Short Story Writing Requirement for Enhanced Biomedical Engineering Education and for Engineering Ethics Competitions — Ethical Twists and Cost Assessment Required

Dr. Charles J. Robinson, Clarkson University

Director, Center for Rehabilitation Engineering, Science and Technology (CREST), and Shulman Professor of Electrical and Computer Engineering, Clarkson University, Potsdam, NY. Adjunct Professor, Department of Physical Medicine and Rehabilitation, SUNY Upstate Medical University, Syracuse, NY.

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Abstract

This paper builds on an important didactic element of course described at the 2011 ASEE conference.[1] This present paper expands on its emphasis on story writing and reflection, but with an added ethics twist. A great short story requires superb character development, an excellent plot often with a seminal event and with twists, ethical dilemmas and an outcome. For our biomedical and rehabilitation engineering (BmRE) course, we also require a triage component, diagnosis, treatment and a cost-of-care analysis. The fact that the students themselves developed the story line internalized the ethical concepts, hopefully transferable to a real-world situation.

In one sense, this writing exercise and the paragraphs related to the ethical question assignments forced the students to use adaptive expertise. A story has no right or wrong answer. Its plot and its characters can be ethically correct, marginally so or completely unethical, or some combination thereof. The story writing exercise and the homework opinion pieces required the students to review the didactic material from the class and then internalize it so that they could write opinions and a cohesive story with a great plot. The first innovation comes from a group's plot and character outlines. Then each author has to innovate his/her own full story in "competition" with others in his/her group. Adding unexpected ethical twists requires further innovation.

Background

This paper builds on a paper presented at the 2011 Vancouver ASEE conference entitled *A First Course to Expose Disparate Students to the BmE Field*.[1] This present paper expands on an important didactic element of that course, namely an emphasis on story writing and reflection, but with an added ethics twist. This inclusion arose from the author's participation in a Consortium to Promote Reflection in Engineering Education (CPREE) workshop at the 2016 ASEE Conference in New Orleans.[2] That participation led to the publication of a short CPREE activity guide on the topic of *story writing as a tool for enhancing engineering education*.[3] Story writing was also employed as a core feature of an IEEE Region 1 student ethics competition.[4]

This paper describes a novel method that incorporates and assesses the internalization of ethical considerations within an introductory biomedical and rehabilitation engineering course open to all in the university. BR200 is a required course for our minors in Biomedical Engineering (for engineers) and Biomedical Science and Technology (for non-engineers). BR200's ethics and writing components fulfill a university Knowledge Area requirement in Science, Technology and Society and a two-communication-point one. From the class syllabus:

> *The educational objectives of this course are to prepare students with an **oversight** of the BmE field and an **insight** into its applications that will enable them to be productive in their chosen careers. … In all cases we will try to integrate lectures and clinical findings. It is important [to]understand the clinical implications of what they learn. … All that the course will cover will have ethical considerations regarding the use and misuse of technology in medicine.*

Ethical Didactics

For over a decade, the ~50 students/ semester (90% engineers, 10% from business and the life sciences = ~1200 students in total) were given lectures on human research requirements and misuse and required to complete the CitiProgram on-line human research course. In other lectures, they were introduced to ethical models,[5] the sensory-motor nervous system and spinal cord injury (SCI) pathology, and assistive technology for a variety of sensory-motor deficits.

As described in our previous ASEE conference paper,[1] students were required to buy a bound lab notebook, take class notes in it, and also include weekly homework assignments and literature review analysis. The notebook was graded as a substantial part of the final grade. Slides from some lectures were provided and students were encouraged to put those in their notebook. The key for notebook use was that all tests were open notebook (only), but difficult. These tests were not a complete measure of retention, as they had notes to rely on, but the difficulty factor helped those with better retention. While not germane to this present paper, this 3-hour biomedical engineering survey course also provided introductions to cardiology, medical imaging, biometrics, prosthetics and orthotics, bio-informatics, biosignals and telehealth.

These assignments addressed the ethical issues raised in the course and are described later.

Did you complete the CitiProgram on-line human research course?
Did you attend the lecture on medical ethics allocation models?
What are the benefits of Speech Generating Devices for individuals with cerebral palsy?
How was assistive technology used to help an individual with amyotrophic lateral sclerosis?
Should artificial limbs be provided to all veterans?
Should all children who are deaf get a cochlear implant?
Should all women at age 40 get mammograms (or wait until 50)?
Write a good short story with ethical twists about 3 individuals who sustain spinal cord injuries.

