Class Exercises Involving Ethical Issues Reinforce the Importance and Reach of Biomedical Engineering (and the Impact of the Coronavirus on Teaching Strategy and Measures of Assessment)

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Robinson’s ethics teaching style comes from an amalgam of academic, industrial (Bell Labs), governmental (VA) and clinical experiences, plus an interest in ethics from his undergraduate days.

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Since the late 1990’s Loretta’s passion has been to create engaging, diverse teaching and learning experiences for students and faculty. As the senior instructional designer at Clarkson University, she has presented at conferences such as the Online Learning Consortium and over the past two decades, she has also presented at a wide variety of other venues including ADEIL; Sloan-C International Online Learning; Sloan-C Blending Learning; eLearning Consortium of Colorado Conference; SUNY Online Learning Summit (SOL); DOODLE; the Teaching and Learning with Technology Conference (TLT), and the Conference on Instructional Technologies (CIT).

All of her presentations focused upon the various topics that support her mission for student success and efficient class management. Loretta has been recognized by Open SUNY as an Open SUNY Fellow Expert Online Instructional Designer. In addition, she is a member of the MERLOT Teacher Education Editorial Board and a MERLOT Peer Reviewer Extraordinaire. As a certified Quality Matters Master Reviewer and peer reviewer in general, she peer reviewed numerous online and blended courses using various checklists including the OSCQR. Her own course, Virtual Learning for the P-12 Classroom was QM certified in 2021. And in conjunction with Erin Blauvelt, Loretta was the winner of the OLC Effective Practice Award for 2021.

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I. Abstract

This paper builds on the ethical aspects of an introductory engineering course — BR200 — an Introduction to Biomedical and Rehabilitation Engineering. Various details of this course have been presented at ASEE Conferences in 2011, 2019 and here in 2021, and elsewhere. The course structure was described in 2011; one ethical innovation (story-writing) in 2019; and here in 2021 the didactic changes needed to adapt to a partial or full online presence as the result of the COVID pandemic. This present paper focuses on the impact of the COVID-19 on the teaching strategy used to introduce and discuss medical engineering ethical issues within the class as it abruptly transitioned from face-to-face instruction to completely remote in Spring 2020 (S20), and as it reappeared as a hybrid course in Fall 2020 (F20) and Spring 2021 (S21).

The focus of this present paper is not on the instructional changes required by COVID (and discussed in our companion paper), but rather on how those in turn changed the approach to the handling of ethical questions and to the assessments of students’ responses to those scenarios. One hypothesis is whether the content or style of the pre-post scenario answers and of the reflections changed between an answer handwritten under time-pressure and one electronically captured with little time constraint. Did the answers or reflections measurably change if more time were to be allowed for consideration? Another hypothesis was that the ethical dilemmas presented increased students’ integration and appreciation of the biomedical engineering field regardless of comment modality.

Biomedical engineering ethics can certainly be taught face-to-face, in a hybrid setting or completely online — but how well? Did ethics instruction suffer depending on modality? Our conclusion seemed clear — It didn’t matter especially if each method employed a blended learning management system like Moodle or other similar platforms. An instructor receives qualitative feedback in the classroom (i.e., a sense of how students are responding). Data from off-line grading of responses can be assessed and quantified. In sum, the major consideration brought about by a switch among in-person, online and hybrid instruction was how to handle the interactive, immersive ethical vignettes that the students were required to respond to, sometimes as an in-class exercise and sometimes as a post-lecture submission. That is a major focus of this paper.

Ethical vignette assignments used in BR200 were authentic assignments, a term used to describe assignments that often focused on messy, complex real-world situations and their accompanying constraints. The concepts of authentic assessment and authentic teaching are also explored in this paper, especially as they relate to ethical scenarios and the student’s grasp of ethical principles. Our results indicate that applying authentic assignments, assessments and teaching strategies to the teaching of ethical principles and practices might prove to be a beneficial adjunct to packaged ethical case studies.

II. Introduction

Instructors and textbooks approach an introductory course in biomedical engineering in many different ways. Some start with history and build a narrative. Some immediately jump to resistors and capacitors, stress and strain, force and torque, etc., depending on the background of the instructor and the focus of his/her department. And other foci exist. It is unknown if any use
ethics as the educational backbone to aid the students in understanding both the science and engineering behind biomedical engineering, but also to make the field come alive as a wonderful life-long discipline in which they might want to practice. Presenting ethical dilemmas and soliciting viewpoints gives students ownership of a topic because much of biomedical and rehabilitation engineering applies to humans, politics, cost-benefit and other considerations.

The COVID pandemic itself raised many medical ethics issues but it also had a profound effect on how a course could be taught. It was so for BR200 for Spring and Fall 2020 semesters. Early Spring 2020, the course with its 42 students proceeded face-to-face as it had for 23 previous semesters. In mid-March 2020 it rapidly pivoted to be a totally on-line course. In Fall 2020, 42 students took it as a hybrid course — some completely on-line and some splitting time being in class Tuesday and on-line Thursday (and vice-versa). This present paper addresses how the class ethical exercises and their assessments changed among those three cases.

