AC 2011-2825: UNLOCKING THE HEART OF ENGINEERING GRAND CHALLENGES: LISTENING TO THE QUIET VOICES

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Unlocking the Heart of Engineering Grand Challenges: Listening to the Quiet Voices

I. Introduction

The National Academy of Engineering listed a series of Grand Challenges for Engineering during this past year.[1] The challenges ranged from making solar energy economical to providing access to clean water to re-engineering the brain to list just a few. Surely, it may be difficult to find many who would find reason to disagree with the identification of any of these topics for both present and future engineers. Rather than object to what is included, I would like to raise the issue of what has been neglected on this list and far too often in engineering – listening to the quiet voices that speak from within each of us, from our heart. I am suggesting this act of listening as one additional entry for this most important list.

In my view, our profession does not encourage very well stopping and listening to each other, to life around us or even to ourselves. This is a skill that given our pace of our modern society, technological advances and our cultural conditioning, must be cultivated for it surely will either develop or quickly wither away. The question at hand then becomes how might we cultivate the ability to stop and to listen? The present work offers a description of one such path, though clearly there are countless others. The path chosen is one based upon an adaptation of a contemplative pedagogy.

II. Contemplative Pedagogy

One approach to developing the ability to slow down and to listen can be found in what is referred to as contemplative pedagogy. One of the most powerful transformative interventions developed by humanity is contemplative practice or meditation.[2] It has been specifically designed to move human cognition from a view of reality from separateness and dualism to a one in which the interconnectedness of reality is directly perceived. Contemplative practice works on the human psyche to shape attention into a far suppler instrument, one that can appreciate a wide range of worldviews and even sustain the paradoxes of life, ultimately drawing life's complexity into a gentle, non-judgmental awareness.

Educators at hundreds of North American universities and colleges are increasingly appreciating the usefulness of secular contemplative practice.[3] At conferences and summer schools at Columbia University and Amherst College and elsewhere for example, professors have gathered

to share their experiences in the emerging area of contemplative pedagogy. Their efforts range from simple silence at the start of class to exercises that school attention; and most recently, to innovative contemplative practices that relate directly to course content.

Jon Kabat-Zinn[4] has spoken about the unification of knowing through contemplation, reminding us both how available mindfulness is, but also how difficult it can be to bring full awareness to the entirety of life. According to Zajonc,[5] the curricula offered by our institutions of higher education have largely neglected this central, if profoundly difficult task of learning to love, which is also the task of learning to live in true peace and harmony with others and with nature. He adds,

> "We are well-practiced at educating the mind for critical reasoning, critical writing, and critical speaking, as well as for scientific and quantitative analysis. But is this sufficient? In a world beset with conflicts, internal as well as external, isn't it of equal if not greater importance to balance the sharpening of our intellects with the systematic cultivation of our hearts? Do not the issues of social justice, the environment, and peace education all demand greater attention and a more central place in our universities and colleges?"

Marilyn Nelson[6] has relayed the story of teaching silence to those whose lives take them into war and conflict. Nelson added that, contemplative pedagogy does not involve teaching a technique. Rather it is teaching an "attitude [of openness to explore] the several ways in which listening can occur and how one can listen *for* and *to* silence."

Contemplative practices quiet the mind in order to cultivate a personal capacity for deep concentration and insight. Examples of contemplative practice include not only sitting in silence but also many forms of single-minded concentration including meditation, contemplative prayer, mindful walking, focused experiences in nature, yoga and other contemporary physical or artistic practices. The concept of contemplative practice is as old as the world's religions. Every major religious tradition includes forms of contemplative practice, such as prayer, meditation, and silent time in nature. Many practices remain rooted in their religions, and others have grown in secular settings.

III. Contemplative Inquiry

One example of a contemplative practice is contemplative inquiry. Zajonc suggests the practice of contemplative inquiry as an essential modality of study complementary to the dominant analytic methods now practiced in every field.[7] Zajonc further argues that "such inquiry is at the true heart of higher education" and is an expression of the "epistemology of love" wherein epistemology refers to a theory of knowledge or, in other words, how we know what we know.

