Searching for the Ethical Engineer – a 50 Year journey

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May 22, 2024

Prolog: This long journey began with a small step: The first test

It was the summer of 1966; I had completed my first year of graduate study in Operations Research at The Johns Hopkins University. A cousin had helped me obtain an internship with an electronics manufacturer at its Baltimore facility. Having had two courses in statistics that past year, I was by default the plant's statistical expert. As I was soon to learn that wasn't an ideal position. The plant was not profitable, and the general manager (GM) was desperately trying to reduce costs. Of particular concern was the plant engineers' development of a new process for making silicon wafers (the major product). At that time, yields were relatively low, and the process was quite expensive. Near the end of the summer, I was given two sets of data – the current process for making wafers and an alternative that was purported to provide better yields for the cost.

As the "statistics expert," the GM asked me to perform the appropriate tests to show that the alternative was clearly better. I did the tests and found just the opposite – the current method was better than the alternative. When I informed the general manager, he asked me to throw out data points until I could show that the alternative was, in fact, an improvement. With two weeks before classes started, I decided it was time to return to campus. I later learned that the plant was closed by the parent company. I never learned what happened to the GM, nor did I care. However, he provided me with a great example that I used to begin every engineering ethics course that I have taught.

Race to the Moon and Beyond

There was one other event that would play a major role in my engineering ethics journey. In 1969, Thomas Paine had been appointed as NASA Administrator, and proposed "the next logical step" to follow the Apollo moon landing: a manned mission to Mars. President Richard M. Nixon appointed a Space Task Group chaired by Vice President Spiro Agnew to assess Paine's plans for NASA's future. The Group's resultant proposal was a mission to Mars. The mission would be launched from a manned space station situated in low earth orbit. The station would be constructed in orbit and supplied by a "space tug"; i.e., a shuttle-type transportation system from Earth. That space tug was to become the Shuttle – in the beginning only one small piece of a much more ambitious plan, but in the end, the only piece that remained. [Pinkus, et al. 1997]

In 1969, the benefit of space exploration given the cost was hotly debated. The country was dealing with a range of domestic social problems - the Vietnam war, the Civil Rights movement, runaway inflation, and a general mistrust of authority all of which affected the "mood" of Congress, and, of course, NASA funding. NASA administrators feared that this mood could result in the agency's demise without another ambitious, attention grabbing project. Cost forced them to drop the idea of a mission to Mars (at least for 50 years); instead, they refocused on a reusable, economical space shuttle. The scientific community with its eye on a space station and space telescope supported the project as did the Department of Defense which wanted an alternative to expendable rockets for launching satellites. Further, commercial users envisioned profits from launching a variety of payloads. To all, an "inexpensive, reusable space vehicle" seemed the solution. [Pinkus, et al., 1997]. But would that be possible, especially from a cost approach? Stay tuned to find out how the Shuttle was sold to Congress, or the slippery ethics of modeling.

The '70s – Coming to Pittsburgh – Who knew that Social Scientists are also Relevant?
Upon receiving my PhD in 1969, I accepted a position as an assistant professor of industrial engineering at the University of Pittsburgh. My research at Hopkins had focused on health care delivery systems, and I was able to continue that work at Pitt and, at the same time, in a consulting position with what was then known as Blue Cross of Western Pennsylvania. Several years earlier, the Pennsylvania Insurance Commissioner, in approving rate increases, demanded that Blue Cross form a research group to investigate ways of controlling hospital costs. Harvey Wolfe, who recruited me to Pitt was also serving as the Director of Research for Blue Cross. As a result, I was actively involved with two research groups – one at the University of Pittsburgh and the other at Blue Cross. This was a very productive time, and we proposed a number of creative ways for improving care and controlling costs.

Our research at the University initially focused on a methodology for determining hospitals' true costs of providing various procedures – we called it microcosting [Shuman, et al 1973]. By the mid '70s we had received NIH funding to examine the allocation of high cost healthcare services. Our focus turned to pre-hospital care, a new concept that had much of its early roots in Pittsburgh. One question that we addressed was: Why did some cities develop pre-hospital care systems while others simply left it up to the police and funeral homes? To investigate this and other questions we began working with colleagues at the Graduate School of Public Health, especially a group of medical sociologists and anthropologists.