A paper elsewhere in this conference reflects on 1) changes made to the in-person Spring 2020 class at its start because of a Fall 2019 two-day Quality Matters (QM) class taken by the instructor; 2) the rapid, fairly painless and sometimes clueless transition to on-line instruction because of the QM rubrics that were already in place for the class; and 3) the painful but necessary transition to a “proper” method of hybrid teaching (split in-class and on-line) that was greatly aided by the University’s offering of a 6-week volunteer (i.e., no pay) summer program for faculty that it entitled “RISE: Reframing Instruction for Success Everywhere.”

The focus of this present paper is not on the instructional changes required by COVID as discussed in that paper, but rather on how those in turn changed the approach to the handling of ethical questions and to the assessments of students’ responses to those scenarios. Did the content or style of the pre-post scenario answers and of the reflections change between an answer handwritten under time-pressure and one electronically captured with little time constraint? In sum, did the answers or reflections measurably change if more time were to be allowed for consideration? Did the ethical dilemmas presented increased students’ integration and appreciation of the biomedical engineering field regardless of class modality, as long as the instructor incorporated didactic changes to reflect the changed modality.

Certainly “ethics” can’t exist in a vacuum. Students must be given enough didactic education to have a rudimentary understanding of the science and engineering behind an issue. Yet because much of biomedical engineering applies to humans, politics, cost-benefit and other considerations often enter any calculation. Presenting ethical dilemmas and soliciting viewpoints gives students ownership of a topic.

At Clarkson University, BR200 is offered as an “Introduction to Biomedical and Rehabilitation Engineering.” Because of the ethics inclusion it has received approval as a Knowledge Area (KA) Science, Technology and Society (STS) course. Undergraduate students must take six KA courses, of which only two can be of the STS category. The course is open to all in the University, with a mix over the last 25 semesters being ~1000 engineering students and ~200 non-engineers. While the focus could be any biomedical engineering sub-topic, rehabilitation engineering was chosen as a major focus as it seemed to be a humanistic lens that could really resonate with all students. And its practice also raises many ethical issues.
Our 2019 ASEE paper described in detail the ethical exercises of the course. That paper mainly focused on short-story-writing as a way to help students internalize ethical issues. As described in that paper, a major graded exercise was, and still is, to have each student write a compelling multi-page story with ethical twists that involved three individuals with differing levels of spinal cord injury. That exercise remained unchanged with COVID. Similarly unchanged was a homework requirement to complete CitiProgram’s online certification in human research basics. That generally took at most 1.5 hours to complete. It covered many medical ethics examples. A lecture on medical ethics allocation models (e.g., greatest good for the greatest number, most for those most in need, nothing for anyone, etc.) still remained an integral part of the course.

Described in that 2019 ASEE paper were the face-to-face mechanisms of these exercises, the students’ use of their notebooks to record their views, and the instructor’s grading of the answers in the notebook (see also ref. 3). This paper analyzes the electronically captured S20 (Google Forms) and F20 (Moodle) responses, and how they differed from preceding semesters.

The major consideration brought about by a switch among in-person, online and hybrid instruction was how to handle the interactive, immersive ethical vignettes that the students were required to respond to, sometimes as an in-class exercise and sometimes as a post-lecture submission. That is the focus of this present paper.

Here we delve specifically into the students’ responses to and reflections on ethical vignettes, and to the changes in instructional practice required by COVID. The vignettes questioned:
1. How Quality-of-Life issues changed for the non-verbal when they had access to a Speech Generating Device?
2. Should all veterans receive artificial limbs?
3. Should all deaf children receive a cochlear implant?
4. What are the ethics of an experimental brain-computer interface?
5. Mammogram safety.

In general, 1) an opinion on a particular topic was solicited from the students before a presentation, 2) a video or lecture was then given, 3) opinion again solicited, 4) maybe a video arguing the opposite point was shown, and 5) a final opinion solicited.

Our 2019 ASEE paper focused on story-writing as another valuable tool for enhancing undergraduate engineering ethical education. While this is still a requirement for BR200, that paper covered that assignment well. As such the story writing exercise will not be considered here.

Ethical considerations formed 10% of the grade for both a term paper and its corresponding slide or poster presentation. These elements are also not considered in this paper.

Following the instructor’s attendance at a 2017 ASEE Conference workshop on reflective activities, a set of reflective questions were added to the BR200 final, two of which were:

1. “This class required you to reflect on a number of ethical scenarios (e.g., triage after spinal cord injury, 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?”

2. “Engineering is an art as well as a STEM field. BR200 is a KA STS COMM 2 course. As such, you had to do a lot of writing, some original, and you had to consider ethical issues. Explain why that might or might not have contributed to your professional development as a future practicing engineer.”