To reinforce how assistive technology could be applied to improve quality of life, the movie "*Only God Could Hear Me*"[7] was played. It showed how individuals speech- and movement-impaired by cerebral palsy or autistic spectrum disorder could communicate, work, and enjoy life. A class assignment was to write down their initial assessment of the quality of life of someone in the film before the film was shown and immediately after it finished. The "before" question was asked while a freeze-frame of a young adult with no arm control and in a wheelchair was being projected. The "after" question wanted that same assessment, but also asked

1) if watching the movie was worthwhile;
2) whether it changed your view of those with disability; and
3) whether the religious slant in some of the movie was acceptable to you.

The instructor compiled all of the responses and sent a copy to the movie's producer, with student names omitted. This movie gave the students a great introduction to the use of alternative and augmentative communication — knowledge that they would need for the writing assignment. And it subliminally led the students to think about the ethics of providing AAC devices to those who could not speak, write or sign.

They also saw how an individual with bulbar ALS was able to travel 20,000 miles in the last 2.5 years of her life through the increasing use of assistive technology.[6] A lesson on prosthetic limb

design showed how mobility and dexterity could be restored to those with limb loss. For the latter, a required homework was to consider in one or two paragraphs whether artificial limbs should be provided to all veterans. We were looking for a caveat that considered the physical ability to use such a limb in the presence of an inappropriate medical status such as severe lower limb diabetic neuropathy or lack of sufficient muscle strength.

After lectures on the neurophysiology of audition and of cochlear implants (CI), the students watched two short movie clips and interact with a visiting teenage cochlear implant user and her mother as they talk about their experiences with CI. One movie takes a very strong stand against "forcing these implants on perfectly normal deaf children."[8] The other talks about feeling totally "rebuilt" after receiving his implants.[9] Both sides have compelling arguments.[10] For in class homework, the students were asked three times "Should all children who are deaf get a cochlear implant" (notice the use of the neutral 'get' rather than 'required.'):

1) right after the neural engineering of cochlear implants was explained,
2) after watching the *Sound and Fury*[8] clip that argued the deaf culture side, and
3) after listening to a bilateral CI-using young adult guest speaker.

These three along with a further out-of-class and studied reflection on the issue completed the homework assignment. No right answer existed. The students had to voice their own opinion. Approximately half felt the need for CI, a strong minority sided with the parent's choice, and a few took a wait-and-see middle ground, even knowing that a critical learning window existed.

After lectures on the principles of ultrasound, X-rays and CT scans, a separate lecture dealt with actual, relative and perceived risk, especially as they all relate to breast cancer statistics. The statistics of Misses and False Positives were presented. The recommendations of the American Cancer Society for mammograms (MMGs) for all women at age 40 were contrasted with a government panel recommendation for MMGs starting at 50, unless familial or other risk factors were in play. Students were asked as a homework problem to take a side on the issue in a few paragraphs, again with no one correct answer, but really focusing on actual vs. perceived risk.

Based on his 30+ years of service in the VA health care system, the instructor also described in detail the engineering behind assistive technology, and the cost of care and assistive technology for individuals with injuries at various SCI levels (C3, C6 incomplete, T8).

Story Writing Requirement

One of our conference papers assessed the value of story-writing and reflection in enhancing the practice of engineering education.[3] We said there:

> *In terms of outcomes, this storytelling activity was trying to get students to think about the importance of their engineering work in relationship to the real world content. It was trying to help students move beyond the technical content of equations and theory to see why this information mattered for real life.*

Our objectives were to see if the story-telling and reflexive activities 1) led to a internalization across multiple lectures of the subject matter of the class, 2) resulted in most writers developing complex ethical twists that might mirror real life scenarios, and 3) in their collective analysis could be used to strengthen the course in future semesters.

Approach

Why storytelling? In many ways the way we implement it flips the classroom. We do not give a classic case report with a known ending and have the students each write about it. We wanted the students to "own" the material, thus addressing our objectives 1 to 3. To that end we ask them in groups of 3 to 4 to brainstorm an interesting plot (real or fantasy) for a story where three people receive a spinal cord injury, one each at C3 (cannot breathe on own, totally paralyzed as a quadriplegic), at C6 but incomplete (thumb okay, rest of body partially paralyzed and paresthetic) and at T8 to T10 (paraplegic, with full upper body use). Students then individually wrote a 2.5+ page, single-spaced short story. They were to put in ethical twists regarding resource allocations.