To describe the method of contemplative inquiry, Zajonc delineates seven stages in this epistemology. (Figure 1)

In the first stage, respect, we may ask if in fact we respect the integrity of the subject of our study. Do we respect the other, be it a river, the Earth's atmosphere or oceans, our employers, our clients, the societies and cultures in which our technological advances impact? Rilke suggested that when we truly respect the other, we "border and protect them" as we seek to know and understand them better.[8] I wonder in engineering how often we introduce this concept of respect into our classrooms. Perhaps in engineering design we might but rarely in other engineering courses. Gentleness, or according to Goethe[9], "gentle empiricism," lies in stark contrast to the scientific method of the Age of Science or Enlightenment. Rather than Bacon's instruction of "putting nature on the rack," gentleness suggests approaching the object of our attention without distortion. Intimacy, the third stage, calls upon us to forgo the notion of disengaged science for the sake of objectivity but rather to approach the object of our attention with delicateness and respect. As quantum mechanics suggests, the notion of separateness of subject and object is misleading at best. According to Parker and Zajonc, "We can still maintain clarity and balanced judgment close-up if we remember to exercise restraint and gentleness."[10] Vulnerability challenges us to put aside a dominating arrogance and to learn to be comfortable with not knowing, with uncertainty and with ambiguity. Participation asks us to join with the other while maintaining full awareness and clarity of mind or in Emerson's words, "the intellect being where and what it sees."[11] Transformation requires that we are transformed by the experience, that is, what was outside is now inside. We are shaped or developed or sculpted by the experience. Imaginative insight can be once again described most eloquently by Goethe who likened imaginative insight to the formation of a new organ: "Every object well-contemplated opens a new organ of perception in us."[12]