Analyses of students’ reflections to these questions is a major activity of this paper.
III. Methods

III.A. Ethical Vignettes: For over 25 semesters of BR200, the ethical vignettes used and before/after questions posed to students were:

1. A one-hour video (MimSpeak)\(^8\) showing use of a Speech Generation Device:
   Before: What is your opinion of the quality of life of individuals with cerebral palsy who cannot speak?
   After: 1) Did your views change after seeing a movie showing real-life examples of individuals with CP effectively using Speech Generating Devices out in the community?
          2) Was watching the video worthwhile?
          3) Was the quasi-religious slant of the video acceptable to you?

2. A guest lecture on Orthopedic Engineering and Limb Prosthetics:
   After: Should artificial limbs be provided to all veterans and why or why not?

3. Videos\(^9\) illustrating the Cochlear Implant Debate and Deaf Culture Awareness:
   Before: Should all children who are deaf get a cochlear implant and why? (Note the use of the neutral ‘get’ rather than ‘required.’)
   Mid: Did your views change after seeing a video showing the deaf community’s very negative thoughts that cochlear implants were destroying deaf culture?
   After: Did your views change after seeing a video showing users who were happily using cochlear implants?

4. Neural Engineering and Brain-Computer-Interface Lectures:
   After: Debate usefulness of BCI (cost-benefit, training needed, ethics, etc.).

5. Lectures on X-ray Imaging Safety and a lecture on Mammograms:
   Before: Should all women at age 40 get mammograms (or wait until 50)?
   After: Did your views change after a lecture outlining the benefits and risks of mammograms, including an analysis of risk factors and a discussion of actual versus perceived risks?

For the students to discuss these vignettes intelligently, sufficient didactic background material was presented in both face-to-face and online lectures, preceding or co-extensive with these exercises. Most young students don’t think about the rehabilitation field or mammography unless they are personally affected by one or the other. Thus, they are rich and novel (to the students) areas for ethical discussion and consideration. Even the language with which we should use to talk about those with disability has gained widespread acceptance over the past three decades.

Many students know Bible stories involving the deaf, blind, mute or lame. To avoid these types of one-word group characterizations, BR200 introduced people-first language\(^10\) that suggested using “an individual who is deaf,” “those who are blind,” etc. The focus thus shifted first to the individual rather than to the disability. That shift can bring about ethical rethinking. Some didactics preceding these vignettes focused on ethereal “Quality of Life” (QoL) considerations — What is it? Can it really be measured? Is it multi-faceted? Are there value judgements made (internal/ external)? Etc. QoL matters often present many ethical dilemmas — which is again why rehabilitation served as a good tool.
One difference from an educational standpoint was that pre-COVID only the presence of a “sufficient” answer was graded, but not whether the exercise changed ethical mindsets. Electronically captured data post-COVID allowed that analysis. Prior knowledge or personal exposure to a scenario was noted. Rating methods and scales used will be covered in the Results Section.

III.B. How Reflections were collected Pre- and post-COVID

After COVID appeared mid-March 2020, paper-based tests could not be collected. But the Spring 2020 BR200 course (S20) had already pivoted at the start of the semester to requiring that essay answers be submitted electronically into Google Forms. That pivot occurred because of the instructor’s participation in his university’s Quality Matters workshop, as mentioned previously. Likewise, participation in the RISE III workshop (described elsewhere) saw the course using Moodle for essay submission for Fall 2020 (F20). An analysis of how these pivots affected the teaching and assessment of BR200 is described elsewhere.

Electronically-captured two terms’ worth of responses (S20, F20) were quantitatively analyzed and qualitatively compared to pre-COVID semesters’ responses, especially of the five semesters’ worth of retyped reflections collected from Fall 2017 to Fall 2019. Spring and Fall 2018 responses to reflective questions 1 and 2 were analyzed in the 2019 paper. F19, S20 and F20 students received grade points for answering these and other questions [see companion paper].

The S20 and F20 blinded answers to reflections 1 and 2 were transferred to an Excel file for demographic and content analysis. For demographics the number of characters (including spaces) in each response was determined [Excel LEN function] and responses sorted by response length. For Question 1, the ethical content analysis metric was as follows: -2 for a negative response, -1 if lukewarm, 0 if a simple yes answer or an equivalent (and actual) statement like “Biomedical Engineering is extremely complex” [LEN=44]; +1 if there was some enthusiasm shown in the response, and +2 for an effusive response (e.g., “far better”). A content keyword tally was also produced.

IV. Results

IV.A. Reflective Question Demographics

There were 55 responses in S20 to reflective question 1 (see Table 1). That was 100% class participation — awarding a grade point per question probably helped. 95% responded to that question in F20, again for credit. Table 1 lists character response lengths (including spaces) to the two sets of questions and response ratings to the ethics exercises and writing requirements.

