Contemplative Practices as a Way of Creating Inclusive Environments in Engineering Education: A story of One Physics Foundation Experience for Engineers

Dr. Madhvi Jayalakshmi Venkatesh, Harvard Medical School; Prakriti Dance; Franklin W. Olin College of Engineering

Madhvi J. Venkatesh, Ph.D., is an educator, researcher, and dancer who is interested in how the skills and practices of different disciplines are interrelated and can be intertwined to cultivate holistic learning and wellness. She is a Co-Founder and Director of Education and Outreach at Prakriti Dance and currently holds appointments as a Lecturer and Associate Director of Graduate Education in the Department of Biological Chemistry and Molecular Pharmacology at Harvard Medical School and as a Visiting Scholar-in-Residence at Franklin W. Olin College of Engineering. At Harvard Medical School, Dr. Venkatesh works with faculty on improving the first-year PhD courses in molecular biology and biochemistry, trains teaching assistants, expands programming to build community among graduate students, and researches the best ways to train and assess PhD students in skills such as experimental design and science communication. Her other work includes contributing to dance performances that raise awareness about the human impacts on marine life and designing and researching a physics foundation course for engineers that embeds contemplative practices. All of Dr. Venkatesh's efforts are united by the goals of of enhancing engagement, inclusion, and personal/professional growth in science, technology, engineering and mathematics (STEM) education.

Dr. Yevgeniya V. Zastavker, Franklin W. Olin College of Engineering

Yevgeniya V. Zastavker, Ph.D., is an Associate Professor of Physics at Franklin W. Olin College of Engineering and a recent Director of the Research Institute for Experiential Learning Science at Northeastern University. She earned her B.S. degree in Physics from Yale University in 1995 and her Ph. D. degree in Biological Physics from MIT in 2001. Dr. Zastavker's research interests lie in the field of STEM education with specific emphasis on innovative pedagogical and curricular practices at the intersection with the issues of gender and diversity. With the goal of improving learning opportunities for all students and equipping faculty with the knowledge and skills necessary to create such opportunities, Dr. Zastavker's recent work involves questions pertaining to students' motivational attitudes and their learning journeys in a variety of educational environments. One of the founding faculty at Olin College, Dr. Zastavker has been engaged in development and implementation of project-based experiences in fields ranging from science to engineering and design to social sciences (e.g., Critical Reflective Writing; Teaching and Learning in Undergraduate Science and Engineering, etc.) All of these activities share a common goal of creating curricular and pedagogical structures as well as academic cultures that facilitate students' interests, motivation, and desire to persist in engineering. Through this work, outreach, and involvement in the community, Dr. Zastavker continues to focus on the issues of women and minorities in science/engineering.

Eleanor Berke, Boston Public Schools

Berke is interested in the ways that role play may cause the body to shift the mind building, empathy and perspective. She has used acting as a tool to cultivate empathy for the immigrant experience, to improve the bedside manner of new doctors and to help build a dialogue around consent and sexual assault. She attended the Lee Strasberg Theatre and Film Institute (NYC), HB Studios (NYC) and holds a Masters of the Arts in Education from the Harvard Graduate School of Education (HGSE). She has created dynamic theatre-based programming at the Lower East Side Tenement Museum and continues to act professionally, while teaching ESL full-time. Berke presented on her use of theatre-integrated language instruction at the International Colloquium on Languages, Culture, Identity in Schools and Society in Soria, Spain in 2019 and has led trainings for ESL teachers in the Boston Public Schools. She was a 2018 Manton Fellow at the Lincoln Center Summer Forum, focusing on integrating performing and visual art into elementary curriculum. In our current trying times, she is producing new plays through Zoom and co-hosting a weekly comedy show on Socially Distant Improv (Instagram Live).

Jimena Bermejo

Jimena is a as a movement artist who has moved away from the classical "rehearse-to-perform" paradigm of her dance training to include imperfections, to break the separation between audience and performer. She uses movement, text, and performance actions to experiment with this closeness. Her recent experimentation with technology such as live feed video allowed her to bring in other aspects of performance into her craft, which now also includes collaborations with other artists including musicians and other artists to challenge her own ideas and movement vocabulary. Jimena uses her own experiences, good and bad, including issues of race, trauma, growing up in Mexico in a family of artists, etc. to mirror and raise awareness to the world around us by observing and gauging art participants' responses and then using art to show the absurdity of some of the behaviors, stereotypes, and relationships in society.

