Mechanical Engineering Technology Division:

"Integrating Culture as well as Engineering Instruction in Capstone Project and Machine Design Courses"

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C.P. Snow's famous 1959 Rede Lecture on the clash of the "Two Cultures": Art and Science continues to reverberate in the halls of science and engineering education. Snow's lecture brought to the surface what seemed apparent to most but never, until then, boldly stated; that there were two cultures, one of science and one of art that seemingly both can never be enjoyed by professionals who clearly must pick only one world to live in. In order to bridge this gap and to emphasize the richness that both cultures can provide the professional, engineering curriculums are requiring that the engineering students seriously take non-technical electives. The battle to gain the attention of an engineering student who is immersed into four 'heavy' courses in engineering and thus doesn't have time for Liberal Arts is not an easy battle to win. This paper will describe the author's efforts in integrating culture within engineering course work and provide examples of the Case Studies that have been used.

Introduction

How often has the following scene been repeated in a typical engineering classroom? The Instructor is returning graded assignments of the Midterm project that involved the analysis of a variety of engine cycles: Diesel, Otto, Brayton and Rankine cycle. The instructions for the assignment included not only to analyze these engines by selecting the best cycle state points for a specific compression ratio and maximum operating temp but also to research the history behind the development of at least one of these cycles and report this historical account via a concise but informative written text. The assignments have been graded with two grades: one for the Technical Content and the other for the Overall Report Format and writing style? As each student receives his/her assignment the inspection of the two grades is paramount for each student and the Instructor hears several very audible lamentations: "*My Technical Content grade was great but I got a "C" in my overall format reporting. Well, at least I did well in the important stuff*." Others are more to the point: *"The Technical grade counts more than the Overall Report Format grade, doesn't it*?" "*You don't expect us to write as well as we can do the technical stuff...the technical calculations are more important aren't they?*" "*What exactly do you expect for the overall reporting of the historical content of the engine development, after all this is a Thermo class not a History class or a writing class?*" and then the worst comment of all, half in jest and half as an excuse for the poor grade: *"We're engineers, we're not suppose to be able to write*"

If the reader has spent any time in the classroom where writing content is being emphasized in addition to the cultural aspects of the technology then the previous account will seem familiar. Although there has been an emphasis on more writing and cultural skills, engineering students are still not accepting the importance of being able to understand the technology, to appreciate the culture from which the engineering need is derived and then to be able to communicate via writing.

Engineering instructors have attempted to describe engineering technology as being steeped in historical context and the human emotions of the engineers and technologists who create the engineering. However, the engineering student is too engrossed in the very demanding and difficult subject matter to put importance on the more cultural, societal (liberal) aspect of the subject. The priorities are clear to the engineering student: with only a short 4 (or 5) years of undergraduate study to capture all of the engineering technical subject matter there is not time to "waste" on the liberal arts/culture/non-technical electives that the college is forcing on us. "*We can learn that cultural stuff after graduation when we have all the time in the world top pursue these subjects*".

The fallacy of course is that there will never be enough time to pursue the leisurely acquisition of the more liberal arts subject matter. The need to learn this material as early as possible is analogous to the investment advisors who correctly instruct the graduating senior that a little money put away now (every paycheck) will compound quickly into significant cash reserves when they are needed in the future.

Engineering students must be made aware of the fact that even just a little culture acquired as early as possible (yes, even before graduation) will serve the student/engineer in his/her career. Culture enables an increase in maturity and an appreciation of the human condition. It also makes the student or professional a better engineer, able to solve problems with more imagination and likely with many more sources of inspiration.

The following paper offers a suggestion on how to engage engineering students with the necessary cultural boot-up (if I may borrow the familiar computer terminology) even when they least expect it. Using another analogy this author suggests providing the "bitter" medicine by hiding it in the desirable ice cream.

Why Culture is Important to the Engineer?

Consider the following observations.