Not surprisingly, we found that the decision to provide quality ambulance care was a political one, and as we were soon to learn this decision provided local health planners and politicians with a major ethical dilemma. We learned that in many of Western Pennsylvania's small towns the local politician's day job was as a funeral home director. Since he or she might do only 35 funerals a year, they had a lot of free time to do other things such as seek local offices – do you see a conflict of interest? It was the mayor or local council that had to decide to introduce trained EMTs and paramedics, who would provide much better care, but the funeral director/politician might risk losing a potential "customer" to a competitor.

We developed models for allocating prehospital care services, which typically meant showing how a more integrated, regional system was a substantial improvement over a number of low volume and poorly trained community volunteer organizations. We received funding from the Department of Transportation to study five, primarily rural areas of the country and help each plan for a regional system. However, as our social science colleagues learned – yes much better services could be provided but only if the elected officials were willing to take on the region's special interests – guess what? In all five cases local authorities were not willing to take on vested interests, even though it would have improved the prehospital care (and the health) of the public. Interestingly, in doing this they were Ignoring what we have taught students in our ethics courses – the safety of the public is the highest priority. [Shuman, et al, 1992]

As part of our research, we worked with the local emergency medical care agency to develop a data system for ambulance services. At one point we had several hundred participants including the City of Pittsburgh. We were interested in assessing the quality of care being provided. The result was a set of physician defined algorithms that could be used to assess various types of cases for quality review. We next developed software that sat on top of the data system and, if the ambulance data form had been completely filled out by the paramedics, we were able to provide an assessment of the quality of care. That same concept was later applied in our research to assess students' ability to recognize and resolve ethical dilemmas.

During this period, I met two individuals who were to play important roles in my ethics journey – Rosa Pinkus and Norman Hummon. Rosa, an historian by training, was on her own journey to become a distinguished medical ethicist. Unlike many academics, she was actually doing ethics, working with a relatively large number of hospitals to train ethics officers. She would work with physicians, patients and family members to help them resolve very difficult medical, and often end-of-life decisions. At Pitt, the dean of engineering, in a move well ahead of its time, had recruited Paul Hammond, a senior sociologist from the RAND Corporation as an endowed professor of engineering. Paul subsequently hired a young sociologist – Norman, who had an engineering background, and who focused on organizational behavior. However, when the dean left in 1975, the new dean didn't see the value of having such faculty in an engineering school. Paul moved to the Graduate School of Public Health and Norman joined the sociology department. We continued to stay in touch and worked together on some small projects. It was smooth sailing for Harvey and myself until January 1981 when Ronald Reagan became president.

The '80s – Ronald Reagan did it: A time to switch fields

By 1980, Harvey and I had built up the Health Operations Research Group that accounted for a fifth of the research funding in Pitt's School of Engineering, before disaster struck. By the summer of 1981, research funding for the National Center for Health Services Research and the Department of Transportation, the two agencies that provided the bulk of our support, was sharply reduced by the new administration. Suddenly, it was time to switch areas. There was another significant event in Spring 1981: on April 12, the Space Shuttle Columbia was launched, after six years of delays and cost overruns.

Remember the Space Tug? Following a series of design changes, and a controversial cost-benefit analysis, in 1971, the Office of Management and Budget had allocated half of the expected $10 to $14 billion development cost for a semi-reusable shuttle. Nixon overruled both his Science Advisor and his Science Advisory Committee in approving the project. Leading up to the 1972 elections, he knew that the space program employed large numbers of people in key states, particularly California, and unemployment in the aerospace industry was high. "On January 6, 1972, a bargain basement version of the original $10 billion shuttle concept was approved for $5.5 billion with a $1 billion contingency." This, as we were to discover would "cause compromises regarding cost, risk and schedule to be made at every decision point during the Shuttle's development, testing and final construction." It also provided NASA management with a major ethical dilemma – do you accept the money for an underfunded project with a scheduled delivery date of July 4, 1976 (guess how that was picked) or do you say, "no thank you – it can't be done at a bargain basement price"? [Pinkus, et al., 1997]

