
5. Lucas, J., 2014, "What is Engineering? Types of Engineering, https://www.livescience.com/47499-what-is-engineering.html accessed on Jan 22, 2022.
6. "How Engineers an make a Difference to the World," Gloucestershire Engineering Training (GET), https://get-trained.org/latest-news/how-engineers-can-make-difference-world , accessed on Jan 22, 2022
7. "NAE Grand Challenges for Engineering," National Academy of Engineering, http://www.engineeringchallenges.org/challenges.aspx , accessed on Jan 22, 2022.
8. ABET, https://www.abet.org/ , accessed on Jan 22, 2022.
9. National Society of Professional Engineers, "What is a PE?," https://www.nspe.org/resources/licensure/what-pe accessed on Jan 22, 2022.
10. Mechanical Engineering Resources: Codes and Standards, https://libguides.msoe.edu/me/codes , accessed on Jan 22, 2022.
11. National Society of Professional Engineers, https://www.nspe.org/resources/ethics/code-ethics? , accessed on 22 Jan 2022.
12. Ittmann, J., Friedland, C. J., and Okeil, A., 2016, "Personal Liability of the Practicing Engineer," Journal of Legal Affairs and Dispute Resolution in Engineering and Construction, 8 (3), https://ascelibrary.org/doi/abs/10.1061/%28ASCE%29LA.1943-4170.0000185 , accessed on Jan 22, 2022.
13. Olanrewaju, R. F. Muyibi, S. A., and Sanni, M. L., 2014, "Responsibility and Accountability of an Engineer in Religious Perspective," Sci.Int.(Lahore),26(5),2429-2432,2014.
14. Van Treuren, K. W. and Eisnebarth, S., 2006, "The Importance of Developing a Consistent Worldview in Engineering Education When Viewing God's Creation," Christian Engineering Conference, Olivet Nazarene University, Bourbonnais, IL.
15. Engineering Management Institute, 2015, "5 Reasons Accountability Is Needed for Success On The Big Engineering Projects," https://engineeringmanagementinstitute.org/5-reasons-accountability-is-needed-for-success-on-the-big-engineering-projects/ , accessed on 22 Jan 2022.

KENNETH W. VAN TREUREN

Ken Van Treuren is a Professor in the Department of Mechanical Engineering at Baylor University and serves as the Associate Dean in the School of Engineering and Computer Science. He received his B. S. in Aeronautical Engineering from the USAF Academy in Colorado Springs, Colorado and his M. S. in Engineering from Princeton University in Princeton, New Jersey. After serving as USAF pilot in KC-135 and KC-10 aircraft, he completed his DPhil in Engineering Sciences at the University of Oxford, United Kingdom and returned to the USAF Academy to teach heat transfer and propulsion systems. At Baylor University, he teaches courses in laboratory techniques, fluid mechanics, energy systems, and propulsion systems, as well as freshman engineering. Research interests include renewable energy to include small wind turbine aerodynamics, small propeller design, and experimental convective heat transfer as applied to HVAC and gas turbine systems.