Contemplating Engineering and Science: Creating Compassionate and Empathetic Learning Spaces in Engineering Education

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***Abstract*—This Work-in-Progress Innovative Practice paper introduces contemplative practices as a way of creating compassionate and empathetic learning spaces in engineering education. Contemplation refers to thoughtful observation, reflection, consideration, or intention, sometimes associated with deeper awareness and sense of presence. As such, contemplative practices – both individual and communal, internal, and external – allow for an emergence of deeper meaning of self and the world through the development of compassion, empathy, connectedness, and creativity. Newly emerging in higher education, contemplative pedagogies bring students' authentic selves into the learning process, fostering a personal and collective sense of belonging, inclusion, and engagement of all student's diverse ways of knowing and being. This is particularly important in today's engineering education where the disinclination to include diverse students' senses of self as they uncompassionately learn to build the technology of the future is harmful for that same future they attempt to build. This paper presents an Innovative Practice that brings together a plethora of contemplative pedagogies in two undergraduate engineering courses – a Physics Foundation and an intermediate-level Social Science courses. To assess the effectiveness of this innovation, we use students' weekly reflective assignments that demonstrate an emerging sense of trust and belonging. We also find that contemplative pedagogies create a scaffolding for students' development of compassion, self-compassion, and empathy – educational outcomes that are otherwise absent in their engineering education. Students report a sense of palpable personal growth and self-discovery as well as an opportunity to reexamine science and engineering through the lenses of their diverse ways of knowing and being. Many reflect on a sense of integration of one's sense of self into an otherwise sterile engineering education devoid of subjective, caring, and heart.**

Keywords—contemplative pedagogies, mindfulness, empathy, compassion, belonging, self-awareness, reflection, holistic, interdisciplinary

I. Introduction

Today's Science, Technology, Engineering and Mathematics (STEM) higher education is accentuated by an exceedingly complex socio-educational context. According to Vanessa Andreotti and colleagues [1], our students engage with their educational milieu while surrounded by six categories of challenges: (1) a cacophony of perspectives that creates a (mis)information overload and impossibility of stable authorities or imposed consensus; (2) oversaturation of unprocessed emotions, which is a result of growing lack of resilience and collective capacity to process complex emotions within and around us; (3) increased volatility, uncertainty, social complexity, and ambiguity, which are associated with social fragmentation and polarized perspectives about "the common good;" (4) meta-consumption as a mode of being with the world, including relating to incentives and rewards and entitlements; (5) proliferation of fragilities in the absence of learning how to be with complexities of the world; and (6) intergenerational resentment, which is often described by the current higher education student population as a broken promise of prosperous future, sick planet Earth, or "watching a train wreck in slow motion."

Within this context, our students enter higher education spaces dis-integrated from their personal and embodied ways of knowing, having been conditioned by years of education of "the mind for critical reasoning, critical writing, and critical speaking, and for scientific and quantitative analysis" [2] and assessed by external measures of their selfhoods. However, Arthur Zajonc argues that "systematic cultivation of our hearts" should hold equal if not greater importance than sharpening the intellect in our educational systems to prepare students for a world riddled by both internal and external conflicts [2]. Within the context of engineering education, David E. Goldberg and Mark Somerville have asserted the importance of cultivating "a whole new engineer" who actively engages six minds – analytical, design, people, linguistic, embodied, and mindful – and whose potential is unlocked through five socio-cultural and emotional "pillars of transformation" – joy, trust, courage, openness, and connection [3]. These qualities then allow "a whole new engineer" to embody empathy, compassion and self-compassion, justice, and activism, as well as beauty, creativity, imagination, and intuition in their work [4].

Contemplative pedagogies, which are newly emerging in higher education, achieve these goals by creating opportunities for students to "become more aware of themselves, become

more conscious of the impact they have on the world … and connect their learning to their values and sense of meaning" [5]. Contemplation refers to thoughtful observation, reflection, consideration, or intention, sometimes associated with deeper awareness and sense of presence. As such, contemplative practices – individual, communal, internal, and external – allow for an emergence of deeper meaning of self and the world through the development of compassion, empathy, connectedness, and creativity. By integrating mind and body as well as experience and knowledge, contemplative pedagogies open new ways of knowing and being that go beyond 'third person' didactic approaches dominant in engineering and scientific training to 'first person' perspectives that incorporate mind, body, and heart. In doing so, these pedagogies explicitly bring in the socio-educational context and support students in finding meaning and connection to themselves, their peers, and the world around them through the "integrat[ion of their] own rich experiences into their learning" [6].