So, with our research portfolio having drastically shrunk, Harvey and I were looking for another project. Gerald Kayten, my father-in-law, was a manager at NASA, and part of a group of NASA managers who were concerned about the direction that the agency was headed and decisions that were being made. He was especially critical of the Shuttle Program. In particular, he was concerned about a cost-benefit study done in 1971 by Mathematica, a Princeton consulting firm, which was used to justify the viability of the project to Congress and the administration. NASA had projected 624 shuttle launches in the 1979 to 1990 period; Mathematica found that the system would be economically viable with 300 to 360 launches in that period. By the early 1980s, it was clear that these numbers were far too optimistic. According to Jerry, NASA knew from the beginning that they would never reach this number of launches. He felt that the ethics of the program should be examined – what a great idea, especially after the Challenger accident!

In discussions with Rosa, Norman and Harvey, we decided that an analysis of the Space Shuttle Program would make a great engineering ethics study – a field that was just beginning to take off (no pun intended) and was attracting National Science Foundation attention. Rather than study the Solid Rocket Booster Field Joints – the cause of the Challenger accident – we would focus on another component. We proposed to critically examine the development of the Shuttle's main engines. They represented a very impressive engineering feat. However, due to both the design challenge and the program's inadequate budget, NASA engineers were forced by necessity to use "all up testing." That is, engineers would design and model all the components, but wouldn't do individual testing until the system was fully assembled. Thus, rather than thoroughly test each component, it was only after the Main Engine was assembled, that full testing would begin. Not surprisingly, the development of the Main Engines was a major reason for the delay and cost overruns of the project, and why the July 4, 1976 launch date was missed by almost five years.

The National Science Foundation's review panel liked the idea and in September 1988 we received $82,000 for an 18-imonth project: "The Ethical Behavior of Engineers: An Analysis of the Space Shuttle Program." Norm provided the organizational expertise (the subsequent loss of Columbia in 2001, demonstrated how critical that was); Rosa provided the guidance on the ethical and historical elements; Harvey and I focused on the engineering. Rosa, always the historian, discovered the NASA History Office, and a treasure trove of documents that had been collected, and probably seldom if ever read. Two special "finds" were a 500+ page binder of unpublished interviews with NASA engineers, and a series of memos and reports from a senior NASA manager and very accomplished engineer, Adelburt Tischler (who passed away in 2017 at the age of 98). We realized that our study could end up as a book! Consequently, we then proceeded to conduct the study with the idea that the final report would, in fact, be turned into a book, with a full chapter on Tischler as an exemplary ethical engineer.

As noted, our study focused on the development of the Shuttle's Main Engine. However, in the end we couldn't neglect the Challenger. Actually, I couldn't neglect the Challenger, my co-authors felt it would take too much time away from our primary focus. However, Phyllis Kayten, my sister-in-law, was then a special assistant to a National Transportation Safety Board (NTSB) member, and, together with her father, they were able to provide me with valuable insights and documents. The result – I wrote a chapter on the nine-year history of the solid rocket booster field joint that resulted in the Challenger accident. That chapter has become a "play" for students to act out as part of the engineering ethics course that evolved from the project (which I would be happy to provide to interested faculty). As Rosa pointed out, despite what the press said, there were few white hats and black hats; rather there were a number of good engineers dedicated to their jobs but working under tremendous pressure especially due to cost and schedule constraints.

As part of the project we developed an engineering ethics framework – originally consisting of three principles that defined the ethical engineer: competence (knowing what you know and what you do not know); responsibility (communicating what you know and what you don't know); and Cicero's Creed II (being cognizant of, sensitive to, and striving to avoid the potential for harm, but opting for doing good). [Pinkus et al., Shuman, 2022] The framework applied to both the individual (ethical engineer) and the corporation (ethical organization). The latter also would apply to a design team, or group of engineers assembled together for a particular task.

