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Humanizing Signals and Systems: A Reflective Account

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Abstract:

In this paper, I authentically and reflectively depict my journey as an engineering educator delving in the challenge of integrating technical content of a continuous-time signals and systems class with the social, value-laden realities that encompass such concepts. I refer to this particular challenge as *humanizing* the technical content of signals and systems. Specifically, I describe the signals and systems course and how I structured content and assessment plans to create space for human values. Additionally, I critically examine how some barriers that worked against my efforts. Finally, I share practical strategies and lessons learned for cultivating integrative ways of thinking about engineering science concepts.

Introduction: Why Attempt to Humanize Signals and Systems?

A cursory examination of perhaps any commentary on engineering education reveals a depiction of a ubiquitously desired product of an engineering degree: a master of *technical knowledge* that can also demonstrate *competence among people* and *consciousness about technical work in relation to people*. Such an integrated form of social and technical, or sociotechnical, competence has formed an underlying premise for visions for the future of engineering practice[1-4] as well as accreditation outcomes for engineering programs[5-7].

Yet, while promoting a desire for sociotechnical competence and consciousness, these numerous documents also characterize engineering education as a place where technical forms of competence are prioritized greatly over social forms. Indeed, a growing body of scholarship suggests that when engineering students *exclusively* engage scientific and mathematical ways of knowing, they disengage from human dimensions of engineering. For example, in her ethnographic research on practicing engineers, Faulkner[8,9] depicts a clear dualism of the technical and social, noting that “engineering professional training, identities and practice are permeated by a strong sense of the technical, which specifically excludes the social” (p. 764)[8]. Additionally, Trevelyan’s[10] ethnographic studies of engineers resonate with Faulkner’s claim, maintaining that “[e]ngineers tend to share an identity mainly framed in terms of the solitary technical: problem-solving and design.” (p. 176). Further, Bucciarelli’s[11,12] ethnographic studies of early career engineers specifically draw attention to the engineer’s disciplinary knowledge of mathematics and engineering sciences in order to frame engineering practice as emphasizing “object worlds” (p. 5)[11] while de-emphasizing inescapably *social processes* of engineering design. Other studies reinforce such findings by showing that while seemingly technical ways of engineering *thinking* and *doing* involve manifold social processes, even if these processes are not always recognized as social[13-18].

Where might this social-technical dualism[8] originate? Several scholars suggest that this dualistic thinking develops in the course of taking *engineering science courses*. Indeed, the aforementioned commentaries, reports, and statements about how engineering *ought* to be, often seem to call for an engineer with *broader* skills than technical. Yet Downey[19] has critically challenged such a premise, commenting, “[t]o focus on broadening may be to lose the battle at the outset because it preserves a distinction between technical core and non-technical periphery… Accordingly, the challenge today is not to broaden it but to *rethink and redefine its core*" (*emphasis* mine).

Other studies corroborate Downey's claim. For example, Cech[20] convincingly demonstrated that, while progressing through the core engineering curriculum, students' interest in public welfare declined. Additionally, in their study on engineering senior design students, Downey & Lucena[21] illustrated the tendency of such students to resort to deterministic mindsets when approaching highly social and ambiguous design problems.

Though such Downey's[19] recommendation to "rethink and redefine [the technical] core" is insightful, instructors of engineering science courses find scant resources available to help them imbue social competence and consciousness in engineering science courses. Certainly, Riley[22] has developed a companion text that includes several textured examples of content found in thermodynamics courses, which elicit engineering students to *engage*, *analyze*, and *reflect* on a certain engineering science topic, drawing on scientific, personal, and social-scientific evidence. However, such resources that guide an instructor to integrate technical content with a complex social reality are certainly an exception rather than a norm.