Jimena Bermejo holds an MFA from Massachusetts College of Art and Design's Studio for Interrelated Media and a BFA in Dance from The Boston Conservatory. Most recently, she has shown her work at The Cathedral Arts Festival in Belfast, U. K, The Judson Church in NYC, Montserrat College of Art Gallery, Distillery Gallery in South Boston, Le Lieu in Quebec, 808 Gallery in Boston, Mobius Gallery, Green Street Studios and The Dance Complex in Cambridge. Jimena is currently a member of Mobius Artists Group performed with many other local choreographers. She is Director of the Dance Program at The College of the Holy Cross in Worcester and is currently faculty at Berklee College of Music, and The Massachusetts College of Art and Design.

David Freeman, Olin College of Engineering

I am a student who is motivated by love, justice, and honesty. While I currently attend Olin College of Engineering in eastern Massachusetts, my home is in Fayetteville, Arkansas, and it is from Arkansas that I will be streaming into the 2020 ASEE Virtual Conference. My heart pulls me more toward music and relationship than it does toward engineering but here I am; it'll all work out.

Ms. Abigail M Fry

Abby Fry is a third-year student at Olin College of Engineering majoring in Electrical and Computer Engineering.

Alex L Hindelang

Contemplative Practices as a Way of Creating Inclusive Environments in Engineering Education: A story of One Physics Foundation Experience for Engineers

Abstract

This Work-in-Progress paper describes a collaboration that aims to integrate art, teaching, learning, research and activist work through the union of four instructors, three undergraduate teaching assistants, and their seven unique ways of knowing that are grounded in our differences - ethnicity, cultures of origin, first language, education, artistic craft, age, class, gender, wisdom traditions. Together, we created an educational scaffolding for a new Physics Foundation offering that aimed to develop learners' capacity for deeper self-awareness and reflection. To achieve these goals, we used contemplative practices (e.g., sensory meditation and visualization, deep listening, beholding, contemplative movement, and critical reflection). Our work combined areas of interdisciplinary exploration in education that have, to our knowledge, previously remained isolated from one another. Throughout the course, we collected ethnographic notes during each class meeting. Other data sources included students' weekly reflective assignments. For the purposes of this work-in-progress study, we analyzed the final assignment where students reflected on the learning environment that they had experienced and how it had influenced them. Our preliminary findings demonstrate that this learning environment provided students with a scaffolded opportunity for self-discovery and personal growth through their diverse ways of being and knowing. Students found this type of experience to be personally significant and valuable, but otherwise absent in their engineering education. This paper serves as a call to engineering education community to engage with contemplative practices as a way of creating more inclusive learning environments for all of our students.

1. Introduction

This Work-in-Progress paper describes a collaboration that aims to integrate art, teaching, learning, research and activist work through the union of four instructors, three undergraduate teaching assistants, and their seven unique ways of knowing that are grounded in our differences - ethnicity, cultures of origin, first language, education, artistic craft, age, class, gender, wisdom traditions. This project brought together our differences to co-create a new educational paradigm for the students at a small engineering college by extending Belenke *et al*. (1986) framework of "silence, received knowledge, subjective knowledge, procedural knowledge, and constructed knowledge" to include embodied and other ways of knowing. Through this framework of more inclusive ways of knowing, we created learning opportunities for all students, particularly those underprivileged by current Western, male-centric pedagogical practices that divorce body from mind and experience from knowledge. By removing these dualisms through and within the learning experience we co-created, we worked with our students to "*render science more accessible to [everyone and particularly to] women and underprivileged communities, [and] also help cultivate citizenry for action and change*" (Wilcox, 2009).

More specifically, we created an educational scaffolding for a new Physics Foundation offering that aimed to develop learners' capacity for deeper self-awareness and reflection as well as engaged them in (1) considerations of interdisciplinary perspectives that transcend the boundaries between science, engineering, mathematics, liberal arts, and humanities; (2) growth

to become more aware of applications of physics/science to collective and individual human experience; (3) development of sense-making of human experiences as embodied beings in the physical universe (Krusberg & Ward, 2018); (4) reflection on themselves as learners with their unique ways of knowing; and (5) development of skills for open-ended learning environments, including life-long learning, communication, and teamwork.