From Table 1, the high rating 2+1 percentages of F20 were 77.5% compared to the combined 89% of S20. S20’s answers were ~3 times longer in characters (average 635 vs. 229, median 537 vs. 184). Why the differences, since for both, answers were submitted electronically? Was it that the S20 use of a free form Google Forms essay answer was less restrictive than the 15-line Moodle quiz box used in F20? Or was it a question of in-person versus remote learning?

Before that latter question can be fully addressed, we compare the S20 and F20 responses to the second reflective question — the one that involved writing. Here the character response lengths
were much closer, but the S20 average length was still 162% of the F20 response (574 vs. 353). For some unknown reason (since the questions were identical), the F20 “writing” answers addressed more of the ethical issues than did the S20 “writing” ones. The converse was true for the “exercise” answers as was detailed in the preceding paragraph.

Table 1. % of registered S20, F20, F19 students responding to Q1 & Q2 and response length

<table>
<thead>
<tr>
<th>LENGTH</th>
<th>F20 Exercises</th>
<th>S20 Exercises</th>
<th>F19 Exercises</th>
<th>F20 Writing</th>
<th>S20 Writing</th>
<th>F19 Writing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Registered</td>
<td>42</td>
<td>55</td>
<td>48</td>
<td>42</td>
<td>55</td>
<td>48</td>
</tr>
<tr>
<td>Responses</td>
<td>40 (95%)</td>
<td>55 (100%)</td>
<td>24 (50%)</td>
<td>40 (95%)</td>
<td>53 (98%)</td>
<td>21 (44%)</td>
</tr>
<tr>
<td>Min length</td>
<td>27</td>
<td>44</td>
<td>36</td>
<td>29</td>
<td>86</td>
<td>20</td>
</tr>
<tr>
<td>Median</td>
<td>184</td>
<td>573</td>
<td>332</td>
<td>459</td>
<td>81</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>229</td>
<td>635</td>
<td>353</td>
<td>574</td>
<td>85</td>
<td></td>
</tr>
<tr>
<td>Max length</td>
<td>647</td>
<td>1642</td>
<td>108</td>
<td>1349</td>
<td>1312</td>
<td>196</td>
</tr>
</tbody>
</table>

RATINGS

| Effusive     | 16 (40%)      | 26 (47%)      | 14 (35%)      | 21 (40%)    | 17 (81%)    |
| Enthusiastic | 15 (37.5%)    | 23 (42%)      | 24 (100%)     | 22 (55%)    | 28 (53%)    |
| Simple       | 7 (27.5%)     | 4 (7%)        | 3 (7.5%)      | 4 (7%)      |
| Lukewarm     | 2 (5%)        | 0             | 1 (2.5%)      | 0           | 4 (19%)     |
| Negative     | 0             | 2 (4%)        | 0             | 0           |

Table 1 also shows F19 data. S19 data were not collected as the University went to an online evaluation system where specific questions could not be asked. The F19 data came from handwritten responses to the reflective questions. Students recorded their answers on a paper handout during the last 20 minutes of the last class session. A member of the class collected the sheets and took them to the instructor’s administrator. She typed the answers into a MS Word document in which no student ID was used. The instructor transferred the data to an Excel spreadsheet from which the data for Table 1 were generated.

A remarkable difference existed between the length and depth of the answers written on paper under time constraints (F19) versus those collected electronically with no time constraints (S20, F20). Possibly even more striking was the significant difference between the longer length of the S20 comments (via Google) about the ethical exercises than the shorter F20 comments (via Moodle). The same trend in length difference existed in reflections regarding the writing exercise. But, as will be shown later, a significant opposite difference existed between shorter S20 and longer F20 response lengths to the cochlear implant in-class ethical vignette.

IV.B. Did Ethical Content Raise Course Interest?

Our second hypothesis was that the inclusion of ethical cases increased the students’ interest in biomedical engineering. Rather than categorizing the answers by keyword, it is instructive to look at some relevant snippets from the S20 raw answers to the reflective question involving ethical awareness. Recall that S20 switched mid-stream to remote learning, but with all homework for the term submitted via Google Forms. General reflections from S20 were:

- **I really liked the reflective activities. And I think these activities were eye opening (X2).**
Interesting responses were received:

- I think that was way more interesting to me because it gave a purpose to why this field is needed.
- These reflections were very interesting and made the material learned more meaningful.
- These topics introduced that BmE, compared to other engineering disciplines, is much more than just the engineering aspect.
- It helps us learn the subject more in depth than any lecture could give and helps us learn who we are.

There was often a misguided first view:

- I frequently realized that my initial answer had not considered everything.
- I learned that you always have to consider all the ethical aspects.
- I was surprised that sometimes the answers that seemed obvious were actually misguided.
- These reflections made me question many of the things that I had simply took for granted.
- These reflections forced us to weigh in and take into account all of the pros and cons.
- It made me understand that there very often is no one right answer to any of the problems presented.
- All these technologies would seem to be straightforward, but while looking into multiple sides it became an ethical mess.