Reflective Practice versus "Best" Practice

With this background in mind, we return to the question that began the former section: Why attempt to humanize signals and systems? Or in other words, why attempt to guide students in learning well-established technical concepts as integrated with a complex, value-rich, social reality? These are questions that the reader might have asked when beginning this paper. These were questions asked by some of my students. And these were certainly questions that I continued to ask of myself. There are at least two ways I could respond to this question. On one hand, I could respond to the question, "Why attempt to *humanize signals and systems?*" In doing so, I could demonstrate to the reader how prior scholarship as well as data from my class should persuade them to humanize technical content. This approach is often seen in papers that promote a "best practice", or a certain technique that may be used in other institutional settings.

On the other hand, I could respond to the question, "Why *attempt* to humanize signals and systems?" In doing so, I could recognize that many factors, beyond prior scholarship and evidence-based practices, factor into instructors' *attempts* to incorporate a change of practice into our classrooms. In contrast to the *best practice* option discussed earlier, this approach might be called a paper to describe *reflective practice*. Indeed, as I tread the path of designing and teaching continuous-time signals and systems (CTSS), scholarly work kept me motivated to continue the journey. However, such evidence-based scholarship did little to support me in the workaday insecurities of integrating human values in a traditionally abstract CTSS course. It did little to aid my recovery from gaffes that I brought to the classroom, which at times, compromised my efforts to integrate human values and technical content.

In this paper, I adopt a reflective posture to discuss my journey as an instructor that attempted to humanize the technical content of a CTSS course. Similar to papers framed as best practices, I do describe of the course, the techniques that I employed to integrate human values in the course, and some preliminary results of these interventions. However, rather than accentuating the mechanism of these interventions, I write to authentically depict my journey in embodying these pedagogical methods.

By adopting a reflective stance in discussing this course, I am contributing to knowledge that relates to the experiential process of *becoming* an instructor rather than the techniques that undergird teaching. As put by Schön[23], "If teaching is to be seen as a form of scholarship, then the *practice of teaching* must be seen as giving rise to new forms of knowledge" (p. 31). This critical account is concerned about making my own "practice of teaching" visible that it might add to the engineering education community discourse, not only regarding how we might better integrate human values with technical content, but also how we might better *embody* this integrated content as an instructor. Thus, in this spirit, I discuss the following sections with a commitment to providing a textured description of my "practice of teaching".

In the sections that follow, I describe the CTSS course, both in a general sense and how it manifests at my university. I then discuss my own background in relation to the technical content of CTSS as well as my motivation to integrate human values with these concepts. Following this, I elaborate on how I designed the course to humanize technical content, and then how this plan actually transpired. Finally, I conclude by discussing overarching lessons learned from this experience and future directions.

Throughout the paper, I rely on data from my own personal log that I maintained as an instructor, reflective entries from the fourteen students in the class, and submissions from a design task completed at the beginning and end of the semester, as described in a later section. The collection and use data was approved by Harding University's Institutional Review Board.

About the Course

Continuous-time signals and systems (CTSS) is a course that introduces students to mathematical concepts that are used to analyze systems or continuous-time signals. For example, by representing a system as a transfer function, derived through the Laplace transform, we might determine whether or not a system is stable. We might also use these concepts to ultimately determine how the system responds to a range of frequencies. Additionally, by applying the Fourier Transform to a signal in order to represent it in relation to frequency, we might determine where *noise* (i.e., unwanted frequencies) occur within a certain signal.

This course exists at Harding University within the third year of the electrical engineering and biomedical engineering degree plan. Although the content of CTSS are applicable to a range of engineering majors, the course introduces concepts that are later sharpened in courses that specialize in electrical signal processing (e.g., medical imaging, digital signal processing) or system analysis (e.g., control systems, part II).