To achieve these goals, we used contemplative practices (e.g., sensory meditation and visualization, deep listening, beholding, contemplative movement, and critical reflection) to co-create science learning through affective and embodied ways of knowing, thereby shifting learners' perception of what is known, how it is known, by whom, and with what tools. For example, as students participated in iterative kinesthetic model-building using their bodies as objects and subjects of scientific investigation, they "start[ed] to understand more viscerally what the structures are, and how some models are more robust than others" (Grabel *et al*., 2017).

Our work combines areas of interdisciplinary exploration in education that have, to our knowledge, previously remained isolated from one another; specifically, we employ contemplative practices including, but not limited to, embodying science/physics concepts, thereby using embodiment as a form of research and inquiry. Throughout the course, we collected ethnographic notes during each class meeting. Other data sources include students' weekly reflective assignments. For the purposes of this work-in-progress study, we analyzed the final assignment where students reflected on the learning environment that they experienced and how it influenced them. Our preliminary findings demonstrate that this learning environment provided students with a scaffolded opportunity for self-discovery and personal growth through their diverse ways of being and knowing. Students found this type of experience to be personally significant and valuable, but otherwise absent in their engineering education. This paper serves as a call to engineering education community to engage with contemplative practices as a way of creating more inclusive learning environments for all of our students.

2. Course Context and Research Methodology

2.1 Institutional Context

The site of this study is 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, which guides their area of concentration. Until this year, 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. Students were usually offered two different "flavors" of such a self-standing physics foundation – Classical Mechanics (usually offered in the Spring semester) or Electricity & Magnetism (usually offered in the Fall). As such, 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 students in the course ranged from first-years (for the Spring semester) to seniors, some of whom chose to enroll in a physics foundation course after they had completed most of their other engineering coursework.

Given the diversity of students' interests, motivations, experiences, values, and needs, we offered a new iteration of the course that (1) leverages a project-based learning paradigm to allow students cognitive autonomy and the ability to choose their focal content area – Mechanics, Electricity & Magnetism, or something else; and (2) embeds contemplative practices as a way of creating an inclusive learning environment celebrating learners' ways of knowing and being. Through the Mellon Foundation-supported program, the leading faculty member partnered with three local artist-educators in helping to design this offering. Together, the four instructors worked on conceptualizing a vision for the course that emphasized embodiment as a way of knowing, perspective-taking, reflection and reflexivity, identity development, empathy, vulnerability, and risk-taking. Three undergraduate teaching assistants also partnered with the four instructors to realize this course vision and bring it to the 18 students who took the course in Fall 2019. Data collection for a corresponding study was performed during the semester.

2.2 Course Description and Goals

The first half of the course was designed to give students a toolkit of various contemplative practices which they could then apply during their final projects (and possibly in other areas of their academic, professional, and personal lives). We introduced students to loving kindness meditation (LKM) in the first week and encouraged them to make this a regular daily practice with a recommended minimum time of at least 15 minutes a day. In preparation for class exercises, students engaged in selected readings about contemplative practices from Barbezat & Bush (2014) or other sources to provide context and framing for their experiences. Over a span of 8 weeks, students participated in different contemplative exercises during class time; these exercises included meditation, beholding, deep listening, layering, embodiment, and reflection. To build on in-class activities, students worked through carefully designed reflective exercises that allowed for documentation of their cognitive and affective responses, states, and growth related to what they were discovering through their engagement with contemplative exercises, both in and outside the class. This learning environment allowed students to become active co-creators of their learning experiences, as traditional expectations of accountability in academic systems were softened; it also enabled students to pursue the development that felt true to their personal and professional goals, values, and identities, while allowing the teaching team to bear witness.

The second half of the course consisted of self-directed projects that students completed individually or in pairs. Students were given full cognitive autonomy to select the cognitive domain for their exploration, whether or not it was traditionally taught as a physics foundation topic. These projects were intended to give students the time and space to utilize some or all of the contemplative practices they had learned in the first half of the course in exploring something that was personally meaningful to their goals, values, and identities. Similarly, the project deliverable was not prescribed, and students could choose to share their project journey in whatever way felt most authentic to their selfhoods and the work they had performed. As a result, some students spoke about the process they had taken in their projects and some shared

artifacts that they had created – video documentaries, poetry, live performances, photo-ethnography related to the personal and scientific inquiry, etc.