Some responses were personalized:

- forcing you to really think about if it were someone or something in your life.
- I was able to apply what I learned in the lectures to real-life situations. This in turn helped me understand the lecture information very much.
- made me realize that there are ethical issues involved that may not be obvious to those who do not have the condition - There can be two opposing viewpoints that both have ethically sound arguments.
- I had to think about the different implications that could succeed each possible decision. This created a much more personal aspect to my thinking.

Some needed researching:

- This also made me realize that these decisions take a lot of time and research.
- As I was answering, I would research more about it since I was more intrigued about these certain topics.
- each time my opinion was greatly shifted because I initially was not fully educated on the topic.

One answer (out of many good ones) from F20 stood out:

- Having to actually right (sic) down ideas and opinions on different topics was helpful for better understanding ethical dilemmas. Furthermore, when debating multiple sides of an argument to decide which to argue for, it truly showed how complex topics could be, and why they deserve the title "dilemma."

A few of the S20 & F20 students’ comments to reflection #2 about the writing requirement in general are worth looking at:

- I believe this is of the utmost importance for STEM students. Too much of STEM curriculum departs from humanities. This is definitely important professional development, as ethical decision making is overwhelmingly important for engineers. Engineers who have not had practice understanding ethical dilemmas will be less prepared to handle them in the future.
As a future practicing engineer, I thought that this class helped me learn things in a new light and a different way. I think my biggest takeaway from this class is the ability to think differently and find newer things interesting.

This class also made me look at more than just the technology used. I liked looking at the other side of it.

I have been a conservative for a few years now. ... those ethical issues had made me face the facts that segregation still exists in this world. ... This has made me more of a moderate over the course of taking this class, and going forward in my career, I will be more sympathetic to less privileged citizens and their problems.

IV.D Ethical Vignette Considerations

Ethical landmines exist in discussing prosthetic limbs for veterans with disability, cochlear implants for children who are deaf, speech generating devices for those with communication dysfunction, brain-computer-interfaces for those with locked-in or other high-level neural dysfunction, and the scheduling of routine screening mammograms for those over 40 without risk factors. Most students have inherent and interesting pre-formed opinions about these issues, some based on personal observations. Through its vignettes, BR200 aimed to provide a balanced look at the multiple sides of each of these issues.

A few examples suffice. A majority of students wrote that all veterans with a limb disability should be provided a prosthesis. Yet a few realized that veterans with amputations due to diabetes and other vascular dysfunctions would not have the energy to use a lower limb prosthetic. That became an ethical consideration. Cancelling “Deaf Culture” was a main issue in the debate regarding requiring all children with deafness to get a cochlear implant. The value of a highly experimental and hard to acquire BCI device could also be questioned. And the mammogram scheduling debate raged as much in the students’ responses as it does in society.

Pre-COVID (and actually pre-Quality-Matters training) the instructor had no way to quantify whether these vignettes changed any student’s ethical perspective based on a student acquiring more knowledge about an issue. Their notebook-recorded answers were simply graded as acceptable or not. That changed when pre- and post-responses to all of these vignettes were collected electronically in Google forms (S20) or Moodle (F20) based on his QM and RISE training. These digital records gave the instructor insight into whether the ethical content of a particular lecture needed to be tweaked and it also provided the quantifiable data that is analyzed here. The students were told that there were no right or wrong answers to these ethical dilemmas.

Two pre-/post- vignette viewpoints were a) not as much subject to prior exposure to the topic and b) might cause a significant swing in an expressed ethical viewpoint. These were the cochlear implant debate re children who were deaf and Quality of Life issues of individuals with a severe non-verbal form of cerebral palsy.

With cursory thought and after the engineering and neuroscience behind cochlear implants were covered, most students naive to the topic felt all deaf children should receive implants. Highlights of the video “Sound and Fury” were then played for the students. The movie featured a father who was deaf heatedly arguing that his congenitally deaf daughter should not get an implant as it was a device that was destroying deaf culture. To the grandmother, it was a matter
of the child being successfully integrated into the hearing world. After the video the students were asked their viewpoints via a timed Moodle quiz question. A third viewpoint was solicited after a video of a successful, adult-onset-deafness user was played, plus a video of the child, now a college student and an implant-user, giving a Ted-talk. Each iteration gave students more information to assess while forming their sequential ethical opinions. Hopefully, it pointed out the need to do proper research to get all viewpoints before making a judgement. With electronic response collection now available, the instructor could quantify changes in perception.

IV.D. In-Depth Vignette Example: Alternative Communication Devices

A similar situation existed pre-/post- the video “Only God Could Hear Me.” It covered the lives of non-verbal individuals, with a focus on those with cerebral palsy (CP) and the marked impact that a speech-generating-device had on their lives. A still photo of one of the individuals featured in the movie was put on the screen at the start of class. For 25 semesters, BR200 students were asked their opinion of that person’s quality of life. To some it was not a pretty sight — hands twisted inward, back severely curved, head to one side. Yes, it was an exercise asking students to judge a book by its cover, maybe unfairly.