Why Cicero's creed II? Cicero stated: "Salus populi suprema est lex," or "the safety of the public shall be the[ir] highest law." While he was speaking about lawyers according to former NAE president Norman Augustine: it is the "oldest statement of ethics for the engineering profession." If that was Cicero's Creed I, then our take on it could be designated as the second creed. [Pinkus, et al, 2014]. We have since added Cicero's Creed III: [An ethical engineer] must consider the long-term, broader impacts of her/his actions upon the people of the world. In that way, s/he becomes a world citizen [Pinkus, et al, 2014].

The '90s – The Pace Quickens – ABET Changes the World

We shopped the final report of our grant to a number of publishers and received interest from two: IEEE and Cambridge. The smart choice would have been IEEE because of its size – 300,000 members is a nice place to start. However, as academics, we went with the academic label and chose Cambridge [Pinkus, et al, 2014]. We also learned about British libel laws. That's why we made sure there was a reference for everything we stated that wasn't opinion. In the end we had over 500 references. As the book project wound down, Harvey and I thought it would be a good idea to turn it into a course. Rosa had already developed two ethics courses for bioengineering students (undergraduate and graduate) and unfortunately Norm had passed away. The course became known as "Balancing Cost, Schedule and Risk" based on the simple concept that as cost and/or schedule pressures increased, risk would also increase. It was then incumbent on the ethical engineer to understand that increased risk and be able to communicate it to more responsible decision makers or authorities. That basic theme has remained consistent as the course morphed into its current form. Harvey retired in 2007, but I continued with it and offered it for the last time in Spring 2019, before retiring.

In developing the course, we had the book and Rosa's work with bioethics courses as guidance. We applied to NSF for a grant to develop both an ethics course and a freshman engineering course, and received $150,000 for the three-year project: "Engineering Interfaces," beginning in January 1997. Our colleague Byron Gottfried developed the Freshman Course sequence, while Harvey and I focused on Cost, Schedule and Risk. We added a young assistant professor, Cindy Atman, to the project to assess our work. That was one of those life changing, or at least career changing moves. Cindy brought along a graduate student – Mary Besterfield-Sacre, and, as they say, the rest is history. Cindy is responsible for switching my research focus into engineering education. When she left Pitt for the University of Washington, we recruited Mary who was then an assistant professor at the University of Texas-El Paso to return to Pitt as a colleague.

In the mid '90s, a number of leading engineering educators and deans, with support from industry (it was the time to focus on quality and continuous improvement) seriously questioned the current ABET criteria. That version of the criteria, which ran nearly 30 pages, focused on "bean counting" – courses, credits, subjects covered. There was a desire for a new focus that would provide incentives for innovation with a system of continuous review and improvement. Draft versions of the new criteria were available in the late '90s, with a proposed implementation for 2000 (hence, EC-2000).

Cindy, Mary, Harvey and I saw an opportunity here – why not assemble the leading people in assessment and apply for an NSF grant focusing on what was to become known as "three a to k" or the 11 outcomes that each engineering program would have to assess? We invited our colleagues Barbara Olds and Ronald Miller (Colorado School of Mines), Gloria Rogers (Rose-Hulman Institute of Technology), Mary Besterfield-Sacre (before leaving UTEP), and Jack McGourty (Columbia) to join us in an ambitious proposal to develop procedures for assessing each one of the eleven outcomes. Barbara and Ron had pioneered a portfolio system for assessment and were working on Cogito – a computerized system to measure students' intellectual development [Olds, et al, 2000a-c; Pavelich, et al, 2002]; Gloria was working on an electronic portfolio; Jack had developed procedures for assessing teamwork; and we had our work with ethics. We received $1,002,790 from the NSF for "Engineering Education - Assessment methodologies and Curricula Innovations," for a four-year project beginning October 1, 1998, with an additional $110,000 beginning September 1, 2001.