> **"An engineer? I had grown up among engineers, and I could remember the engineers of the twenties very well indeed: their open, shining intellects, their free and gentle humor, their agility and breadth of thought, the ease with which they shifted from one engineering field to another, and, for that matter, from technology to social concerns and art. Then too they personified good manners and delicacy of taste; well-bred speech that flowed evenly and was free of uncultured words; one of them might play a musical instrument, another dabble in painting; and their faces always bore a spiritual imprint"**

Aleksandr I. Solzhenitsyn
"The Gulag Archipelago"

"Choice manifests itself in society in small increments and moment-to-moment decisions as well as in loud dramatic struggles; and he who does not see choice in the development of the machine merely betrays his incapacity to observe cumulative effects until they are bunched together so closely that they seem completely external and impersonal...technics...does not form an element in human culture and it promises well or ill as the social groups that exploit it promises well or ill. The machine itself makes no demands and holds out no promises: It is the human spirit that makes demands and keeps promises.

Lewis Mumford
"Technics and Civilization"

But now consider a most recent observation by a popular writer and "science/engineering" enthusiast:

"David was an engineer, and he had an engineer's bluntness and lack of social skills."

"PREY", a novel by
Michael Crichton

Culture by dictionary definition is:
"...the act of developing by education and training; refinement of intellectual and artistic taste; cultural beliefs, social forms and material traits of racial, religious and social groups"

It would seem a waste of time to even suggest that someone would argue that the study of culture in the context of engineering is unimportant. If the study of culture in engineering curriculums is deemed necessary then why hasn't this study been more continuously introduced in the curriculum and accepted by the engineering student? The classically educated person would have studied Latin, Greek and mathematics as well as natural philosophy (or physics as it is known today). Perhaps it's better stated that the "...complete and well- rounded education" of any professional should have a solid footing in the arts as much as in the sciences. Unfortunately it seems that with the increasing number and difficulty of the engineering course work to be done, in a relatively short time and within the framework of a relevant, formal technical education, the priorities are set quickly. The student chooses to forego the cultural aspects of a civilized education for the temporary riggers of the specialty training that must be mastered. In short, the cultural education must wait until after graduation when the engineer has more time for these more earthly (dare it be called trivial) pursuits. There is even now a recently published collection of short stories entitled " The Best American *Non-Required* Reading" (emphasis is the author's) which would imply that even the more liberal education must make priorities of their time in formal academics forsaking some of the more interesting, if not acceptable cultural readings.

Unfortunately, this short sighted-ness on the part of some engineering students can quickly lead to complacency even after graduation. More importantly and of dire consequence is the fact that it may result in an engineer who doesn't understand the cultural context of the need for the actual engineering that he/she is studying in the first place. In short, the cultural education gained as quickly as possible contributes to making the engineering student a better engineer for knowing why the engineering is needed in the first place.

Methodology

Assuming that all would agree that the cultural education of an engineering student should be emphasized then the next question is: "How can this be done within an engineering education while not wasting the student's time?" This author has found a reasonable solution to this dilemma by integrating the cultural and the engineering aspects just, as they will occur in the real world of engineering experiences. There's always a cultural component to a particular engineering subject or problem that puts the engineering application into an historical context of human need. For example, there are many and varied stories of Leonardo Da Vinci's successes and failures with the technical aspects of his art; of Michelangelo the famous sculptor who once "blew the whistle" on a competitor who had received the commission to build St. Peters Cathedral; or of the engineer, Paconius, who promised his Greek King more than he could timely deliver in order to win an order for the transport of building stones. The author has woven these stories and others into a capstone and machine design class instruction. The stories bring to the student the cultural dimension of the engineering discipline, which is after all, one of the most human of activities.

The best way of describing the proposed technique is to offer the Case Studies taken from several courses that this Instructor has offered to his students. While reading each of these Case Studies taken from the author's Instructional Lecture Notes, keep in mind the general common features that are intended to attract the attention of the reader (the student engineer):

1. The attempt to seamless integrate (some would say "sneak up on the student") the engineering problem or life situation into a cultural setting,
2. The clear references to names and dates in a readable style that is done in a writing style that is less of the sterile engineering that is often found in technical papers and texts and more of a common language.
3. The action item(s) at the end of the Case Study presentation that attempts to have the student study or at least appreciate the human or social content of the situation as well as engineering content.
4. The subliminal message to the student that there is a world of interesting reading materials other than engineering texts.