In Fall 2014, the course met for two 75-minute sessions each week. I introduced topics that would normally be expected in a CTSS course (e.g., see the Signals and Systems Concept Inventory[24]). Specifically, I designed the course to present the content of CTSS in a loosely connected flow of 6 modules, each spanning two weeks:

1) definitions, classifications, and time-operations of Signals
2) convolution of continuous-time signals
3) Fourier series and transform
4) distortionless transmission and filtering
5) definitions, classifications, and response of systems
6) Laplace transform & representation of systems (e.g., transfer functions, Bode plots, pole-zero plots)

We used the text *Linear Signals and Systems* by B. P. Lathi[25] as a common reference for learning and discussing these concepts. Moreover, I recommended the text *Signals and Systems Made Ridiculously Simple* by Karu[26] in order for students to have supplemental reading to support their own learning.

As prior research had shown[27, 28], students of CTSS typically encounter difficulty in with the concepts of convolution and transforming signals or systems between time and frequency domains. Therefore, I organized the course to prioritize these particular concepts, following the recommendation of Wiggins & McTighe[29] to strategically prioritize content rather than "cover" an array of concepts in a linear sequence.

About the Context: Students and University

As we educators well know, a course comprises much more than its academic content. While the content of a course might appear static, there exists in a class a dynamic, intersubjective experience that involves the instructor and students, all of which occur in a specific context. The setting of the particular course was at Harding University, a faith-based, Christian institution, whose mission is to *integrate faith*, *learning*, and *living*. The university has several distinctive features that align with its mission. For example, immediately before the CTSS class began, the students were in a campus-wide chapel service, which often included a time of prayer, singing hymns, and listening to a speaker deliver a concise message from the Bible.

Fourteen students, all biomedical or electrical engineering majors, were enrolled in the course. Each of my students identified as Christian, and most shared the particular church affiliation of the university. Moreover, the students hailed from an array of regional locations, with no two sharing the same U.S. state in common.

About the Instructor

In this section, I briefly describe my role in designing the CTSS course. I began teaching this particular class in the fall semester of 2014. This was my third occasion to teach the subject, but it had been four years since my previous occasion to teach this course. I had just returned from an engineering education doctoral program to this university, having been granted a three-year academic leave by my employer, and my graduate studies were quite different than the content of CTSS. Indeed, I felt as if I was entering this course *tabula rusa*, having begun a research career in qualitatively examining the psychological experience of students and professionals[17, 30], an investigation space that was rather different than the concepts of CTSS. I did have a master's degree in electrical and computer engineering, but admittedly, I entered the course a bit daunted at the idea of teaching the subject that had become distant. Consequently, I spent the latter part of the summer reacquainting myself with these concepts that had once been so accessible.

Yet, in some regard, my ongoing research bore relevance in course preparation. My investigations have highlighted how engineering students exist in our programs and courses as *whole persons* that are crystallizing what it means for them to be an engineer in relation to who they are as persons[17]. While such students might not have a very informed perspective on what it means to be an engineer, they do attempt to form this career identity, and often through their coursework experiences[15-17].

As an instructor, I set out to engage these students as whole persons, guiding them in these concepts in ways that aligned with cherished personal identities. For every student in this course, at least one of these identities was that of a Christian – an identity that I share with them. Thus, while I designed the course activities to reflect specific content, I also attempted to anchor this content in the premise that *what they come to know* and *how they come to know it* will strongly relate to *how they come to be*[31]. As the overall goal of their faith was related to *being* a certain way as Christians, I developed a plan to present these concepts in a way that related to these personal identities. In designing this plan, I reasoned, this course would engage their whole persons, thereby motivating them to engage the course concepts without feeling like they needed to abandon who they were in order to do so.

Humanizing Technical Concepts: The Plan

Thus, I set out to *humanize* continuous-time signals and systems. And from the first class meeting, I unequivocally communicated this intention. The first two of my nine learning outcomes specifically related to how the students would be expected to reflect on how content learned in this course related to human values. They are stated as follows:

LO1: **Signals and Systems and Faith:** Reflect on how the concepts from this course integrate with the mission of your faith.

LO2: **Signals and Systems among People:** Reflect on how *real* electrical systems interact with persons, and critique how these electrical systems affect social or environmental systems.