Prior to 2020, students wrote their opinions in their notebooks as part of a graded homework assignment. In S20 and F20 the responses were electronically captured during class time. Table 2 compares the S20 results (all remote) collected during class time by Google Forms with those collected in F20 using the Moodle Quiz function. For this synchronous exercise in the hybrid F20 class, 37 respondents were remote and 5 physically in class.

Only one of the F20 students noted that it was “unfair to judge [QoL] just on the image provided.” Kudos to that student. Surprisingly 6 had known someone with CP. Three others knew that minds remained sharp despite physical limitations. These were included in the nuanced “other” category, where “it depends” was the gist of the responses. Two factored in the role of a good caregiver. 27 rated QoL as poor based simply on the photo (and possibly other beliefs). Six of that group qualified the rating as “somewhat poor.” Ten F20 students’ views were markedly changed after viewing the hour-long video, and with 17 they were somewhat changed. Prior exposure to CP limited others’ views of the scale of change.

Perhaps the biggest difference perceived by the instructor between these opinions captured in a notebook versus those captured via Moodle was in the length of the opinions. Unfortunately, and in contrast to the reflections discussed previously, notebook answers were not transcribed so their lengths could not be ascertained. They were however mostly remembered as being short. Table 2 lists the statistics on the length of the S20 and F20 pre- and post- observations. Note that the F20 post-observations were ~150% longer than those made of just the photograph.

Students finished the post-reflections at class’ end. This might have allowed for more time to write. An impressive observation was the character length of response that the F20 students were able to do in 5 minutes regarding the pre-question. Rounding the average up slightly to 500 characters yields 100 characters per minute. Given an average 5-character word length plus 1 for each space, that is equivalent to about 17 words per minute which is near the norm (15 WPM) for reflective typing. The maximum value of 1132 equates to an impressive 37 WPM.
This vignette was presented remotely in S20 and as a hybrid exercise in F20. Recall that that S20 cohort abruptly switched mid-semester from face-to-face to remote learning and that Google Forms entry was used rather than entry via Moodle Quiz blocks as was done in F20. The S20 responses to the exact same vignette show some interesting differences from F20 (Table 2). Both the S20 pre- and post-responses were significantly different in length from each other (paired t -5.08, p<0.001), and from their compatible F20 responses (two-tailed t, p<0.001). Why might that be, since students had the same amount of time in S20 and F20 to reflect and answer pre- and post-? Both Google Forms and Moodle quiz used answer blocks for responses. Both platforms were easily accessible. The questions were the same. The student mix could be assumed to be the same. It does seem like the use of Moodle elicited far longer responses than did Google forms. But all is tempered by the F20 class knowing its hybrid structure while the S20 class was thrown into remote learning.

Could it be that the students taking this course in S20 were more reflective or wanting to give their opinions given the newness of the pandemic, lockdown, etc.? During this time, the world took a shift, priorities changed, people were inspired by the work of the "new heroes". Might students have been feeling more introspective because of everything thought-provoking going on around them? Interesting questions! As mentioned previously, these vignette length statistics (Table 2, F20>>S20) were diametrically opposed to the length statistics (Table 1, S20>>F20) generated by the students’ responses to reflective question 1.

**Impact:** Having opinions digitally available allowed the instructor to judge impact. These selected F20 reflections were representative of those in F20 and S20:

- *In the movie, those afflicted by cerebral palsy expressed their frustration with the disease, but later shared how happy they were to be able to live a life in any capacity. I thought this humanized the disease to a new degree for me.*
- *Just because they have CP doesn’t mean that they can’t enjoy life.*
- *it allows the audience to see that even with their disability they can work well in society, and that they don't use their disability to their disadvantage. They work around it and come up with new ways to communicate.*
- *This documentary's purpose seems to show us their point of view, since we do not see that often enough (and the expanding technologies of course). I was impressed by their resilience through everything that they have been through. ... This documentary really makes me want to help progress communication aids in some ways in my future careers. This is my dream job, being able to use my engineering and medical skills to be able to communicate and make relationships with patients.*

Digital data collection meant that these types of analyses could have been done on the other F20 vignettes stored in Moodle and on the S20 ones collected in Google Forms. For brevity such analyses are not included here.
V. Discussion
This paper focused on how the instructional changes required by COVID changed the handling of ethical questions and whether student responses to those scenarios differed.

V.A. Handwritten vs Electronically Captured Responses

Comparing response lengths: Did the content or length of the before/after thoughts on ethical vignettes changed between an answer handwritten in a notebook under time-pressure pre-COVID and one electronically captured during COVID under the same time-constraints? Indeed, a marked difference existed. Responses entered via Google Forms (S20) or Moodle quizzes or assignments (F20) were longer than those placed in a notebook (F19 and before). To be sure, the instructor recollected that a few students (exact number unknown) filled nearly a full page with comments about a particular vignette. But most were recalled to be a paragraph or less in length.