Each of these vignettes is intended to demonstrate the use of cultural references. These references sometimes have little or no origin in the engineering art or science but references that lend color, allegory and preciseness to the scenarios. The attempt here is to show how the world of engineering and the world of "everyone & everything" else must intersect if the engineer is to be able to truly succeed as a human being that must relate with others. It was ***C. P. Snow, author and onetime scientist***, who first suggested (in an essay that got considerable attention) that the two worlds of Art and Science are not mutually exclusive. One can learn from the other and that, in fact, no one can really be intellectually whole without a little from both sources of human endeavor.

We shall discuss the to often-portrayed phenomenon of the engineer's world disconnected from the world of non-engineers and how this disfranchisement can detract from the engineer's success.

CASE STUDY No. 1:
In Your Spare Time; You are Cordially Invited to the Marriage of Two Cultures: ART and SCIENCE

Consider the following true to life engineering scenarios paying close attention to the bold, italicized phrases.

1. The project engineers were exuberant upon the results of the last tests. Not only did the complicated and brilliantly executed experiment function perfectly but the results matched the engineer's predicted results perfectly. In fact the results were so perfect that the Project Manager insisted that several independent engineers check the original analysis, the experimental equipment and the test results. The conclusion was quickly determined that the two project engineers had collaborated to falsify the test results. What gave them away? The test results matched too well with the analytical predictions. ***The engineers were hoist by their own petards.***

2. The Brewery was known for its exceptional beer. The President of the company insisted on giving the credit to not only the brew master, for he was a descendent from the old German family who started the brewery 150 years ago, but also gave praise to the engineers who faithfully monitor the entire process, carefully specifying only the best, most reliable equipment and who personally supervise the installation of all components that enter the plant. Upon asking them whether they ever get tired of seeing thousands upon thousands of cans and bottles of beer being produced only to disappear into transport trucks to be carried to the awaiting customers, one expressed his desperation in the following manner: ***"water, water everywhere and not a drop to drink!"***

3. The Company President had planned for the anticipated announcement of the Company's most recent engineering trump. So meticulously was the planning that the President even chooses the music that would precipitate, at just the correct moment, the unveiling of the engineering marvel. As the curtains lifted to reveal the gleaming, culmination of two years of painstaking work, the orchestra was instructed to play the last ***2 minutes of Beethoven's Pastoral Symphony*** as a suitable tribute to the engineers who worked on the project.

4. The United States Department of Defense needs to name the programming software that it wants all of its contractors to be sure to use in the design of future military equipment. The standardization of the programming code would certainly help coordinate the design, modification and operation of its many military products if the basic programming language that is used to direct that hardware were the same. The military picks the name ADA after the 37 year old woman who is historically credited with programming the first computer; even if it was a completely mechanical device: the Babbage Engine. The woman is none other than the only (legitimate) daughter of Lord Byron; one of England's most famous poets (some would say: infamous based on his roguish life style!). Oh! Did you also know that they could easily named a plane in her honor based on her interests in the science and engineering of flight; about 60 years before the Wright brothers?

5. Everyone knows of Cyranno De Bergerac (the one with the fancy way with words but a longish nose to point them in the right direction!). But did you also know that the author wrote about a fanciful trip to the moon, centuries before Jules Verne, H.G. Wells or President Kennedy's 1961 commitment to "...Land a man on the moon and return him safely to Earth"

6. In Greek mythology, Jason and his hand picked companions set off in the ship ARGO to search for and to attain their goal: the Golden Fleece-the magical remedy to all problems. Despite many trials and miss steps the intrepid heroes do not waver in their adventure and ultimately succeed. They get their job done and return home with their prize! Can this story taken from Greek methodology be actually a metaphor for an engineering team's efforts to complete the project professionally and ethically; to get the job done?

CASE STUDY No. 2
WHY ISN'T GOOD DESIGN ENGINEERING ALWAYS ENOUGH TO SUCCEED?