2K – Assessment and ABET
Thus began a very comprehensive investigation of engineering education assessment. We enumerated the various assessment methodologies [Shuman, et al, 2000; McGourty, et al, 2001], and meticulously decomposed the ABET outcomes. For each one of the eleven outcomes, we developed in rubric form a compressive framework consisting of a set of attributes and achievement levels based on Bloom's taxonomy. Using this framework, each outcome was expanded into a set of attributes that could then be adapted by engineering faculty to assess their own programs' outcomes. Further, we documented how our characterization of outcomes could be used as part of a rigorous assessment and feedback process as required by ABET. [Besterfield-Sacre, 2000; McGourty, 2002].

This project marked our first extensive foray into the potential use of rubrics for assessment purposes, including the assessment of ethical decision making. It also solidified, relative to engineering ethics, our focus on students' achieving two outcomes – the ability to recognize a potential ethical situation developing in the workplace, and then the ability to resolve the situation without resorting to whistle blowing. Clearly, this was beyond the ABET requirements of 2000, but the current ABET outcomes (2023-24) now require that:

> 3.4: 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.

> Compared to the EC-2000 requirement:

> 3.f an understanding of professional and ethical responsibility

Taking Ethics Around the World
For 21 years Pitt served as the academic home for the Institute for Shipboard Learning that operated the Semester at Sea program. That meant Pitt got to select a faculty member to be the academic dean for each voyage. The academic dean was then responsible for building what amounted to a small liberal arts college by recruiting faculty from around the world and putting together a curriculum of seventy or more courses approved by the appropriate Pitt department. This sounded like a gig I couldn't pass up. In 2000 I was selected to be the academic dean for the Spring 2002 voyage and went about finding 25 colleagues who I would want to sail around the world with, and, more important were very good teachers, who could offer voyage relevant courses. I spent a year and a half recruiting faculty and overseeing course development. Then, in January 2002, the adventure began – 620 students from over 200 different institutions, 28 faculty with 21 spouses and another 21 dependent children, along with two dozen adults who liked being part of a floating college.

I had to offer one course that would be voyage relevant and would attract enough primarily liberal arts students to make the course go. I adapted the ethics course to the voyage. We would start in Nassau and go to Cuba, Brazil (Salvador), South Africa (Cape Town), Mauritius (as a late replacement for Kenya that was judged too dangerous after 9/11), India (Chennai), Singapore, Vietnam (Ho Chi Min City), Hong Kong, Shanghai, and Japan (Osaka) before ending in Seattle. I was able to find a case for each country. However, while 80% of the course was classroom based, the other 20% had to come from field work. I required the students to come up with six short "cases" over the course of the voyage. Three incidents stood out from the course – two papers and an incident. One student wrote an essay about meeting a former Olympic gold medal winning boxer in Cuba who now worked as a security guard in a cigar faculty. To support his family, the guard was forced to steal cigars and sell them on the black market. It was a touching piece, and the student did say it was true. The other paper described the student bargaining with a shirt seller on the Great Wall of China. It was getting late in the day and they were arguing over a couple of RMBs. In the end the seller agreed to the student's very low offer. The student took the shirt, paid the seller, and noticed the sad expression on his face. As the student reflected in his essay, he realized they were bargaining over approximately a quarter, which was worth very little to the student, but might determine whether the seller could feed his family that night.

The incident: in 2002, the shipboard internet was $0.50 per minute, so I made sure to bring a number of articles and other references for each case. As we approached India, I introduced the students to the Bhopal case. I divided the class up into two teams, one representing the government of India, and the other representing Union Carbide. The plan was to hold a debate between the two teams as to who was responsible. The night before the class, one team went into the library and checked out all the articles I had brought on Bhopal, making sure that their opponents would not have any source material! At least it provided me with a great ethics teaching example!