The length of answers to the reflective questions provided a quantitative insight to help compare handwritten versus typed-in online answers. Table 1 pointed out the marked differences vis a vis the ethical writing requirements between 1) the average F19 reflection response length (85) handwritten on an evaluation form for no credit (50% turn-in), and 2) the average length collected in S20 (574) and F20 (353) for reflections entered with no time limit (but with a deadline) into an online portal for grade points (100% turn-in). It was much easier to separate levels of enthusiasm in the online answers versus the F19 handwritten ones (again see Table 1). In sum, better compliance and longer and better nuanced answers came from:

1. Awarding a few points for answers to course evaluation questions;
2. Allowing reflections to be composed without time pressure;
3. Having students type in answers via online tools (i.e., Google Forms or Moodle).

These principles can be equally applied to both face-to-face and online courses. Further, when the students typed in the answers, it meant that handwritten answers no longer had to be transcribed into text to be analyzed. Not only are today’s students used to and comfortable writing electronically, but it could also be looked at as being easier since editing is so much faster. Making edits to a handwritten statement involves crossing out, erasing, etc. One might conclude that students probably were not as apt to (or willing to) edit, review, etc., things handwritten. However, Vincent\textsuperscript{14} addressed this issue across a number of countries. The study focused on the contrasting use of paper and digital media within an educational setting. Fortunati and Vincent\textsuperscript{15} explored these research questions in a preliminary study:

*How do students perceive the affordances of electronic reading/writing when compared to writing and reading with paper? And, have electronic writing and reading become richer experiences than paper writing and reading?*

They based these questions on theories and concepts regarding electronic writing (Ong\textsuperscript{16}) and media richness theory (Daft and Lengel\textsuperscript{17}). They found that handwriting was preferred for intimate conversations, research and learning use, even though the students well used digital media. Students easily switched between digital and paper. Vincent\textsuperscript{14} concluded:

*The choice between digital or paper-based reading and writing was greatly influenced by the amount of dexterity the affordances of each medium offered to the students. The practical qualities of*
easy search and correction is judged by many respondents to only be possible with computers and despite problems of posture and tired eyes, writing and reading online is usually more practical in the education setting. ... The normative practices of students show that there is still a demand for pen and paper as well as keyboard and screen and that in some instances the use of paper is preferred.

V.B. Face-to-Face vs Online

This deep insight into the students’ collective thought processes gave the instructor a good judge of how the didactic side of the vignettes worked. But it also markedly raised up the debate concerning whether face-to-face lecturing was better than remote learning when it came to having students react to ethical vignettes. This is hard to judge from the data because two things occurred simultaneously: Distance learning only and informed Moodle use.

Grading in Moodle forced the instructor to carefully read all vignette submissions. Moodle made it easy for him to provide constructive feedback individually to each student. It really was the only method available to the instructor that could provide a feedback tool at all. Yes, providing feedback took more time (~3 min per student), but the instructor got a far better feel for the individual ethical mindset of each student — some liberal, some conservative — some religious, some agnostic — some empathetic, some hardened, etc. — but all with well-thought-out answers. No answer was right or wrong. The depth of thought in most responses was outstanding.

For this instructor, presenting ethical vignettes in person in a full classroom allowed him to 1) play the crowd (i.e., to emote one side vs another about a topic) and ask individual students questions, and 2) to see in the students’ faces and body postures how they were responding. These provided instantaneous qualitative feedback. Unfortunately, quantitative feedback could not be achieved because of the way that the instructor used and graded the notebooks or Google Forms.

For the instructor, presenting ethical vignettes online in an empty classroom or from home was tough. He couldn’t judge reactions, even when the students were simultaneously entering their reactions online. Yet when in Moodle he reviewed, graded and commented on each remote student’s reactions to a particular vignette, he got a far deeper appreciation of how his presentation on a certain ethical dilemma resonated with the students individually and collectively. Given the preceding two paragraphs, the preferred way to go would seem to be to combine face-to-face lecturing with online techniques of grading and commenting via the Moodle-submitted reactions. Germane to this question, Bernstein produced an excellent commentary on hybrid learning. In it he stated “According to the Center for Digital Education:

‘Blended learning uses online learning resources to supplement face-to-face instruction, while hybrid learning uses online resources to replace portions of students’ instruction that would otherwise be delivered face-to-face.’”

In an interview conducted by Grush, Jared Stein, VP of Higher Education Strategy for Canvas by Instructure, proposed an important takeaway from the pandemic: Blended learning environments can help us prepare for the future. Heeter reported on a 2009 study where Michigan State University instructors and students completed surveys about their technological and pedagogical expectations for a high quality, in person course in their discipline. In her summary statement, she concluded:
Students were much more likely than were instructors to expect their in-person class instructors to provide an online gradebook, online syllabus, and online weekly announcements. Students were more likely to want interactive online problem sets. Students were considerably less enthusiastic about class discussion and group work in the classroom than were instructors; students were more amenable to online discussion than they were to live classroom discussion. Student interest in blogs and social networking paralleled that of instructors.