Consider the following pairing of engineers and their primary focus of interest:
⇒ James Rumsey, John Fitch and Robert Fulton (Engineering interest: Steamboats)
⇒ Henry Ford, Preston Tucker and John Delorean (Engineering interest: Automobiles)
⇒ Elisha K. Root and Samuel Colt (Engineering interest: firearms)

When historians list the first successful use of a steamboat, Robert Fulton is given the credit. Yet Messer's Fitch and Rumsey not only were contemporaries of Fulton and all were competitors of each other, but Fitch and Rumsey demonstrated a successful steamboat at least 10 years before Fulton. What is so special about Fulton?

Everyone knows Henry Ford (the First!) and if not the man then certainly the motor company that still bears his name and makes one of the finest automobiles in the world. But what of Mr. Preston Tucker who in the mid-forties tried to implement 'revolutionary' ideas for an automobile, including: automatic transmission, an aluminum block engine, a transverse engine (installed in the rear), head lights that follow the curve of the road, fenders that turn with the wheel, swivel (bucket) seats! Incredible ideas for automobiles that were 10 to 15 years ahead of their time. Why is there not a Tucker Motor Co. and why are there only 30 (approx) of his automobiles in existence?

Why is DeLorean's car only famous for its starring role in two (or is it three) 'Back to the Future' movies? Yet, it has a stainless steel, gull-winged body with considerable futuristic styling and very much a sports car that some consider out classes the Ford Mustang.

Samuel Colts' name is emblazoned in the minds of every John Wayne movie fan and is almost a metaphor of 'winning the west' and defending the country by having armed the military. Who then is Mr. Root? Why isn't his name on every weapon that the U.S. cavalry rode into action not to mention its use as the name of a malt beverage.

ESSAY DISCUSSION POINTS

Each of these engineers has something in common: they were intelligent and exceptional in administering their engineering talent. Why then did only one of each of the three groups shown above "succeed"; using the most common use of the word?

The answer to this question will be discussed in this essay and hopefully help explain how young engineers can avoid such pit-falls as they start their careers.

CASE STUDY No. 3:
HISTORY & ENGINEERING:
Tracing Engineering Failures (and Successes) due to History

Engineering is one of the most human of engaging activities. One does not have to be a professional Engineer in order to BE an engineer; although it has been said that what separates an Engineer from the layman is how long it may take to accomplish a specific task to some given desired degree of quality and/or completeness. It is sometimes desirable to think that, unlike other more common activities, engineering is not prone to the fluctuations, abnormalities and seemingly randomness of History; that is: the causality of events that are largely controlled or influenced by those leaders who we choose to represent us in everyday affairs as We go about Our more lofty goals: the saving of Mankind.

It may be very discouraging to learn for the first time, therefore, how the goals of a professional engineer who is attempting to extend human comfort and development or as the Declaration of Independence has put it: "...Life, Liberty and the pursuit of Happiness" are in fact heavily influenced by History. It has been demonstrated over and over again that engineering projects are sometimes (some would say: most often) not under the control of the Engineer. History can promote and foster or degrade and discourage personal or corporate engineering goals and projects.

To list some well-known recent, historical examples, one need only cite:
- The development of the atomic bomb (The Manhattan Project) during World War II
- The space race and the formation of NASA and the contribution of W.W.II, German scientists/engineers
- Energy Conservation and the formation of the Department of Energy and the quest for power generation from nuclear fusion
- The government cancellation of the B1 bomber while promoting Lockheed's Skunk Works
- The cancellation of the Super Collider Project after an expenditure of $10 billion
- The Cold War and the fostering of 'Star Wars' Projects

Many more little well known examples of the influence of government on engineering endeavors:
- The hindrance of the development of the Blast Furnace by Henry V (!)
- The Hindenburg air ship explosion and the curtailment of air ship transport engineering
- The development of interchangeable parts ostensibly for the promotion of interchangeable weapon parts
- Research in the establishment of a vacuum to pump water out of mines is hindered by the Church dogma (!)
- Engineering "...all (the) roads (that) lead to Rome..." was the result of Rome's interest to expand its influence: its culture as well as its military.
- The development of the first computer: to plot shell trajectories as well as to decipher military code

The effects of History on engineering endeavors begs that Engineers keep their talents up to date and generally well read if only for self preservation if not to be good, contributing citizens of the United States.
We shall discuss this aspect of the Engineer's life.