The first learning outcome called for the student to engage the concepts of the course with his or her faith identity. The second learning outcome, which was strongly related to the first, called upon the student to meaningfully connect the abstract content of this course to real systems that interacted with people. With these learning outcomes established, I had created a tangible space for the integration of human values and CTSS concepts. The students were evaluated based on how they demonstrated learning according to the nine course learning outcomes. Consequently, they received an actual grade for their demonstrated engagement with connecting the abstract, technical content to their personal faith and to a broad ecosystem of people.

Having established a *space* for the integration of human values and signals and systems, I then set aside *time* that I could devote to guiding the students through this integration. I also needed to develop clear activities and lectures that could guide the students into such integrative thinking. As earlier discussed, I presented content in the form of modules that spanned two weeks (i.e., 4 lectures). On the syllabus, I reserved the fourth lecture of every module to discuss real examples that related to the technical content. Thus, I intended for 7 of 30 class meetings to be explicitly dedicated to discussion where we, as a class, would critically analyze real signals and systems in ways that reflected the more abstract course content. Such critical analysis would involve both critiquing the system in a way that drew on technical concepts from the course *and* assessing how the system interacted with people, particularly in ways that cultivated social (in)justice and connected with human values.

As a result of these lectures, I intended for the students to maintain a log throughout the duration of the course, where they would reflect on a targeted question that I would leave them with at the end of the class meeting. These reflections would be used to assess LO1 and LO2, as stated above, mostly in relation to King & Kitchener's[32] framework for categorizing *reflective thinking*. Students that demonstrated *quasi-reflective thinking*[32], with little or infrequent personal examples to texture and substantiate their reflective statements, would marginally pass the learning outcome, earning a grade of D for the respective outcome. Alternatively, if a student frequently documented reflective thinking, substantiating claims with personal examples, they would demonstrate *excellence* for the respective outcome, thereby earning a grade of an A.

As I correctly expected my students to be new to systematic, reflective thinking, I established these bi-weekly logs to be an activity where I would provide feedback at two occasions to improve their process of reflection, calling on them to provide more evidence to their claims. At the end of the semester, I evaluated them based on their reflective process at that point. Thus, I would give formative assessment to this learning activity, attending to the process of their reflective thinking but also allowing them freedom with regard to the content of this thinking.

Thus, at the first day of class, the plan to humanize CTSS was set. Yet, as we educators well know, such well-laid plans do not always turn out as expected.

Humanizing Technical Concepts: The Difficult Journey

While I scheduled lecture periods to humanizing concepts from CTSS, I felt quite novice in actually making these connections myself. Perhaps out of optimism, or perhaps out of sheer naïveté, I began the semester with very little background on how the concepts of CTSS might actually be apparent when considering a realistic, sociotechnical system. As discussed in the previous section, I had planned seven lecture periods where I would specifically integrate human values, social justice, and specific CTSS concepts. Yet, as the semester progressed, these seven lecture periods were reduced to four—and the sociotechnical discussion only occupied half of the designated class time.

Additionally, when I discussed the content of CTSS, I could sense the confusion from students on difficult concepts. Each time I came to a planned lecture on integrating human values with the technical concepts, I encountered a dilemma that I recorded in my instructor log:

> "[P]art of the deal in teaching this class is that I… teach them a set of concepts – too many concepts to teach in one semester. When they are struggling to grasp these concepts, I am often faced with a choice. Do I guide them to think about how these concepts—that they do not feel they understand—interact with humanity? With their faith? Or do I use the class time to review the concepts a little more, to go with their book and decompose the problems that they face. I have varied in the choices that I made here, and I almost always feel like I made the wrong choice" (author's log, November 2014).

Nonetheless, these four focused periods of discussion comprised three specific activities, which I elaborate on in the sub-sections that follow.