Through the combination of engaging students in contemplative practices and allowing them to realize projects of their own self-design, the teaching team hoped to accomplish the following course objectives:

- Elucidate the characteristic features of various physical systems using embodied ways of knowing;
- Apply basic notions of science/physics to new systems;
- Use empathy, compassion, vulnerability/openness, as well as risk- and perspective-taking practices to define "a problem" and explore the solution space;
- Use multiple contemplative practices (e.g., compassion and loving kindness, contemplative movement and embodiment, deep listening, beholding, sensory meditation and visualization, contemplative videography, critical reflective practice, etc.) to communicate a problem, its analysis, and solution;
- Implement self-directed learning strategies, including learning initiation (e.g., goal setting and selection of learning strategies), conduct of learning (e.g., management of time, resources, and motivation), and learning conclusion (e.g., self-reflection, self-assessment, and goal setting for next activities); and
- Implement teamwork practices to acquire higher competency.

Importantly, students were also asked to self-define their personal goals at the beginning of the semester so that they could personalize the learning experience to meet them. These personalized goals then served as a guide for the students' learning journeys through the course and were a critical point of reflection throughout the course, including the final reflective assignment.

2.3 Data Collection and Analysis

Data sources for the entire project incorporate ethnographic notes taken during each classroom session, videos of some of the activities (e.g., embodiment of current flow, mechanical machine, etc.), students' weekly reflective assignments, and a summative end-of-the-semester reflection. For the purposes of this Work-in-Progress paper, we analyze only the final assignment where students reflected 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. Thematic analysis (e.g., Crabtree, 1999) was used to identify preliminary themes presented in this paper.

3. Preliminary Findings

The following six sub-sections detail the six emergent themes that we identified through our preliminary analysis. Each theme is supported by evidence in the form of a typical quote found in students' summative reflections.

3.1 Student Perceptions of the Course Environment

Many students reflected on their opportunity to co-create their experiences in this class rather than the traditional expectation of meeting teaching team-defined standards. One student described the course as *"a sandbox to experiment with various forms of stimuli and techniques to refine learning and productivity with an emphasis on leveraging contemplative practice."*

Self-directed exploration was indeed a key design element within the course, particularly during the second half of the semester when students were focusing on their self-defined projects. Students appreciated the time and space to learn in a self-directed manner. One student captured this sentiment by saying:

> *I think this class fostered learning in a way not many classes do. There were infinite ways to be a part of this class and infinite things to learn, but the teaching team gave us the freedom to do and learn whatever we pleased as long as we were mindful.*

An essential part of creating this type of environment involved placing trust in students and creating a safe, nonjudgmental space for exploration and sharing. Another student explained the nature of the environment by saying:

> *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 really be myself in all ways. I was able to participate in things that stretched my education to be different.*

3.2 Evolution of Personal Goals over the Duration of the Course

The creation of a self-directed learning environment where students were invited to explore what was most meaningful to them required trusting students to define some of their own learning goals and providing them with a safe space to pursue these goals. As students' own self-perceptions evolved during the course, we encouraged them to revisit their learning goals and adjust them to ensure that they were exploring what felt most urgent and important to them at any given point in the course. Many students initially had set more technically-oriented personal goals or wanted to *"bridge the disciplines of contemplative practice and physics"*. Over the duration of the course, many of the students' personal goals evolved from having a more physics/engineering focus to being more focused on reflective practice, sensory awareness and their own personal development. For instance, one student explained the change as follows:

> *Initially, as I tried to bridge the disciplines of contemplative practice and physics, my goal was to leverage the tools of each discipline to enhance my experience in the other. Since then, I changed my learning goal to one around leveraging the lesser used senses of smell and taste to some end. Now, my goals have changed yet again. My newest learning goal is to learn about myself (through meta-reflective practice).*

A similar trajectory was narrated by another student:

> *At the beginning of this semester I was more worried about applying this course to physics and learning about how contemplative practices can be used in teaching*

science concepts in engineering. … during the semester these ideas and goals completely changed. I became less preoccupied [with] how [the content of this course] would transfer to the world and change my education and the ideas of physics and engineering. I began to focus on appreciating and really being in this course and learning what I could from the people, activities and time that we were together. I also shifted the focus to myself, to learning to care for myself more fully and spend some energy and time in this course focusing on how it can teach me about myself and I can use it to increase my comfort and happiness in myself.