Today's scholarship on effectiveness of contemplative pedagogies demonstrates that they are supportive of and beneficial for all learners and promote more inclusive educational environments [7][8]. Specifically, contemplative practices allow for the co-creation of an educational paradigm that extends the Belenky *et al.* framework (1986) of "silence, received knowledge, subjective knowledge, procedural knowledge, and constructed knowledge" to include embodied and other ways of knowing and being [9]. In doing so, contemplative pedagogies create learning environments where all students' diverse ways of being and knowing are not only seen and accepted but also actively engaged. This renders the content "more accessible to [everyone and particularly to] women and underprivileged communities, [and] also help[s] cultivate citizenry for action and change" [10].

Despite these benefits, contemplative pedagogies have not been engaged much in STEM curricula. Apart from the reflective practice popularized by Donald Schön [11], we found little literature documenting the use of contemplative pedagogies or mindfulness in STEM. Venkatesh *et al*. (2020) recently reported on a new course for engineers that provided students with opportunities for self-discovery, personal growth, and examining science and engineering through their diverse ways of knowing and being [12]. In this Work-in-Progress Innovative Practice paper, we expand on that work to include descriptions and preliminary assessments of two undergraduate courses for engineers and to demonstrate that students in these courses develop compassion, self-compassion, and empathy in addition to the aforementioned outcomes. This is particularly important in today's engineering education where a lack of compassionate learning environments and engagement of diverse students' senses of self adversely impacts both students' current educational experiences as well the future they attempt to build.

II. Description of Innovative Practice

A. Context of Courses

The courses described in this paper were implemented at a small, private engineering college that embeds non-traditional learning throughout its curriculum. All students enrolled in the College select from one of three engineering majors and can choose their area of concentration within a given engineering major. As such, both courses described in this paper were designed for engineers and embed contemplative pedagogies as a way of creating inclusive learning environments that celebrate learners' ways of knowing and being within the context of engineering education.

The first course was implemented in-person in fall 2019 as one of the two options for a Physics foundation requirement. At the time, students had a choice of taking a self-standing physics foundation course or completing their physics foundation requirement by taking an integrated course block that engages multiple content areas. As a block, the physics requirement was usually completed by students by the beginning of their fourth semester at the College; however, a one-semester self-standing physics foundation option could have been taken at any point during a student's time at the College. As such, self-standing physics foundation courses did not have specific content that was critical for subsequent courses; instead, students were given an opportunity to engage with scientific ways of knowing while learning foundational content that may or may not have been explicitly leveraged in students' concurrent or subsequent studies. Therefore, the eighteen students (8 woman-identifying, 9 man-identifying, and 2 gender-fluid; 5 BIPOC) in this course ranged from second years to seniors, some of whom chose to enroll in a physics foundation course after they had completed most of their other engineering coursework.

The second course was implemented remotely in spring 2021 and was positioned as an intermediate-level Social Science elective. The ten students (6 woman-identifying, 4 man-identifying; 5 BIPOC) in this course also ranged from second years to seniors, including one "super" senior. Two of these were seniors (Environmental Science and English majors) cross-registered from a nearby college.

B. Course Goals

Both Innovative Practice courses described here aimed to (1) enable student engagement with STEM in a holistic and embodied way, particularly in its applications to collective and individual human experience, including considerations of ethics, social justice, and activism; (2) create opportunities for students to make sense of human experiences as embodied beings in the physical universe; (3) allow students to develop a capacity for deeper self-awareness and reflection while also developing as intrinsically motivated learners; and (4) create multiple iterative opportunities for students to utilize sophisticated and transferable critical thinking and problem-solving skills by engaging with problems that require an interdisciplinary and holistic perspective, including self-knowledge. The physics foundation course engaged additional goals that more explicitly tied to a scientific knowledge area of students' choosing.