The judgment criteria were as follows (and known to the students):

Hx1 (1 pt): What 3 characters are involved? Sex? Age? Background (good/ bad)? Need really good character development.
Hx2 (1 pt): What happened to cause their injuries? Need really good and believable story line.
Dx (1pt): What is the diagnosis (C5 incompl, C3 compl, T6 Compl)? Describe the injuries in some detail.
Tx (2/3 pt): Triage and treatment give limited resources? Basis for this allocation? Any ethical questions?
Rx (1 pt): Cost of rehab, and who should pay? What factors will affect quality of life (i.e., abilities, disabilities?). Cite references for costs.
Style (1/3 pt) Wow Factor/ Writing Style/ Grammar

For a perfect grade of 5, the story needed 1) superb character development, 2) an excellent plot often with a seminal event and with twists, 3) a triage component (hopefully with ethical dilemmas); and diagnosis: 4) treatment (again with possible ethical issues) and 5) cost-of-care and quality-of-life analyses. A superbly wow story was given 4.7 to 5 grade points; a great story, 4 to 4.6 points; a good story, 3 to 4. A story lacking got <3 pts. A story not turned in got 0 pts.

It was graded on the elements described above, including the Wow! Factor. Of particular importance was their cost (dollars and quality of life) analysis of the assistive technology needed for long term use. The best paper received a bookstore gift card. Judges were BmE faculty and staff and an English professor. Over the last decade, 1200 such papers were written for this course. Less than 4% were poorly written and it was quite difficult to pick winners from the top 10%. At the written end-of-class assessment almost all students reflected that they got much insight from this exercise into how biomedical and rehabilitation engineering applied to the real world.

At the start, they were orally given an example: Husband is well known for cheating on beloved ER head nurse and being abusive to her. Both plus one other sustain SCI injuries and are transported to the ER where the wife had worked. Husband's injury is the most severe (C3 complete), wife's the least (T6). The ER could tend to slyly give favorable treatment to their beloved boss (or not). How did their relationship get to where it is now? What's each character's background?

Data from Fall 2018 BR200

43 registered (13 sophomores, 14 juniors, 16 seniors). Breakdown of majors: (Engineering and Management 11; Chemical Engineering 10; Electrical Engineering 2; Biological Sciences 10;

Business 5; Other 5). Breakdown of Minors: (5 BmE, 1 BS&T). [n.b., the mix differs substantially between Fall and Spring terms, with many from Mechanical Engineering in the Spring].

For the fall, 40/43 turned in SCI papers. After the administrator recorded the grades, deidentified data were used to generated the following statistics: Average single spaced length = 3.0 pages (Max 7, Min 0.9). Average point grade (5 best) was 4.67 with 17 [41%] maxing at 5. Two lowest scores were 1.0. For grammar/ punctuation, etc. (no errors =33; slight errors = 5, more errors = 4; Moderate = 2). Group-decided topics are given in the table below, with the number in parentheses show those reviewed for prize:

4 (1) Bronx Zoo, Marriage Trouble, Cheating Husband (1 w cheating wife also), Gorillas loose
4 (2) Child Lost to Gorillas in Jungle, later taken and raised by parent killer, child (and gorillas!) get revenge
4 (1) Mexico vacation, Parachute sabotage, Mafia debt
4 (2) Alaskan Hospital, Terrorist cell, FBI with insider mole, drug paralyzed target
4 (0) Aspiring Rapper, Dishes more famous competitor, ends up getting mentored
3 (1) Bigfoot or Sasquatch plus geese hunting (2); 1 with BF as hero
3 (2) Army, War, Bomb Injuries, Nurse Lover, records switched
2 (0) Boat trip, wreck, psycho
2 (0) Manhunt game, Bad ladder on water tower
10 (1) Miscellaneous single topics (best = unknown twin hit in road)
40 (10) Total

Most were powerful and well written stories using a narrative style, making it hard to select the best ones for prize review. One or two used a dialog voice. Almost all had impressive character development and good plots. Ethical dilemmas were well used by most and incorporated an ethical decision group presented in class. Most well weaved into the story the required discussions of the cost of future care and of the assessment of future quality of life, based on topics discussed in class and on their literature searches. Many of the 10 chosen for prize review had unexpected plot twists, often ethical, in the last paragraph or sentence, as did maybe 5 others. Three brought tears to the reader's eyes. Similar findings occurred for this assignment over the last decade.