The Energy-Conversion Playground Design Task

As I began the semester, I was familiar with the energy-conversion playground (ECP) design task scenario that had been developed by Mazzurco, Huff, & Jesiek[33] in order to elicit the types of considerations that students prioritize when thinking about certain design challenges. The ECP called for the student to imagine being on a design team that is collaborating with an NGO in a majority world context. The design team in the scenario is considering implementing a playground that converts mechanical input (e.g., via merry-go-rounds, see-saws) to electrical energy. Thus, broadly, they called to consider a system that relates two signals: human-powered mechanical input and electrical power as output.

I introduced this scenario in my first designated *human values* lecture, which took place in the third week of the semester. It was far from a perfect fit for integrating into the class. While the scenario did relate to signals and systems in a very broad sense, the specific concepts of CTSS were difficult for students, or their instructor, to see. For example, in this scenario, the student would not really consider analysis that could determine a system response based on input (e.g., by deriving a transfer function). Rather, as the task elicited, they approached the system from a high-level perspective, writing their considerations of the design challenge.

After the students had completed the ECP design task, we watched three videos to illustrate the stories of teams who had actually completed this design task. These videos depicted the project in a very laudatory way, and I hoped that they would discriminate problematic features of this scenario, such as the potential for exploiting children for powering a critical infrastructure. Following this, we discussed their design considerations. I recorded a summary of my perception of this conversation following the class period:

> "I am very uncomfortably incorporating social justice and human values into the curriculum. I started this with the [ECP design task]. Surprisingly, no one was very attentive to the ethical ramifications of using children for power generation… I was disappointed in that I found myself lecturing more than allowing for discussion… Ultimately, I was attempting to convey that the problems that they solve in this course are situated in real contexts, and sometimes, these contexts are more important than the *signals and systems* problem itself. I look forward to reading

> their reflections on these topics to see if some of them did respond to these ideas. At the moment, I do not think they feel troubled by the idea of *helping* by any means necessary. [I] am not going to criticize those who help, even in my private log, but I do see the playground scenario as *not inherently good* and certainly not inherently *equitable*" (author's log, *emphasis* from original entry, September 2014)

Following this exercise, I recall the discouragement that accompanied my first attempt to humanize signals and systems. I intended to reveal a complex, problematic scenario of a sociotechnical system. But as demonstrated in the quote, I felt that I had hijacked the discussion by dominating the conversation. When the students did speak, however, they showed enthusiasm in what they thought was a brilliant helping strategy, seemingly blind to the potential marginalization to children or other communities, which was imbued in this scenario (see Mazzurco et al.[33] for more details on this exercise).

Two weeks later, in the fifth week of the semester we returned to this discussion by watching a documentary on a similar system, *Play Pumps*[34], which portrayed problematic sociocultural dimensions of this suggestively innovative system. This second discussion did illuminate complex features of an *energy-conversion playground*, and students recognized this in their log. For example, after the second discussion, one student reflected in a log entry:

> "Before I saw the second video, I would have asked more technical questions about the [ECP] project's feasibility. After seeing the play-pump's failure, I now see how important it is to consider our responsibility to the communities we *tamper with*" (Cindy, *emphasis* mine, September 2014).

Cindy's keen statement demonstrated an emergent awareness of how design tasks might actually serve to "tamper with" majority world communities rather than empower them. Even students that earlier championed the ECP design began to become more aware of the problematic social context surrounding it:

> "It might seem like such a big help and like the godly thing to do, to go and fix someone else's problem for them without really teaching them or talking with them, but what if it's something they don't want?...There is no cure-all that will fit everyone's need" (Tanji, September 2014).

In sum, the ECP design task, and associated discussions, had given students a broad glimpse at how knowledge gained in this course might relate to socially complex systems, including those that unintentionally promote social injustice. After a second period of discussing the topic, I felt more encouraged in my faltering attempts to integrate human values in a CTSS course.