CASE STUDY No. 4
Can you really whistle while you work- separating the Fairy Tale from Real Life?

BACKGROUND

Consider the following paraphrased story of an actual event. The setting is in the stately office of the patron of the arts who has recently commissioned the design and construction of a magnificent edifice. He is being lectured to by a renowned engineer and artist who bring to the patron a story of defective workmanship in the building that the patron has only recently commissioned. The discussion follows these lines:

"I am telling you that the architect's cement mix is substandard. He is using the cement mix with very little solid stone in which to fill the principal support columns. If his thievery and fraud is allowed to continue not only will you need to redo the work in your lifetime but also the damage that could be wrought could endanger the lives of the workmen and also the people who occupy the building. You must check the workmanship for yourself. Hire independent audits if you don't believe me. But I am telling you like it is!"

The patron listens but he has heard the story from the engineer before. The architect is world renown for his artistry as well as for his technical competence. Besides, he won the right to design and build the structure after a fair competition was arranged where in even the now disgruntled engineer was forced to admit that his designs were inferior. What we have here, the patron reasons, is simply an attempt to demean the efforts of a superior architect. He, Pope Juleps, will not allow this to happen, even if the complaining engineer/artist is Michelangelo. Perhaps Michelangelo will not be so disappointed if he allows him to paint some pictures in the Pope's private chapel! That will at least keep him busy.

Michelangelo-whistle blower!? Advance the clock now 480 years later. St. Peter's Basilica is still standing-but only after the first architect was finally released of his duties having been found to have been fraudulently scrimping on the building materials. This was discovered AFTER several columns would not stand up long enough to support even the scaffolding that was to hold the workmen. That discovery took 15 years however. Michelangelo did finish the project, the correct way and it now stands as a monument to human artistry, strength of will and genius.

In 1986, Mr. Roger Boisjoly's whistle blowing was not heard loud enough or soon enough. It took only 72 seconds for the unimaginable to happen- 5 astronauts are killed (possibly, not so instantly) despite warnings that the launch environment exceeded launch parameters. Mr. Boisjoly is now 'self-employed'.

PROBLEM STATEMENT

How are these events related? What are the responsibilities of engineers to the trusting public but also their families and themselves? We will discuss this in class.

CASE STUDY No. 5:
LEONARDO da VINCI and The BATTLE of ANGHIARI

BACKGROUND:

Leonardo da Vinci is one of the most recognizable names in Art, Science and Engineering. Among his most famous paintings are the Last Supper and the Mona Lisa. Not listed among his most famous of art works is the "Battle of Anghiari". Not surprising because it was never finished! It took over 3 years for the Maestro to be commissioned the work, to conceive of its theme and content and to even prepare cartoons of the figures of men and horses in battle. The painting of those cartoons, as frescos, onto a 20 by 8 meter wall in the Grand Council Chamber in the Palazzo Vecchio began in earnest in June of 1505. By May, 1506 the enormous fresco was in ruins. The paint, so meticulously applied by the famous Maestro Leonardo, would not dry evenly as a result of a miscalculation by Leonardo. Some of his detractors (Michelangelo, for one) would even go as far as to say that Leonardo had failed as a painter. In fact, they would be mistaken; Leonardo failed, not as a painter, but in this instance, as an engineer.

The Leonardo's misfortune was due to his desire to use a new fresco painting technique that required that the painting be dried by applied heat and not by its naturally drying in air. Leonardo hoped to complete the fresco faster by painting larger sections of the fresco before drying the paint and then allowing the entire, newly painted section to be 'forces dried' using caldrons of coal fire. Unfortunately, his lack of understanding of heat transfer caused him to heat portions of the painting at high temperatures while other portions of the painting were barely warm. The result: the wet portions of the fresco painting began to run; from the top of the huge fresco to the bottom. The streaks were ghastly and left Leonardo with no alternative but to admit his mistake and discontinue working on the fresco.