A worry about a writing assignment such as this is that the students could have paid someone or a professional service to write the stories for them. A solution used by many is to gather a previous writing sample during an in-class exercise (which we had from the AAC movie[7] comments).

Assessment

Besides the university mandated on-line student assessment, the students voluntarily and anonymously fill out a written assessment form. Answers were compiled by the center administrator without the instructor handling the forms. This assessment asked for comments on the traditional questions: Expectation met or not; Notebook requirement useful or not; course likes/ dislikes; and instructor likes/dislikes. But four additional questions were asked that called for reflection. Two were germane to the question of ethics internalization. The comments that they garnered are listed below, with numbers in parenthesis indicating how many gave that same answer.

Reflective Activity I: *You were asked to reflect on a number of biomedical scenarios (e.g., triage after SCI, Artificial limbs for all vets, cochlear implants for all deaf children, mammogram*

debate, technology for the elderly, etc.). How did these reflections give you a better understanding of the complexities of biomedical engineering and its ethical aspects?

Fall 2018 Direct Quote Responses To RA-I (n=25)

- I definitely see all aspects of production, marketing and demand now
- I think it really showed that technology has come such a long way
- (4) It helped me understand medical ethics more as well as learning what these engineers do
- (5) It made me think about the effects that Biomedical engineering has on such a large portion of the population
- (4)These reflects help me grasp that this field is so more complex than just advancing the technology
- It exposed me to a variety of aspects of biomedical engineering I never considered.
- They helped me establish an opinion, but mostly open discussion/debate in class was most beneficial
- There is a lot of ethical issues I did not consider
- Biomedical engineering is very complex and we only went over a broad overview
- Knowing their perspectives on their own lives helped me to understand their situations and needs
- (4) These reflections made me understand that biomedical engineering is not just a science. It also involve the incorporation of human thoughts and ideals.
- Better developed my understanding of BME

The 28 Spring 2018 RA-1 responses covered a similar span. Seven wrote: **"***It shows how biomedical engineering has ethical issues and that everyone has different opinions which makes discussions harder."* Two wrote**: "***It shows that there are two sides to every scenario and it shows the ethical concerns with each."* Seven others said*: "They gave me a better understanding of bio-medical engineering."* Others said*: "It made me realize how important and how much it applies every day." "It made the subject more real, since the discussion weren't technically involved, it was a nice break." "It made you look from different viewpoints." "They allowed me to give my personal opinion and to learn more about technological advancements."*

Reflective Activity IV: *Engineering is an art as well as a STEM field. In this class you had to do a lot of writing, some original, and you had to consider ethical issues. Explain why that might/ might not have contributed to your professional development as a future practicing engineer.*

Fall 2018 Direct Quote Responses to RA-IV (n=19)

- I wouldn't be opposed to working in this field, but was already familiar with the ethical problems
- I'm not going to be an engineer but it helped me understand things more through research
- Expanding my knowledge the field of engineering has on society helped my understanding.
- (2) This helps me grow as an overall person and fine tune my other skills not used constantly.
- (5) It exposed you to different aspects of the field aside from engineering
- It did because I was able to use my imagination which is important in engineering
- Not many Eng. Classes address writing so I appreciated this aspect.
- I am not an engineer so some of this will help me, but this class was for fun
- I definitely thought more about the ethics behind issues than I used to
- It was a good exercise for my writing skills
- It contributed to my created writing skills
- (2) I think it contributed to my development because I learned a lot that I didn't know
- Creativity was enhanced

The 27 Spring '18 responses to RA-IV were like those above, but two stand out. Both said:

"The creativity was so important to actually fully understanding the material, it made me think outside the box." Another two wrote "*Biomedical engineering considers a lot of ethical issues so I feel you have to think originally regarding ethical issues."*

Engineering Ethics Competitions

We add a short addition here that follows up on the story-telling idea. Most business or engineering ethics competitions present a known case study and have each team of contestants discuss and debate how they might have better ethically attacked the problem. For a recent Region 1 IEEE student ethics competition,[4] the students were instructed to develop their own scenario where a grey-area ethical engineering issue existed, and to describe how they might resolve it. The plots developed were superb, and the winning team actually scripted a play that spelled out the dilemma and solution. A veteran judge of ethics competitions was completely skeptical in the beginning that a story telling approach would work. But he was won over by the quality and thoughtfulness of all the entries developed under this approach.