C. Course Format

The courses leveraged a wide variety of contemplative practices ranging from generative (e.g., visualization, beholding), to creative (e.g., improvisation, journaling), to activist (volunteering, bearing witness), to movement (e.g., walking meditation, dance), to ritual (e.g., establishing personal spaces), to stillness (e.g., silent meditation, quieting mind) [7][13]. Both courses followed the same overall structure wherein the first half gave students an experiential

understanding of various contemplative practices and the second half was dedicated to supporting students in completing self-directed final projects. The two courses mainly differed in how and when students were introduced to certain contemplative practices because of the emergent co-creative nature of contemplative pedagogies, teaching team differences, and implementation between in-person and virtual formats.

Meditation and contemplative reading were essential parts of the course cadence. Students were introduced to loving kindness meditation in the first week and were encouraged to establish a regular meditation practice of at least 15 minutes a day. Each lesson began with a 5 to 10-minute guided meditation and a collective contemplative reading. These Readings were often, but not exclusively, drawn from Mark Nepo's *The Book of Awakening* [14] and were read aloud to the group by course community members—students, course assistants, and instructors—followed by a one-minute silent reflection. The combination of meditation and contemplative reading formed a group ritual for all participants and helped establish a sense of individual and collective presence for that day's activities.

Some of the examples of practices used in both courses are beholding and deep listening. Beholding is the act of taking the time to look at something and notice what we see, how it makes us feel, and how we connect with the object of observation, thereby "chang[ing] the ways in which we see the world, enhancing one of the primary means through which we interact with the world: sight" [7][15][16]. Deep listening is "a way of hearing in which we are fully present with what is happening in the moment without trying to control it or judge it" [7][17][18]. We also constructed learning opportunities for students to engage with movement and embodied explorations of space, time, momentum, stillness, and motion. In the Social Science course, which was taught remotely during COVID-19 pandemic, students explored these concepts through improvised movement in their own spaces while these were explored collectively in the in-person Physics foundation course [19][20].

Each week, students engaged with a carefully designed reflective assignment that built on the in-class activities and was guided by prompts and readings relevant to the week's experiences. This allowed students to become active co-creators of their learning experiences as they documented their cognitive and affective responses and growth in relation to their engagement with contemplative practices, both within and outside of class. As a teaching team, we responded to every student's reflection by sharing what emerged for us as we read through their submission, be that through asking questions of wonderment or sharing elements of resonance. Rather than reflecting the supposed "quality" of a students' submission, feedback was intended to let the student know they were witnessed in their growth through the semester.

For their final projects, students were invited to use the contemplative, sensory and experiential approaches that were most resonant with them in exploring topics of personal relevance or interest and sharing them with the class. Students had the option to complete this project individually or in pairs. During the Physics foundation course, some students chose to work in pairs and other chose to work individually; in the Social Science course, all students chose to work individually. In both courses, students were given full cognitive autonomy to choose the domain for their exploration so that they could select something that was personally meaningful to their goals, values, and identities. The format of the project deliverable was not specified to allow the students agency in choosing an output that was authentic to their ways of knowing and being and to the work that they had performed. As a result, some students shared the process they had taken in their projects and some shared artifacts that they had created, which included video documentaries, poetry, live and recorded performances, photo-ethnography related to the personal and scientific inquiry, websites, and musical compositions.

III. Assessment of Effectiveness

A. Assessment Data Collection and Analysis

For this Work-in-Progress Innovative Practice paper, we used the summative end-of-semester reflections, in which students were asked to reflect on the learning environment that they experienced, how it influenced their learning and selfhood development, and their growth towards achieving their personal and professional goals. We used thematic analysis [21] to assess the effectiveness of our innovative work.

B. Preliminary Assessment Findings

We identified four themes that typify students' experiences.

1) Contemplative pedagogies create a sense of trust and belonging. Students noted that the course learning environment provided a safe, nonjudgemental atmosphere and promoted student agency through the co-creation of experiences. One student captured this as follows:

> *I was able to focus on myself and not be concerned about judgement and lack of understanding. I was able to be driven by a space of intrinsic motivation and allow that to guide my learning and be myself in all ways. I was able to participate in things that stretched my education to be different.*

Another student further elaborated on the learning environment and its value in engineering education as follows:

> *This course was a space of love and understanding and being unashamed of the self which is an amazing thing to have in general especially at a university and engineering school...I was glad to be able to be a part of an experience that is challenging the machine system that education is and allow[ing] individuals to be individuals and support[ing] whatever that may mean.*

2) Contemplative pedagogies allow for the development of compassion, self-compassion and empathy, which students recognize is essential for their professions. Students reported on their newfound appreciation for the need for empathy and perspective-taking if engineering is to have positive impacts. One student captured this sentiment as follows:

> *Engineers need to be more than tech-smart, we need to be able to empathize and connect with the world, see it for what it truly is and be able to identify what solutions it truly needs. If we are [u]nstable in how we are connected to ourselves and those immediately around us, it will be virtually impossible for us to do it to the entire world. These lessons of understanding human experiences from different*

perspectives, empathizing with them and considering them in the decisions we make is what will set us apart as conscious and ethical engineers that add positive value to the world.