The Eletrocardiogram Signal

Though I found promise in the two discussions from the ECP design task, I also felt that this discussion was so distant from the specific concepts of CTSS and I needed to generate a different example to make a stronger integration between the social and technical concepts of signals and systems. By the ninth week of the semester, we were discussing how we might use the Fourier transform to represent a signal in relation to frequency and detect unwanted noise from the frequencies. At this point, I was contending with the guilt of not upholding my earlier commitment to humanize the technical concepts of this course.

I decided to guide the class through Riley's[22] framework of thinking through sociotechnical concepts in engineering science courses, that is for students to (1) engage a topic, (2) analyze a situation related to the topic, (3) reflect on a question that was generated through analysis, and (4) change "either their way of thinking or in the world at large" based on what they learned (p. 5). As I had just assigned them a task to filter out noise from a (simulated) electrocardiogram signal, I introduced the students to Riley's framework and gave them time in class to work through the framework in response to the haphazardly generated questions "What is an electrocardiogram?" and "Who gets to see an electrocardiogram?"

While this example might have led to an excellent discussion, I felt that my own blunders in the lack of planning the discussion mitigated any of its promising potential. Admittedly, I entered this conversation too rushed, and I felt the thick sense of awkwardness in the room as students dutifully responded to my prompts in their notebooks. Any guise of professionalism that veiled my embarrassment was set aside when a student asked me, in front of the class, "Excuse me, why are we doing this?" I felt a flush of simultaneous indignation and humiliation as I attempted to calmly respond to his question. As documented in my log:

> "I tried to suppress my internal anger at the question, but I don't know if my red ears did me any favors. I calmly explained how the most important outcome of this class was that they learned this knowledge in light of their relationship with Christ. But I am still bewildered, why do I owe anyone this explanation? They are here [at the university]… for the sake of their faith. *Why am I on the defense when I am trying to intentionally nurture this faith? Why do I get those questions when I am doing something that is fairly indicative of a value-based education?*
>
> "I am amazed at how deeply some of my students still bifurcate their identity in relation to Christ from their identity in engineering. *But I am more amazed at how I continue to do this, myself. Why am I so reluctant to introduce tasks that cause them to think about how these concepts interact with themselves*? With social justice? With human values? With their belief in Christ?" (author log entry, *emphasis* mine, November 2014)

In just a dash of hindsight, my emotional impulse to blame my students for their difficulty to engage the content of this course as sociotechnical was misplaced. Rather, I was upset at myself. Without realizing it, I had embodied the social/technical dualism that I set out to debunk. I would not explicitly espouse this, but the dualism within me came in my continual reluctance to engage the tension between scientific concepts and a complex, human reality.

Presently, I regret my reaction to the students, but I present it in the paper as an authentic part of my journey as an instructor. Despite my best intentions, I felt my attempt to humanize these technical concepts slipping from any sense of control.

Being a Christian and an Engineer

By the final week of the semester, I had struggled to maintain my objective to humanize the technical concepts of CTSS. Yet, I devoted one lecture to discuss my own journey in reconciling my spiritual identity as a Christian with my professional identity as an engineer. At this point in the semester, I had grown close to these students, and in fact, we had planned a holiday party at my house for that week. Despite my multiple mistakes as a relatively new professor of CTSS, they had shown me considerable grace, and I was compelled to finish the journey that I had sent them on. I had done well to problematize how their engineering identity might relate to their faith identity. It was my turn to model a sense of resolve with this question. I was compelled to demonstrate the same transparency I asked of them regarding my own integration of faith and engineering identities.

Before I began this final lecture, I handed out a blank ECP design task and asked the students to complete it a second time. After scanning results from both iterations of this task, one in the third week of the semester and one in the fifteenth week, I handed back both design tasks to them and asked them to reflect on the results.

My journey into humanizing the concepts of a CTSS course was met with considerable difficulty. I did recognize the need to hone my technique in executing this endeavor, notably by preparing more textured, sociotechnical examples that relate to precise concepts. Yet, as discussed earlier, I was confronted with my own implicit sense of betraying my attempts to integrate human values with technical content.