As students progressed through their learning journeys in the course, the teaching team provided support for some students whose shifting goals were manifestations of shifting identities revealed during the self-discovery that they experienced in the course. This was particularly evident for students whose initial goals were motivated by external pressures and expectations rather than their own interests. One student explained the shift as follows:

I wanted to do something technically impressive for a portfolio and for my own self-image as an engineer, but accessible and contemplative for a layperson audience. Something like the demonstrations at museums or the educational youtube videos I watch. But I didn't actually want to do that. It fit my self-image of something I would want to do, but learning something technical on my own was something I was incredibly resistant to when it got down to picking a more specific project. My growth came first when I recognized that I didn't want to do something with a lot of calculation involved and I pick[ed] something enjoyable for myself instead. I was thinking about who I was as an engineer and wondering if I could be an engineer while not having anything technical on my portfolio, and I decided after talking with [Instructor] and my therapist and looking at what I like to do and what's out there, that I don't care, I'll just make a portfolio of what I actually do and then find a job that fits that.

3.3 Situation as a Physics Foundation Course

While students acknowledged the value of the course, a number of students did not feel that this course should be situated as a physics foundation course based on what they believed such a course should cover. In describing the course, one student said:

I think it can provide with new problem-solving skills but did not provide the concepts concretely nor any equations or applications that is necessary to learn to be successful as a mechanical engineer.

Indeed, based on the teaching team's objectives described in 2.2, this course's goals and objectives engaged student learning beyond specific content (or just content); thus, this course did not set out to fulfill the narrow definition of physics education that involves teaching formulas and theories. Given the strong bias towards this expectation, the same student even went as far as to say that the physics foundation label diminishes the value of what this course experience actually provided:

I think that labeling this course a physics class is a way to take away the value of what it is and make it try to fit something that it is not, this then also makes it so that outsiders will see it as not fulfilling what it claims.

Other students did not take such a strong stance against situating this course as a physics foundation, but expressed that the course did not match their expectations for what would be covered in such a course.

However, there were also students whose value systems and attitudes about what physics instruction may entail were more congruent with the teaching team's objectives. These students shared their appreciation for the ability to learn and interact with physics, and science more broadly, through different ways of knowing and being. For instance, one student stated:

> *I personally find that physically interacting with a concept rather than learning it only in theory can be extremely helpful.*

Another added:

> *I was able to explore a handful of scientific and technical concepts that had previously eluded me and demonstrate my knowledge in a medium that I had previously not employed (augmented reality!)*

In fact, the experience of engaging differently with scientific concepts in this course significantly changed one student's perception of science:

> *I became better at applying scientific concepts in situations that I normally would not have, while also becoming less blindly enamored by science as a tool. 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.*

3.4 Evolution of Reflections on Engineering Culture and Engineering Identity

Many students described profound changes in their view of engineering and their role as engineers over the course of the semester. For one student, this change was in the form of recognizing a multi-faceted complexity in engineering solutions:

> *My perception of engineering has changed a decent amount since starting this class. I've always seen math/science/engineering as fields where you can only be right or wrong. Especially in engineering, I began to see that when you take time to contemplate your problems, there are often multiple viable solutions or paths.*

For multiple other students, the change in their view of engineering related more to the importance of empathy and taking the time to understand problems through deep listening and acknowledging multiple perspectives. One student explained her new perception of engineering as follows:

> *Engineering is by people for people. We should be mindful when approaching a problem of all the nuances we don't understand. Engineers often see a problem in its simplest terms and "fix" it without understanding what the issue really is or if it [i]s an issue at all. 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 expressed similar sentiments about the need for empathy and perspective taking for engineering to have positive impacts:

> *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.*

Perhaps the strongest statement about the need for empathy and reflection in engineering came from a student who asserted that these were the tools that could prevent engineering from perpetuating deeply entrenched systems of discrimination in society:

> *When working on projects in a constant go-go-go mode, it is easy to forget how it affects people and communities. This leads to the perpetuation of sexism, racism, and societal influences throughout engineered products and services. This can be seen through the racism and sexism inherent to many models used widely throughout engineering; such as facial recognition models. Only through slowing down and using reflection as a tool of empathy, can we work to undo these negative societal forces.*

This student's statement aptly sums up the importance of engaging engineering students in contemplative practices such as deep listening and reflection to help them develop into socially responsible and ethical engineers.