DISCUSSION POINTS:

If you could have been Leonardo's consultant how would you have designed a means (i.e. an engineered system) to minimize the unequal heating of the fresco? Remember, you can only use the technology that was available at the time; i.e. no electricity, ho propane fueled heaters, no computers, etc. But then you don't need those artifices because you are endowed with the finest of human tools: a Renaissance mind.

Show how we learn from a genius' mistakes; even if its" Geniuses DO MAKE mistakes but then they MOVE ON!

CASE STUDY No. 6

HOW TO BUILD A COUNTRY:
STEP 1. 'LET FREEDOM RING' FOR YOUR ENGINEERS AND INNOVATORS

Fourteen years after the signing of the Declaration of Independence and the hard won fight against the Sovereignty of King George the first Americans were still fighting a battle. This battle was no longer on the battlefield but rather on the field of economic survival. The struggling country needs to manufacturer goods not only for its internal use but also for export to raise money for purchasing other goods that are needed by the growing populace. How does the young government kick-start the economical survival engines that can begin to power its people onward to self-sufficiency?

The solution that the U.S. government turned to was as dramatic as it was surprising to most of the populace. On April 10, 1790, the Government passed the U.S. Patent laws that clearly stated its desire to promote the innovation of the "Yankee" farmer, blacksmith, school teacher and in short, any American citizen to become capitalists. They would be guaranteed for the first time in the United States to be protected from anyone infringing on their invention and gaining from that invention all that is rightly theirs to garnish from a hungry Country and world.

The establishment of the United States Patent and Trade Office was critical to the success of the United States as a power to be contended with in Industry. It could safely and arguably be said to be the visible sign of the Country's birth into the Industrial world of established nations.

Over two hundred years later, the United States maintains its Industrial and economic supremacy due in no small part to the for sight of the first Americans to let the first, school-of-hard-knocks trained and promoted engineers of America to "...do their thing"

We'll talk more about the U.S. patent Office, what qualifies for a patent and how to get a patent.

CASE STUDY No. 7

"...Leave not a rack behind. We are such ***stuff***
As dreams are made on; and our little life
Is rounded with a sleep."
The Tempest; Act 4, scene1, 148-158 (W. Shakespeare)

In the real world of engineering the "...stuff" that the world is made of are the numerous natural and man-made materials which transform the Art and Science of engineered ideas into reality; into useful shape and function.

Consider what happens when the 'stuff' is chosen poorly; without good or any engineering judgment.

CASE I:
The marathon is considered a celebration of human strength and determination over extraordinary physical demands and pain. It is also true however that the Greek victory at the Battle of Marathon would have been a defeat for the Greek army and a victory for the Persians if not for the superior metallurgy of the Greek shields. Thus, what is celebrated as a victory of human physical endurance should also be considered a victory of materials science (not that the term was coined at that time) or metallurgy.

CASE II:
The race to be the first explorer to reach the South Pole was among the many conquests of the human spirit that was attempted during the turn of the century. In 1912 Captain Robert Scott and his expedition were only a few miles away from their victory before they realized that they would have to settle for being the second team at the South Pole. On their return to their base camp after this disappointing turn of events they planned on recovering the inventory of heating oil that was strategically placed along their return route so as to not freeze in the extreme cold conditions of the South Pole. Now disappointment turned to quickly to despair as they discovered that the tin containers of the precious fuel oil were failing allowing the fuel to drain away. Captain Scott's diary, kept until his death, had this entry towards the end: "...We should have got through in spite of the weather but for... a shortage of fuel in our depots *for which I cannot account*." (Italics mine)

CASE III:
The Titanic is forever emblazoned in the hearts and minds of sympathetic travelers and international citizenry alike. Over 2,000 people die in less than two hours after a collision with an iceberg. The ship is immediately flooded with an unstoppable torrent of water that enters through large tears in the ship's hull. The riveting of steel sheets to form the ship's hull is now suspected to have not helped to stop the tearing as was expected by the ship designers. Twenty (20%) of the rivets used in the final assembly are now suspected to have been defective.