Discussion

The concept of *storytelling* has recently reemerged as an important part of engineering design education, as it forms critical component of how to best link with the client of the design.[13-17]

In a 2007 ASEE Conference paper, Adams et al[18] go further to say that story telling is vital *"in engineering education to make explicit knowledge that can advance engineering education as a profession."* They also state that *"Story telling provides a vehicle for scholarly discourse that makes explicit our implicit knowledge, promotes reflective practice, and provides entry points into a community of practice."* Their focus was on stories told to a group that commented on the self-reflective properties of storytelling and storytelling as a pedagogical strategy.

We could well paraphrase Adams et al and say "Our exercises required our students to *make explicit THEIR implicit knowledge, to promote THEIR reflective practice and to provide THEM with an [imaginary] entry point into a community of BIOMEDICAL ENGINEERING practice."*

Elsewhere, Brue, in his paper on the craft of storytelling in engineering education[17] states:
The power of story lies in its inherent wholeness. A good story, in all of its complexity and nuance, resists dissection, analysis, and explanation. A story simply invites us to participate in the narrative, to see ourselves inside the story.

Thus Brue equates both storytelling *and* engineering to respected crafts, which they indeed are. Our class invited its students to see themselves as *engineering craft people* inside their story or reflection as they developed and participated in the narrative. Ethics added the spice of complexity and nuance that could make a story a good one.

In a great review article about the use of storytelling in engineering design, Devaney and Johnson[13] add a crucial caveat at the end. Without a core of fundamental knowledge and practice a story by itself might fall short or become flat. Our course used storytelling as both and internalizing tool and as a measurement technique to see how much implicit knowledge that a student was basing the story on, and to see whether it would be plausibly consistent with the practice of biomedical engineering.

In one sense, this writing exercise and the paragraphs related to the ethical opinion assignments forced the students to use *adaptive expertise*. As stated in Martin et al's[11] paper on biomedical engineering ethics: *Adaptive expertise refers to the ability to use knowledge and experience in a domain to learn in unanticipated situations.* It is contrasted with *routine expertise* of the kind needed to solve a typical engineering homework assignment requiring a strictly mathematical solution. These two contrasting expertise are considered in the *How People Learn* framework that has a rich pedological history.[12]

From the deidentified reflective comments and scores garnered by each paper, it was clear that the competitive story-writing exercise enabled all but a few students to internalize much of what was taught in this introductory biomedical and rehabilitative engineering course. The excitement in the groups as each began in class to develop their plot line(s) was palpable. And even more so after the instructor visited each discussion group in class and hinted at embellishments that they might employ. Even with the same basic plot, the three or four individual stories that emerged from a group were slightly to moderately different in how the plot progressed, with a few adding superb and unexpected ethical plot twists at the end. Many of the stories seemed to be a labor of love (and creativity) rather than just a need to write a term paper. Why so?

As for real life: a story has no right or wrong answer. Its plot and its characters can be ethically correct, marginally or completely unethical, or some combination thereof. In fact a completely predictable no-conflict story would probably be very boring. The story writing exercise and the homework opinion pieces required the students to review the didactic material from the class and then internalize it so that they could write a cohesive story or opinion. A winning story a few years back used the f-bomb word repeatedly, but as a necessity for great character and plot development. That student came from a disadvantaged background and poured his/her experiences into the story, while still adhering to the necessary requirements for the story. That's adaptive expertise!

Story writing forced innovation and internalization — and some competition. The first innovation came from a group's plot and character outlines. Then each author had to innovate his/her own full story in "competition" with others in his/her group. Adding subtle or unexpected ethical twists required further innovation. A student needed a good internalization of the subject matter (in this case neuroscience and rehabilitation engineering among others) to be able to develop a realistic plot. The fact that the almost all of the engineering students in the class over more than a decade wrote very compelling stories also belied the off-stated dictum that *engineers can't write*. They certainly can, given the correct motivation.

A secondary rationale for employing story-writing and reflection and for analyzing those activities was to provide the instructor feedback on how to modify the course in the semester(s) to follow as part of a continuous improvement process. As an example, a few students in this cohort had some problems with cost-of-care calculations, not so much for assistive technology, but more so for long term care. Thus, this current term, a better overview of these costs was added to the lecture on assistive technology. Similar tweaks have continuously been made to other lectures that have required a reflective activity.

IRB Review

Clarkson's Institutional Review Board has reviewed this project (19-49E) and has rated it minimal risk, exempt educational research.

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