Rubrics for Assessing Student's Ability to Recognize and Resolve Ethical Dilemmas

The assessment project evolved into a second large study. We had been intrigued by Ron and Barbara's Cogito project and felt that producing software to assess students' intellectual development was complementary to developing software to assess students' ability to recognize and resolve ethical dilemmas. We proposed a pilot project to NSF to see if this, in fact, was achievable. That is, could we develop algorithms and software to assess a student's analysis of a posed ethical dilemma? This would be a combination of Cogito and the system Harvey and I had developed to assess prehospital care almost 25 years earlier.

We received $75,000 funding from the NSF for an 18-month pilot project "Assessing Engineering Students' Understanding of Their Professional and Ethical Responsibilities," beginning on January 1, 2002 (as I was leaving to go around the world). We added Carl Mitcham (Colorado School of Mines) and Rosa as consultants – two individuals who had long involvements with engineering ethics. Carl questioned our use of Cicero's creed, claiming it was never adopted by engineers. The result was an invited chapter on Cicero's creed in Carl's co-edited *Ethics, Science, Technology, and Engineering: An International Resource*. [Pinkus, et al, 2014].

Our plan was to develop and test a rubric for assessing students' responses to posed cases. If we could do that consistently and accurately, it was felt that we could then develop software that might obtain comparable results. We started with a hypothetical model of the ethical engineering decision making process. This then provided the framework for our rubric development. Rubrics were beginning to be used to assess students' responses to similar posed situations. [Shuman, et al, 2014a]. We based our rubric on certain of that early work, especially a rubric developed by Rosa and her colleague Kevin Ashley to assess bioengineering students' abilities. A panel of nine experts assisted with rubric development. The rubric was then validated in a pre-test, post-test process, using 80 (pre-test) and 78 (post-test) students enrolled in engineering ethics courses. Rubric results using two raters per case were compared to experts' assessment of those same cases. Our resultant rubric consisted of five attributes, with each attribute having five levels of achievement. [Shuman, et al, 2004]. These were:

Recognition of Dilemma (Relevance): Ranges from not seeing a problem to clearly identifying and framing the key ethical dilemmas.

Information (Argumentation): At the lowest level (Level 1), respondents ignored pertinent facts or used misinformation. Moving higher on the scale, respondents listed information without justifying relevance or applicability. At the high end respondents made, and justified, assumptions, sometimes bringing in information from their own experiences.

Analysis (Complexity and Depth): The lowest level respondents provided no analysis. At the highest level thorough analysis could have included citations of analogous cases with consideration of risk elements with respect to each alternative.

Perspective (Fairness): Perspective starts with lack thereof—a wandering focus. The score moves higher for taking one point of view, then several, then an overall view. In the ideal the respondent would consider the global view of the situation, and the perspectives of the employer, the profession, and society.

Resolution (Argumentation): The base category was when rules were cited as the resolution, even if used out of context. For the ideal case the respondent's resolution would consider potential risk to the public and/or safety, and other stakeholders. The highest category of resolution proposed a creative middle ground ("win-win" situation). [Sindlar et al, 2003; Shuman, et al, 2004].

The validated rubric was then used to assess the responses of 120 volunteer students. We demonstrated that it was possible to develop a rubric for assessment of student responses that would provide relatively consistent results among trained raters and would have face validity with ethics experts. Further, we also documented that it was possible to divide a cohort of students' ability to identify and resolve moral problems into levels. Faculty could then use this measurement tool in the assessment of students' comprehension, analysis, and resolution of ethical dilemmas in an engineering context.

In addition, we demonstrated that a course in engineering ethics could result in significant improvement in students' ability to recognize and resolve engineering ethical dilemmas based on the results of the pre- and post-test. In doing this we found that a wide spectrum of students who did not have such a course tended to perform at approximately the same level independent of their year (freshman through graduate student) or their grade point average. Of concern (now even more so with the new ABET criteria) was that levels of performance may be somewhat below what engineering educators would hope students should achieve. Finally, we found that having had an introductory ethics course, most likely offered through a department of philosophy, while certainly valuable from a general educational perspective, did not seem to help students in their ability to address specific engineering ethical dilemmas. [Shuman, et al, 2005]