In addition, some students specifically articulated how contemplative practices allowed them to develop compassion and empathy. For example, one student said:

I think deep listening is an essential tool for being an engineer. We have to learn to listen, to understand things deeply and from multiple perspectives, and then approach the problem with all these things in mind.

Another student, who intends to be an educator, specified how contemplative practices have helped her develop self-compassion and the importance of that in her career:

The discipline of specific contemplative practices has really been helpful, helped train my brain in how to let go, wait, reserve judgement…It has taken my focus off of how do I best serve my students, and made me realize that the best way I serve my students is to nurture my heart, my compassion, my acceptance of myself, because in doing so, I will care for them more fully, I will be able to empathize despite the pain, and I will be operating, not out of reaction, but out of response to them in the present moment.

3) Contemplative pedagogies allow for personal growth and self-discovery. Almost all students highlighted personal growth as a meaningul outcome, though they described how this growth manifested in different ways. One student shared:

This semester, I have grown in self-confidence. I am able to appreciate myself for who I am, recognize my strengths and acknowledge my mistakes and weaknesses. I am also able to quickly identify ways to fix them and act on it.

Another student explained how a greater sense of self-knowledge improved their ability to learn:

Having a class which gave me the time, skills, and resources to grow as a person has been incredibly valuable towards improving my academic performance and confidence. Without a solid basis and sense of self, people are unable to properly engage with technical topics. I believe it is important that skills such as empathy, identity development, contemplation, mindfulness, and reflection are taught in the classroom.

Some students reported that this opportunity for self-discovery was rare in their formal engineering education. For example, once student said:

I gained new ways of exploring foreign concepts and better connected with my sense[s] and emotions. This newfound appreciation for the self is something that comes very rarely in an engineering education.

4) Contemplative pedagogies allowed students to reexamine science and engineering through the lenses of their diverse ways of knowing and being, thereby promoting interdisciplinary connections. One student, who reported that the course helped her understand "how to incorporate contemplative and creative practices into her future career" elaborated on this as follows:

Through photography, I aimed to practice contemplative art, in which I stood silently and tuned into and out of my senses…From that iterative process of looking and re-looking, I noticed that way the light changed from day to day and from hour to hour, and what times certain organisms were out. This project built upon my interest in ecology. It helped me develop an awareness of organisms and their environment in the contemplative way that a good naturalist has, and which I haven't developed as a student that has learned ecology through books and articles.

Another student explained how this learning environment enhanced their ability to see connections between disciplines:

My subconscious perception of science has become less siloed from those of other subjects and so I have become better at seeing the relevance of science where I would have missed it before.

IV. Discussion and Future Work

As we have demonstrated above and using Donald Schön's language, contemplative pedagogies benefit students' reflections and learning not only "on action" but also "in action" [11]. Current literature and our own praxis and preliminary research findings [12] demonstrate not only positive cognitive learning outcomes but also multiple positive non-cognitive gains. When reflecting on the ways students work toward goals in both courses, they often reported successes that were identified through the lens of their personalized journeys. Students in both courses shared their ability to be more aware of their individual and collective human experience as embodied beings in the physical universe and within the engineering education paradigm. Through their work, students demonstrated significant improvements in their ability and motivation to engage with reflection for deeper self-awareness, which then also provided opportunities to "sit with" their new understanding of self-compassion, compassion, and empathy. Students reported the need for learning environments that allow them to slow down and "be with what is" in comparison to the high energy and speed that their engineering education is otherwise.

Our next steps to build upon the preliminary assessment of our Innovative Practice presented in this paper include analysis of additional data sources for a multi-methods study. For this exploratory work on the effectiveness of contemplative pedagogies in STEM education, we will rely on qualitative methods to perform inductive work that establishes a theoretical framework for further quantitative and mixed-methods analyses.