The Old Ironsides is also forever emblazoned in the hearts of patriotic Americans. Assembled approximately 110 years earlier, it survived numerous battles with enemies who had as their only purpose the intent to inflict critical damage to its hull and thus put it out of commission; using cannon fire at close range. However, today Old Ironsides stands as a symbol of a young nation and the Titanic stands as a symbol of misfortune that recognizes no ethnic or social class distinctions.

We shall discuss the importance of materials selection and even materials invention in the successful deployment of engineered systems.

Where Does the Instructor Begin to find Cultural/Engineering Anecdotes[1]?

Without exaggerating, the simple answer is everywhere! After all, isn't engineering and its practical application to 'real-world' problems steeped in the context of common human needs, requirements, constraints and dreams; or in short a common cultural heritage or shared goals? In this author's experience most writings will contain your "Holy Grail" of integrated engineering and cultural heritage.

Conclusion

Does this method of instruction of culture and engineering work?

Yes, if this author and Instructor's experience is considered typical. The students often look at the story line that is presented as a slight reprieve from that class' more arduous instruction. Questions often arise as to the source of the information that has been presented: books, magazine articles, word-of-mouth or actual experiences of the instructor. The students begin to recognize the more social dimension of the Instructor rather than the one dimensional, technical image that is most often portrayed by the nature of the instruction. The students begin to more readily relate to the historical figures that are often quoted in such Case Studies as being "human like you and me; with successes but also sometimes more failures than successes". For example, if Leonardo can screw up a painting because of poor engineering and still be as a famous as he is, 500 years later; then maybe I can be less critical of myself"

Although, a formal assessment has not yet been done by the author, two anecdotes of the positive effect that this method of instruction has had on several students who contacted the author several months after the class room instruction was given. One student volunteered that as he was reading C.S. Foster's "The African Queen" (this was not assigned reading in the instructor's Fluid Dynamics Course that was taken by this student) he was reminded of the engineering description of the need to use Control Volumes in engineering analysis and that it could also be used to "focus your attention on any problem that comes across your path" when he came across a passage : "…although a river engineer could have calculated the volume of water passing a given point in a given time…". The student's thoughts were immediately brought back to his Fluid Dynamics instruction. This is certainly evidence of an effect that the instruction has had on the student and possibly not as haunting as the second example offered here. For a Heat Transfer Final exam given several days before Christmas one of the problems in the exam requested that the student use resistant networks to diagram the heat transfer paths for "…chestnuts roasting on an open fire." A casual and impromptu meeting between the student and the instructor several months later allowed one student to indicate that she could no longer listen to the Christmas song without remembering the Final Exam.

But what other evidence is there to indicate if the methodology 'really' works? The reader may be able to answer this question by asking themselves whether they would like to hear the follow-up lectures that are promised to the students in each of the Case Studies as presented in this paper?

If the answer this question is a resounding "No!", then please consider the following observation as the author's last word on the matter:

The quality of mercy is not strain'd;
It droppeth as the gentle rain from heaven
Upon the place beneath: it is twice bless'd;
It blesseth him that gives and him that takes:

"The Merchant of Venice"
Scene I, Act IV
William Shakespeare

[1] The author is preparing a short text for entry-level engineering students that will provide these Case Studies and more.

References

1. **The Works of William Shakespeare**
2. **"The Bride of Science"; Benjamin Wolley; McGraw-Hill, 1999**
3. **"Design Paradyms"; Henry Petroski; Cambridge Univ. Press 1994**
4. **"Nuts and Bolts of the Past"; David Hawkes; Harper and Rowe 1988**
5. **"Engieering By Design"; Voland, Mc Graw-Hill**
6. **"Technology"; Donald Cardwell; Borton 1995**
7. **"Stuff"; Ivan Amato; Basic Books 1997**
8. **"Prey"; Michael Crighton, 2003**
9. **"To Engineer Is Human"; H. Petroski; Barnes & Noble, 1994**
10. **"Power Systems Analysis"; Charles Gross; Wiley 1986**
11. **"The Axemaker's Gift"; James Burke and Robert Ornstein; Grosset & Putham 1995**
12. **"When technology Fails" edited by Neil Schlager; Gall Publishers 1994**

13' The African Queen"; C.S. Foster