Humanizing Technical Concepts: The Promising Response

Yet, despite my faltering attempts to humanize technical content, the intended objectives were actually met with success. The students likely did not develop a systematic understanding of how the concepts of CTSS related to human values, but as evinced by the ECP design task results, they *did* appear to recognize that real-world signals and systems were sociotechnical rather than purely technical.

Following the procedures laid out by Mazzurco, et al.[33], three students in my research group and I randomized and rated the stated considerations from two iterations of the ECP design task. The four categories that the authors describe are technical (T), non-technical constraints (C), stakeholder considerations (S), broader considerations about cultural ecosystems (BC). We then came to consensus on how we rated each consideration.

Based on our analysis, the students of the CTSS class made a distinctive shift how they prioritized design considerations for the energy-conversion playground design, as demonstrated in Figure 1. Notably, the aggregate number of considerations that centered on sociocultural considerations increased from 7 (10.3% of total responses) to 29 in the second iteration (41.4% of total responses). Moreover, the aggregate frequency of technical centered responses reduced from 26 in the first iteration (38.2% of total responses) to 4 in the second iteration (5.1% of total responses).

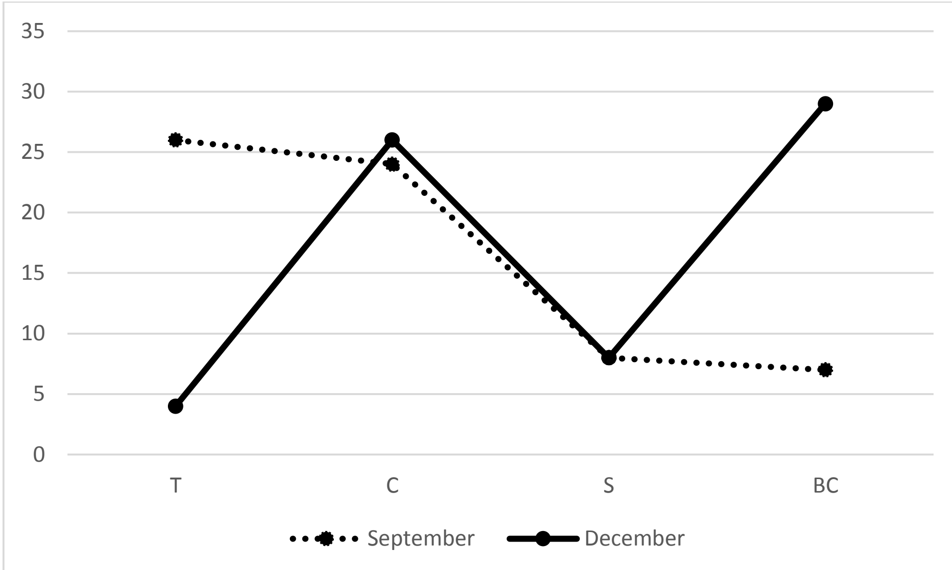

Figure 1: Total count of design considerations rated as technical (T), non-technical constraints (C), stakeholder centered (S), or broader considerations (BC). Blank and unknown responses are not displayed.

Additionally, according to their reflective journals, many students expressed distinctive ways to engage the content of CTSS as a whole person, including through their faith identities. To be sure, a few students did not holistically resonate with the concepts. Most strikingly, an anonymous student feedback response stated "the journals thing is weird and I usually fail to see the connections between the signals and systems that we talk about in class as to the signals that you want us to write our journals on."

Yet most of the students described a way that that engaged the content of the course in a way that was personally meaningful to them. Some students, such as Rubin, found that his class experience provided a powerful metaphor for him to engage his Christian faith identity:

> "This is my confession to how signals and systems relates to my faith in Jesus Christ. *I am a signal in this world*, though weak and strong, full of great things and failures, but as Christ as my *system*, He continually changes me and make[s] me new" (Rubin, *emphasis* mine, December 2014).