Rudnicka extended this work, using the rubric and cases to further study ethical decision making by teams of undergraduate engineering students. As part of her study, she developed a model of ethical decision making. Using this model she then assessed both individuals and teams of engineering students in solving posed ethical dilemmas. Her experiments suggested that teams did, in fact, achieve better results than individuals when resolving what was termed less complex ethical dilemmas. However, when the complexity of the scenario was increased both teams and individuals had difficulty obtaining satisfactory resolution. Further, students who had completed an engineering ethics course also had difficulty in resolving the complex problems, both individually and in teams. [Rudnicka, et al, 2013]

Lemons to Lemonade: Model Eliciting Activities and E-MEAs

The quite promising results from our pilot studies motivated us to apply for a much larger project. I had met Professor Jun Fudano from Kanazawa Institute of Technology in Japan. Jun was responsible for providing ethics instruction to all of Kanazawa's undergraduate students – 1,200 per year. I participated in two workshops with Jun who honored me with a "Visiting Professor" title. At one of the workshops, I met Ibo Van de Poel from Delft Institute of Technology, who also was responsible for providing ethics instruction to all DIT's undergraduate engineering students. Mary, Ron, Barbara and I developed a cross-cultural proposal – we would compare engineering students from Japan and the Netherlands to U.S. using the assessment system we had developed. Unfortunately, even though I always considered this to be the best proposal we had ever put forward, it wasn't funded. After two tries we gave up. The second review panel questioned why one would want to do a cross-country comparison rather than simply focus on domestic students. Evidently we were at least ten years ahead of our time.

While the larger ethics study was not to be, Eric Hamilton, who had been an NSF division director, was now at the Air Force Academy. Eric had seen the original proposals and also the work we had done with Barbara and Ron. He felt these models could fit with a distributed learning project that he had begun. This resulted in a series of exploratory meetings that also included mathematics educator Richard Lesh (Indiana University) and Heidi Diefes-Dux and then graduate student Tamara Moore (Purdue University). Lesh had developed the concept of model eliciting activities (MEAs), as a means of very successfully introducing model building to pre-college students, especially those who might be mathematically challenged. Diefes-Dux and Moore had introduced the concept to freshmen engineering students at Purdue. What evolved was a large proposal to NSF focused on models and modeling, specifically introducing the MEA concept throughout the engineering curriculum.

We were awarded $2 million from NSF for a four-year study "Improving Engineering Students' Learning Strategies through Models and Modeling." Pitt was the lead institution with Colorado School of Mines (Miller and Olds), Purdue (Diefes-Dux), Pepperdine (Hamilton who had moved from the Air Force Academy), Cal Poly San Luis Obispo (Brian Self who had also moved from the Air Force Academy), and Minnesota (Moore who was now a faculty member). Our major contribution to the project was the development of the ethical model eliciting activity or E- MEA. The ethical MEA extended Lesh's original concept by requiring students to resolve am ethical dilemma embedded within a larger, unstructured, posed engineering problem. We developed engineering scenarios that were designed to elicit differing perspectives on ethical issues. Examples included confidential information versus public safety or employee loyalty versus whistle blowing. We also had one about throwing away data points until the desired conclusion was reached. (Remember that summer job I had?) We also extended the MEA concept in this fashion to study the strategies that engineering teams used to resolve complex ethical dilemmas, using process-level assessments of their MEA problem solving activities. [Shuman et al, 2009; Yildirim et al, 2010].

We found that the proper use of MEAs in the classroom can result in substantial learning gain, certainly as much as the more traditional instructional methods that used "back-of-the-book" problems as the sole homework exercises. However, with the E-MEAs, we learned that not only could we assess students' problem-solving skills, but we also documented that these activities could improve students' abilities to better acquire the majority of the ABET professional skills [Shuman, et al, 2005]. That is, when used in combination with such assessment tools as concept inventories, grading rubrics, and reflection essays, E-MEAs provide both a learning intervention and an assessment method for a substantial portion of the ABET outcomes [Bursic, et al, 2011].