Some of the students who said that their views on engineering did not change often already held strong views about the human side of engineering and how engineering should be used purposefully and ethically. These students found hope in the fact that many of their colleagues in this course had now come to adopt this view of engineering. One of these students shared:

> *I am now a little more hopeful that other people will come to see engineering as this powerful tool for good but also a thing to be handled carefully. I think that engineering can be so small and it should really be a thing to be used to improve the lives of others and the environment and should be more about the purpose than the making. I think that engineering in general and [the College] has a bit of a "lets just make stuff" mentality – and although I think learning from doing is so so powerful, I think that there is a more responsible and ethical way to do this. I have always felt this way, extremely driven by the people I will be working with and making the world a better place and I find that even at [the College] this is lost among students and I hope that with courses like this we can bring engineering to really be what I feel it should be.*

3.5 Self-Discovery and Personal Growth

In reflecting on their experience with the course, all students highlighted personal growth as a meaningful outcome and one that they would take with them into other parts of their life. Depending on where students were in their own personal journeys, their descriptions of personal growth manifested in slightly different ways.

Many students emphasized their own self-discovery in examining their own strengths, weaknesses and beliefs. For instance, one student explained:

> *I cannot overstate how valuable this course has been to me and how well the activities were laid out to help me figure out… myself. 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.*

This same student went on to describe how her personal gains can also improve her capacity to relate to others professionally:

> *I feel like these skills will continue to help me in the professional world as I handle the many stresses of working in teams, interacting with colleagues, making decisions, and hopefully performing and existing to my fullest potential and satisfaction.*

In fact, many students described an improved capacity to relate to others as a result of developing empathy and open-mindedness. One student elaborated on this as follows:

> *I think I gained a better understanding for people in general: underneath their everyday appearance, performance, accomplishments and expression, how are they really doing? How are they really feeling? What are they really coping with? The answer, I now strongly believe, is far more complex and much heavier than some people tend to assume. It's easy to idolize people who do impressive things; similarly, it's easy to judge people who seem like they're not actually doing their best or doing "enough".*

Considering that an increased self-awareness serves as a foundation for relating to others, students' descriptions of increased empathy and open-mindedness often followed as a logical extension of their own self-discovery. This seemed to be the case even when the process of growth was challenging or uncomfortable. As one student related:

> *I have finally progressed to the point where I can be vulnerable enough with my own sense of self to acknowledge, accept, and incorporate how subjective my ontological perceptions will always be. Doing so will mean living with the dysphoria of never having the same security in my worldview, but that comes in exchange for being a more open-minded, honest, and ultimately empathetic person in the world, which I think will be more than worth it.*

A few students were also explicit in the impact of their improved sense of self on their learning capacity. One student described the course as a *"learning foundation class"* because applying contemplative practices improved this student's ability to learn. Another student elaborated on this connection by explaining that self-knowledge was a prerequisite for fully being able to learn technical content:

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.

3.6 Role of this Learning Experience in (Engineering) Higher Education

Despite the immense value that students found in participating in this learning experience, multiple students said that such transformational opportunities to develop self-awareness were typically absent in engineering education and rare throughout the entire educational system. One student reflected on the novelty of the experience by saying:

In my whole time in formal education, I have never had a class which asked me to be contemplative, mindful, and reflective upon myself.

Another student added:

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.