A confounder might have existed for this discussion. Could it have been that for some reason a select cohort of students felt more comfortable discussing ethics in an electronic vs. hand-written format? Given that the class had many more engineering students taking this course than non-engineers, perhaps that could have been a factor in the preferred electronic method when discussing ethics — a thought process quite different from what engineering students used in most of their other courses. When we blinded the data, we did not bring over class majors or student levels (i.e., senior, etc.). It was clear from the responses that some students had had a previous didactic exposure to medical or engineering ethics and stated as such.

So, a dilemma occurs. Biomedical engineering ethics could certainly be taught face-to-face, in a hybrid setting or completely online — but how well? Did ethics instruction suffer depending on modality? The conclusion seemed clear — it didn’t matter especially if each method employed a blended learning management system like Moodle or other similar platforms. An instructor would receive qualitative feedback in the classroom or from well-organized chat rooms, and quantitative feedback from off-line grading of responses to ethical vignettes.

V.C. Ethics-Based Vignettes for Authentic Assignment and Assessment

In essence, the vignettes required of the students what has been termed Authentic Assessment. Authentic Assessment is defined as a didactic technique\(^6\)

> That requires application of what students have learned to a new situation, and that demands judgment to determine what information and skills are relevant and how they should be used. Authentic assignments often focus on messy, complex real-world situations and their accompanying constraints; they can involve a real-world audience of stakeholders or “clients” as well. ... Authentic assessments can be contrasted with conventional test questions, which are often indirect measures of a student’s ability to apply the knowledge and skills gained in a course.

Fox et al\(^5\) explained that “Authentic assessment engages students in processes and evaluations that are meaningful to them, both now and in the future.” Swaffield\(^21\) stated that authentic assessment engaged students in processes and evaluations that were meaningful to them, both now and in the future. Students were influenced to move from being consumers of knowledge to creators of knowledge. Aitken and Pungur\(^22\) noted that authentic assessment facilitated a greater level of self-reflection amongst students who became enfranchised not only in their own learning process but in the evolution and development of modules and courses. In keeping with the instructor’s findings, the IU-Bloomington CITI group noted that\(^6\)

> Authentic assessments may require more time and effort on an instructor’s part to develop, and may be more difficult to grade. To address the difficulty of grading authentic assessments, it is often useful to create a grading rubric that specifies the traits that will be evaluated and the [judging] criteria.
For these vignettes (activities not typically used in an engineering course), students clearly engaged in practice that became meaningful to them immediately and that they will hopefully take with them in the future. Their reflections make it clear that they found the vignettes to be meaningful. Whether they liked the activity or not, they all learned something new about themselves or others. Further, the instructor got a feel for their ethical mindset (especially with online grading), and whether ethical considerations might now form an integral part of their future engineering or non-engineering mindset. Falchikov noted that:

“An instructor’s experience could be enhanced as students become more engaged and more actively involved in their own learning. The instructor’s motivation and professional learning and development may also be enriched, through collaboration with students, colleagues and external bodies.”

This discussion about authentic assessment raised the issue of Authentic Teaching, especially as it relates to ethical considerations. ScienceDaily noted that:

Authentic teachers showed a willingness to share details of their life, and displayed elements of their humanity by telling personal stories, making jokes, and admitting mistakes. They also demonstrated care and compassion toward students by recognizing them as individuals and attending to their needs both academically and personally. ... Our implication is not simply that teachers should engage in limitless amounts of self-disclosure. Rather, by making efforts to engage with students beyond their expected roles in the classroom, teachers can greatly impact students' perceptions of them and their course. ... Perhaps more importantly, at-risk students are positively impacted by teachers they perceive as authentic in their communication.

The instructor for BR200 spent over 30 professional years in a clinical hospital setting, with a prime focus on those with disability and especially with spinal cord injuries. An overlapping 35 years were spent teaching in engineering and non-engineering university departments. He shared those experiences with all of his BR200 courses over the years and in other biomedical engineering classes that he taught. He brought forth ethical vignettes that he himself experienced, and his personal and clinical knowledge of quality-of-life issues. One example of the latter was through a lecture on the assistive technology that he increasingly had to employ for his first wife as she battled the ravages of bulbar amyotrophic lateral sclerosis (ALS).

VI. Conclusion

The COVID pandemic greatly affected student and instructor lives, since university instruction in general was radically changed by the pandemic. BR200 was no exception. Switching ethical vignettes from a face-to-face class to an online one worked, but only because the instructor had just started to use a learning management tool when the crisis hit, and with work, refined it so that he could quantify the ethical responses. The ethical vignettes and story writing requirements seemed to transfer seamlessly between in-person and remote learning because they were authentic assignments that required the students in either case to “own” the situations raised in the vignettes and in the story plot that they developed.

Finally, applying authentic assignments, assessments and teaching strategies to the teaching of ethical principles and practices might prove more beneficial than having a reliance on packaged case studies.
VII. Bibliography


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