Where to now?

When ABET first proposed its new criteria, we found some positives, but a number of concerns. Specifically, the original proposed outcome (3.5 in 2017) stated: “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.” This eventually was adopted as 3.4 as stated above.

Mary and I felt that ABET was packing too much into one outcome. We stated that “assessing students’ ability to recognize and make informed judgments requires an upper-level engineering ethics course, not an introductory freshman or philosophy course.” We doubted how many schools would be able to offer a full course – at that time, with the exception of a few U.S. schools, and Delft and Kanazawa, we didn’t know of any other examples where all engineering students were required to have an engineering rather than a philosophy course in ethics. It was only bioengineering programs that had introduced a required course. Chemical engineering programs were also introducing some of the same cases in a course focused on safety. Moving forward, it is quite possible, that other programs, in response to ABET, will begin to develop their own forms of ethics courses. This is happening with computer engineering/science, and most likely will also happen within civil/environmental engineering.

Our experience in teaching such a course, combined with our work with assessment, and Rudnicka’s study have convinced us that engineering ethics cases in context are complex and challenging. Consequently, students have difficulty in appropriately resolving them. Further, until an engineer must confront a potential ethical dilemma in practice, it’s not clear how s/he might respond. Finally, we felt that it is problematic to assume students will be able to learn how to deal with such situations in multiple contexts as ABET now require. We proposed that “the impact of engineering solutions in these multiple contexts suggests providing an expanded range of service learning/design projects both domestically and internationally to address this criterion.” Consequently, we believed that the revised ABET outcome criterion 3.4 would have been best left as the original separate outcomes, rather than aggregated into something that would prove very difficult to assess. [Shuman and Besterfield-Sacre, 2017]. It is unclear if more engineering schools will begin to introduce courses across the curriculum, or leave it up to the individual programs to continue to develop courses that are less broad but fit the discipline’s needs.

My last foray into the ethics world was working with a group of faculty who were selected to participate in a National Academy of Engineering workshop focused on overcoming the challenges to introducing ethics into the engineering curriculum. Together with Sarah Pfatteicher, Sharon Jones, and Rosalyn Berne, we produced a special issue of *Advances in Engineering Education* with a set of papers by authors who have attempted to integrate ethics within the engineering curriculum. That issue appeared in Spring 2020 with an overview editorial by Rosalyn and Sara [Berne and Pfatteicher, 2000], and seven papers [Brightman, 2000; Hitft, 2000; Laas, 2000; Riley, 2000; Taraban, 2000; Brown, 2000; Tang, 2000]. I taught the ethics course for the last time in Spring 2019. How successful was the course? I received this e-mail from a student who had taken the course seven years earlier:

> I wanted to send you a brief email saying thank you and that I appreciate everything that came out of my one semester course with you as an undergrad at Pitt during the class “Cost, Risk, Schedule: Engineering Ethics”. I just had this moment of realization, as I was updating my to do list at work; which included the following items, a request for me to do a cost breakdown so a more granular review of this proposal’s cost can be performed to see where cost can be reduced, a request to update the Risk Register and review if items can be removed or decreased, and lastly a request to

meet with the proposal scheduler to see where efficiencies can be gained to reduce the schedule or get this subsystem off of the critical path…

As I was writing out this list and realizing how the three tasks are at odds with one another and wondering how this wasn't being understood (or understood and ignored) I remembered sitting in that class with you and talking over these issues repeatedly and reviewing case studies. That course was one of the better experiences I had during my curriculum and one that I feel I continue to get more from as I move along my career.

Acknowledgements

This journey could not have been completed without the help of a number of colleagues. At the risk of leaving someone out, and alphabetizing (without ranking) these are: Cindy Atman, Mary Besterfield-Sacre, Eric Hamilton, Norman Hummon, Richard Lesh, Michael Loui, Ronald Miller, Barbara Olds, Rose Pinkus, and Harvey Wolfe. Students have included Ewa Rudnicka, Mark Sindlar, and Pinar Yildirim.

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