Other students, such as Jamie, connected to this sentiment that what he learned in the class would translate to how he would *be* in the workplace:

> "[What I learned in the course] will affect [me] by the questions I will ask before a product is put into production. Will this product be beneficial to society? ...What are the social implications of this device?" (Jamie, December 2014).

Julien also discussed his awareness, gained through the class, on how what he *knew* would connect to a certain way he would *be*:

> "In Signals & Systems, I have primarily learned about signal processing & representation. *What makes this class unique is that I have also learned to ask myself, 'What am I doing with what I've learned*?'…On the surface, this course has taught me the theory of Signals & Systems, but more importantly, *I've learned to examine myself and think critically* about how what I learn will not only enable me to find mathematical solutions but also social, ethical, and perhaps faith solutions with people I work for in the future" (Julien, *emphasis* mine, December 2014).

In sum, my journey to humanize technical content in CTSS was met with multiple obstacles, both from external circumstances and from within my engineering sense of self. Yet, despite these difficulties, the journey taken in this course became transformative for junior-level engineering students. While my attempt to humanize technical content might have been faulty on multiple levels, these students came to embody these concepts, and where scientific knowledge intertwined itself with whole persons, technical content became human.

Concluding Thoughts: Allowing the Social/Technical Paradox to Coexist

As I conclude this paper, I want to clarify that my reflective posture is not intended to portray a sense of contentment in the multiple blunders of my *technique*. If anything, this journey motivates me to pursue honing the craft of integrating human values and technical content, not only in CTSS but also in other courses. Indeed, my journey as an instructor of this subject has only begun. As I consider future work, I look to establishing more robust curricular tools for electrical engineering instructors that also teach CTSS, including by generating textured, sociotechnical examples that illustrate the technical concepts. I also look to investigate how this course, integrated with human values, qualitatively affects the way that technical content is mentally represented. Might such integration positively help students grapple with these difficult concepts?

In the meantime, I humbly offer my own reflective journey as a contribution to the experiential knowledge of teaching practice. I have attempted to make visible those obstacles that hinder instructors from incorporating human values in an engineering science course, even when they feel committed to doing so. By making these hindrances visible, I hope to foster conversations that support each other in promoting sociotechnical endeavors in the engineering curriculum.

I close this paper by examining an excerpt from Parker Palmer in his text *The Courage to Teach*. In this passage, he introduces the notion of "holding the tension of opposites" (p. 83)[35]. Palmer maintains that "among the most difficult demands of good teaching" is to hold paradoxes in tension (e.g., spaces that welcome *silence* and *speech*, spaces that are *hospitable* and *charged*). He culminates this discussion with a poignant excerpt:

> "If I do not fully live the tensions that come my way, those tensions do not disappear: they go underground and multiply. I may not know how to solve them,

> but by *wrapping my life around them* and *trying to live out their resolution*, I open myself to new possibilities and keep the tensions from tearing me apart.
>
> "There is only one alternative: an unlived life, a life lived in the denial of the tensions that teaching brings. Here, I play a masked professional role, *pretending outwardly that I have no tensions at all while inwardly all those tensions I pretend not to have are ripping the fabric of my life*" (p. 86) [35].

Perhaps other engineering instructors share my sentiment of being a novice in reconciling the social and technical worlds of the engineering science course. To us, it is tempting to abandon the pursuit of reconciling these worlds. Though we may agree such integration would benefit students' professional preparation, the tension of the social/technical paradox might be a place that the instructor wishes to avoid. I find Palmer's guidance to be a useful conceptual tool here. We may long to embody and project a coherent integration between the technical concepts we are drawn to and the social world that we live in. Until we find that integration, however, we can "live out the resolution" of the social/technical paradox that accompanies our profession, thereby "hold[ing] the gateway to inquiry open, inviting students into a territory in which we can all learn" (p. 85) [35].

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