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References

[1] V. Andreotti, S. Stein, R. Susa, C Ahenakew, E. Jimmy, D. D'Emilia, et al., "Gesturing towards decolonial futures." Gesturing Towards Decolonial Futures. https://decolonialfutures.net/ [accessed April 11, 2022]/

[2] A. Zajonc, "Love and knowledge: Recovering the heart of learning through contemplation," *Teachers College Record*, vol. 108, pp. 1742–1759, 2006. https://doi.org/10.1111/j.1467-9620.2006.00758.x

[3] D. E. Goldberg, and M. Somerville, A whole new engineer: The coming revolution in engineering education. Douglas, MI: ThreeJoy Associates, Inc., 2014.

[4] Big Beacon, "8 Steps to a Whole New Engineer." (Video, 2:26.) Oct 2014. https://www.youtube.com/watch?v=pVRO3nKWdLM [accessed January 15, 2022].

[5] Contemplative Pedagogy Network. 2020. "What is the contemplative pedagogy and the Contemplative Pedagogy Network?" https://www.contemplativelife.org/practice/contemplative-pedagogy-network/all/teaching-learning [accessed April 25, 2022]

[6] D. Barbezat and A. Pingree, "Contemplative pedagogy: The special role of teaching and learning centers," in To Improve the Academy, vol. 31, J. E. Groccia and L. Cruz, Eds. San Francisco, CA: Jossey-Bass, 2012, pp. 177–191.

[7] D. P. Barbezat and M. Bush, Contemplative Practices in Higher Education. San Francisco, CA: Jossey-Bass, 2014.

[8] A. Zajonc, "What is contemplative pedagogy?" in Contemplative Practices in Higher Education: A Handbook of Classroom Practices (Draft), 9. Northampton, MA: The Center for Contemplative Mind in Society, 2008.

[9] M. F. Belenky, B. Clinchy, N. R. Goldberger, and J. M. Tarule, Women's ways of knowing: The development of self, voice, and mind. New York, NY: Basic Books, 1986.

[10] H. N. Wilcox, "Embodied ways of knowing, pedagogies, and social justice: Inclusive science and beyond," NWSA Journal, vol. 21, no. 2, pp. 104-120, 2009.

[11] D. A. Schön, Educating the Reflective Practitioner: Toward a New Design for Teaching and Learning in the Professions. San Francisco, CA: Jossey-Bass, 1987.

[12] M. J. Venkatesh, D. Freeman, A. Fry, A. Hindelang, J. Bermejo, E. Berke, and Y. V. Zastavker, "Contemplative practices as a way of creating inclusive environments in engineering education: A story of one physics foundation experience for engineers." Proceedings of the 2020 ASEE Conference & Exposition, Montréal, Canada.

[13] M. Duerr and C. Bergman, "The tree of contemplative practices," The Center for the Contemplative Mind in Society. www.contempativemind.org/practices/tree [accessed April 18, 2022].

[14] M. Nepo, The book of awakening: Having the life you want by being present to the life you have. Boston, MA: Red Wheel/Weiser, 2000.

[15] CMind: The Center for Contemplative Mind in Society, "The Tree of Contemplative Practices: Beholding." https://www.contemplativemind.org/practices/tree/beholding [accessed January 6, 2022].

[16] P. G. Grossenbacher, and A. J. Rossi, "A Contemplative Approach to Teaching Observation Skills," *Journal of Contemplative Inquiry*, vol. 1, pp. 23-34, 2014.

[17] CMind: The Center for Contemplative Mind in Society, "The Tree of Contemplative Practices: Deep Listening." https://www.contemplativemind.org/practices/tree/deep-listening [accessed January 6, 2022].

[18] P. Oliveros, "Quantum Listening: From Practice to Theory to Practice Practice," *Fall 2000 Plenum Address for Humanities in the New Millennium, Chinese University*, Hong Kong, 2000.

[19] S. Foellmer, "Choreography as a Medium of Protest," *Dance Research Journal*, vol 43(3), pp. 58-69, 2016.

[20] A. Olsen, and C. McHose, *Bodystories: A guide to experiential anatomy*. Barrytown, N.Y: Barrytown, Ltd., 1998.

[21] B. Crabtree, Doing Qualitative Research. Newbury Park, CA: Sage, 1999.