The value and the unique place of this type of experience in the higher education system is best summed up in yet another student's words:

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. I hope that this course will be integrated in some way at [the College], perhaps as a part of other courses and reshape the idea of reflection to be more meaningful in courses. I think it was a moment of "finally some real self-reflection and self-improvement and self-love" in this … college experience. I feel as though the courses which "listen" to users or employ reflection are often very surface level and it is not really about the genuine part as much, the really being. I hope that also these concepts can bring more support to individuals, I think the education system (including [the College] – even if it is better) is so flawed. It is a space where folks are pressured so much by negative motivation and forced to fit a mold and I really want this course to challenge that system and to grow to make [the College] better at being open and allowing students to be individuals and grow into adults that are self-reflective and genuine to their self and hopefully, in the long run, happy and intrinsically motivated.

4. Discussion and Future Work

Our findings indicate that we were able to create a unique environment where students were empowered to direct their own learning. This nonjudgmental, supportive learning environment allowed students the space and time to explore and reflect in a way that was transformative for them. Many students embraced self-discovery and personal growth over the course of the semester in ways that were specific to each individual. As they evolved through the course of the semester, many redefined personal goals, increased self-awareness, and adopted a broader, more multi-dimensional view of engineering. This was reflected in a greater awareness of empathy and perspective-taking as an essential part of ethical and socially responsible engineering. This emphasizes the importance of employing contemplative practices as a part of training engineers for the complex, interconnected, diverse world in which they will work. The fact that many students noted that they had never before participated in such a learning environment further highlights the importance and urgency of this work.

Our ongoing and future work will involve qualitative analysis of the ethnographic notes collected during every class meeting and all of the written reflections that students submitted throughout the semester. Additionally, we will conduct post-experience interviews with students to further shed light on the impacts that participating in this learning experience had on their views of themselves and their relationships to the world, the learning process, and the engineering discipline. Ultimately, we hope that our ongoing efforts to collect and analyze more qualitative data can further elucidate the transformative power that contemplative learning environments can have on engineering education, and more generally, on the entire higher education paradigm. However, even these initial findings indicate the value of contemplative practices in creating more diverse and inclusive learning environments that personalize students' learning, allow for growth of selfhoods, and promote students' affective development in addition to achieving relevant cognitive outcomes.

Acknowledgements

The authors would like to acknowledge the institutional funding and the Mellon-supported program that partially supported this work.

References

Bagley, Carl, & Cancienne, Mary Beth. (2001). Educational Research and Intertextual Forms of (Re)Presentation: The Case for Dancing the Data. *Qualitative Inquiry*, Vol. 7, No. 2, pp. 221–237.

Barbezat, Daniel P., & Bush, Mirabai. (2014). Contemplative Practices in Higher Education. San Francisco, CA: Jossey-Bass.

Barbour, Karen N. (2002). Embodied ways of knowing. Women's solo contemporary dance in Aotearoa, New Zealand. Unpublished doctoral thesis. The University of Waikato, Hamilton, New Zealand.

Barbour, Karen N. (2004). Embodied Ways of Knowing. *Waikato Journal of Education.* Vol. 10, pp. 227-238.

Belenky, Mary F., Clinchy, Blythe, Goldberger, Nancy R., & Tarule, Jill M. (1986). Women's ways of knowing: The development of self, voice, and mind. New York, NY, US: Basic Books.

Cancienne, Mary Beth, & Snowber, Celeste N. (2003). Writing Rhythm: Movement as Method. *Qualitative Inquiry*, Vol. 9, No. 22, pp. 237–253.

Crabtree, B (1999). *Doing Qualitative Research*. Newbury Park, CA: Sage.

Grabel, Laura, Weir, Michael, Appel, Laurel F., Johnson, Elizabeth, McCarthy, Richard, & Lerman, Liz. (2017). Science Choreography: A Movement-Based Approach to Biology Teaching. *CBE-Life Sciences Education*, Vol. 12, No. 4.

Krusberg, Zosia, & Ward, Meredith. (2018). Classical physics and human embodiment: The role of contemplative practice in integrating formal theory and personal experience in the undergraduate physics curriculum. *The Journal of Contemplative Inquiry*. Vol. 5, No. 1. pp. 87-106

Myers, Natasha. (2012). Dance your PhD: Embodied animations, body experiments, and the affective entanglements of life science research. *Body & Society*. Vol. 18, No. 1, pp. 151-189.

Wilcox, Hui Niu. (2009). Embodied Ways of Knowing, Pedagogies, and Social Justice: Inclusive Science and Beyond. *NWSA Journa*l, Vol. 21, No. 2, pp. 104-120.