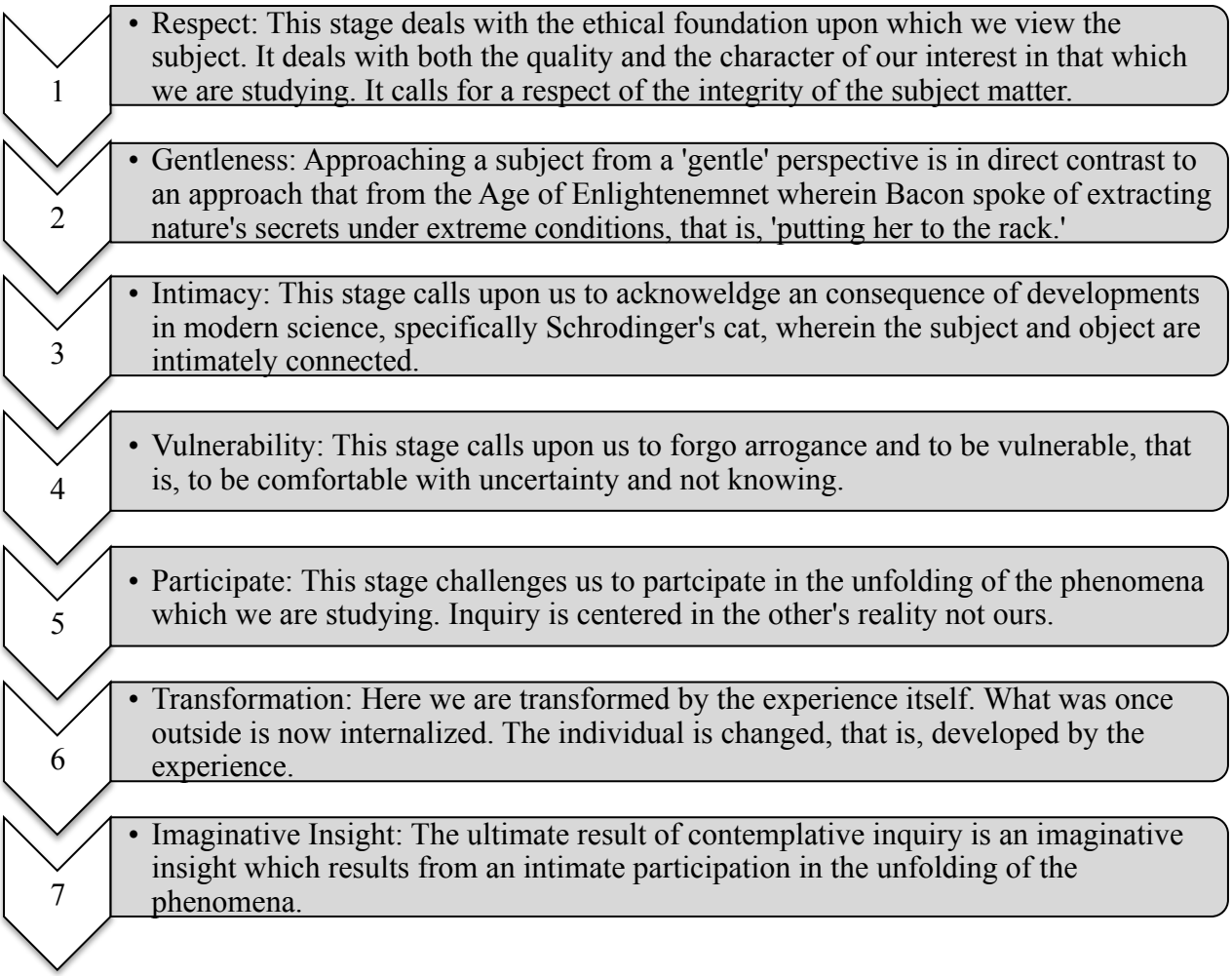

Figure 1 Seven Stages of Contemplative Inquiry

The next section of the present work will detail how the method of contemplative inquiry will be utilized in an undergraduate engineering science course. The course chosen is one in fluid mechanics, in this case, in a bioengineering program, but it is merely meant to be an illustrative example of how such pedagogy might be used.

IV. Application to Engineering Science Course: Fluid Mechanics of Living Systems

As an illustrative example, the method of contemplative inquiry is developed for an undergraduate engineering course in fluid mechanics in our bioengineering program. From the outset, students may be told that the fluids course is going to be taught using a different paradigm then perhaps they had experienced previously in engineering. The ultimate goal for the course is given to them as the development of that imaginative insight, that quality of understanding that

describes “the creative insight which each scientist, scholar and artist recognizes as the axis around which their work turns but which cannot be produced upon demand.”[13] That is all that may be offered about this mysterious goal though it can again be brought back to their attention throughout the semester.

The writing strategies Nelson[14] utilized in her course she taught at West Point included: “journaling, which focuses and complements the meditation experience; free-writing, which comes close to recording ‘inner speech’; and clustering, which taps into the creative, intuitive, right-brain function that lies at the core of meditation.” Each of these strategies will be adapted for the bioengineering fluids course. A regular class session would include five minutes of meditation at the beginning of each class meeting; fifteen minutes of daily meditation outside of class; journaling; and various writing exercises. Each class period will begin and end with a moment of quiet contemplation. Various techniques are available from my simply standing quietly in front of the classroom to the recitation of a mantra to a ringing of a bell and a calling for undivided attention to some object at the front of the room. I muse about how much easier my teachers had in my high school – a Roman Catholic college preparatory school taught by strict Christian Brothers in long, flowing and intimidating black robes! There, each class hour started with an invocation to the divine mystery and a remembrance of the patron saint of that particular order.

My intention is to begin with a meditative practice borrowing from the practice of yoga. The immediate response will likely be a combination of shock, disbelief and laughter but gradually as each day passes, my hope and suspicion is that the immediate reaction will be slowly replaced by many more thoughtful looks and much less time passing before quiet and order are present.

Insight, or as it is also referred to as *Vipassana* meditation, is a simple form of Buddhist meditation that calms and concentrates the mind.[15] The practice originated with the Buddha over 2,500 years ago. In the form offered here, the practice starts with learning to keep one’s attention on the breath. This is a form of concentration practice. The course progresses through mindfulness practices, such as noticing the body, the feelings, one's thoughts and one's life patterns. As the practice continues, one learns to be more present in the moment.

This practice is a meditation practice and not a religious system of belief. As an introduction for students to the practice of meditation, five different techniques are presented which include:

- Mindfulness of breathing
- Mindfulness of the body
- Mindfulness of feelings
- Mindfulness of the mind
- Mindfulness of patterns[16]

These different techniques will be presented during the first five weeks of the class. Subsequently, students will be asked to mediate upon the following subject matter, each of some considerable relevance to the course:

- As the course is focused upon the flow of fluids, it is easy to make connections among the flows in pipes as observed by Reynolds[17] in 1895, the flow of oxygen in our respiratory systems including our lungs as well as the lungs of other living animals, and the flow of blood in our arteries and our veins as well as those same flows in other living creatures.[18] Further, similar analytical ideas will be extended to the flow of sap in trees. Students will be asked then to meditate on the flow of air in their respiratory systems, the flow of blood in their cardiovascular systems and the slow movement of sap in the majestic sugar maple trees that inhabit our region of the country.
- After some preliminary development in class, we shall focus upon the lift and drag characteristics of single birds and migratory flocks of birds discussing similarities and differences between the low speed aerodynamics of our technological world to that of the natural world.[19,20] Students will be asked then to meditate on the migrations that occur throughout the year as native birds deal with the changing weather patterns we experience throughout the year.
- Comparisons between laminar fluid mechanics and turbulent fluid mechanics will be made. The closure problem and its implications in engineering will be considered. Focus will be placed on the uncertainty that surrounds turbulent flow fields such as those encountered in the flow of blood in the human heart. Somewhat unexpectedly, the lack of turbulence in the heart indicates a weakened heart in a seriously weakened condition. Students will be asked then to meditate on the flow of blood in their bodies both through the pumping action of the heart and the cleansing action of the kidneys.
- Emphasize how accounting and conservation equations are used to derive familiar laws, such as Kirchhoff's current and voltage laws, Newton's laws of motions, Bernoulli's equation, and others.[21] Extensive examples that span the breadth of modern bioengineering, including physiology, biochemistry, tissue engineering, biotechnology, and instrumentation shall each be a focus of a weekly meditation.

V. Proposed Research Outline

The research question for this particular effort is the following:

> "Do students develop a deeper understanding of the course material when presented concepts in an environment incorporating a contemplative pedagogy?"

In response to the proposed integration of meditation and other contemplative activities into the course, a socio-cultural theory offered by Cole and Engstrom[22] shall be used as the theoretical

framework for the study. Vygotsky conceived socio-cultural theory[23] in the early 1920's. It emphasizes the central role of social relationships and culturally constructed artifacts in organizing thinking. It attempts to theorize and provide methodological tools for investigating higher cognitive processes by which social, cultural and historical factors shape human functioning. Cole and Engstrom's model provides several dimensions along which one can study the classroom as an activity system. They identify factors, other than the subject matter or students or teachers, which must be taken into account when trying to understand how knowledge is distributed within a system. These factors include the curriculum and language use, rules, community.

A mixed methods approach[24] will be taken in assessing the results. This approach involves the collection and/or analysis of both quantitative and qualitative data, which seems particularly relevant for the proposed work. A key feature of mixed methods research is its methodological pluralism or eclecticism, which frequently results in superior research (compared to mono-method research).

VI. Final Thoughts

Let me attempt to tie the proposed course and its teaching back to the Grand Challenges of Engineering as described by the National Academy. The Academy states in its Declaration of Principles:

> "The profession of engineering has been, true to its Latin root *ingeniare*, about invention. For the past one hundred years, about as long as most college of engineering programs have existed, the list of the most important engineering achievements is dominated by devices: planes and spacecraft, cars and agricultural machines, lasers and PET scanners, to name a few from the National Academy of Engineering report of the last century. Almost a decade into the new century, another NAE committee has addressed the new engineering grand challenges and come to a much deeper unfolding of invention: Their list includes making solar energy economical, preventing nuclear terror, advancing health informatics, clean water and reverse engineering the human brain. None of them are just devices. Nearly all address complex social issues that require innovative technology and systems approach to solve but cannot be solved in a vacuum. They will also require engineers to shape public policy, transfer technical innovation to the market place, and to inform and be informed by social science and the humanities. These are challenges to 'change the world,' and many of them are inherently global."

In a 1993 talk at Berea College, Parker Palmer[25] pointed out that "every way of knowing becomes a way of living, every epistemology becomes an ethic." He argued that the current epistemology has spawned an associated ethic of violence. Surely, science (and engineering) has brought enormous advances, but we cannot turn away from the central fact that the modern

emphasis on objectification predisposes us to an instrumental and manipulative way of being in the world. As Parker suggested, knowing does, indeed, grow into a way of living. The implications of this position are important in light of our work as engineers. It is not calling for a rollback of science and engineering but rather a resituating it within a greater vision of what knowing and living are really all about. That re-imagination of knowing will have deep consequences for education, consequences that give a prominent place to contemplative pedagogies.

Ultimately the question becomes what is the necessary business of education in general and engineering education specifically? Postman and Weingartner[26] offer the following set of questions and ideas: "Is it to create eager consumers? To transmit the dead ideas, values, metaphors and information of three minutes ago? To create smoothly functioning bureaucrats? These aims are truly subversive as they undermine our chances of survival…we would like to see the schools go into the anti-entropy business. Now that is subversive, too. But the purpose is to subvert attitudes and beliefs and assumptions that foster chaos and uselessness."

I began the present work with a call for an integration of the skill of listening and of stopping or at least slowing down in the teaching of engineering. I have offered one idea or path as to how such a skill might be included in a specific course, that being, an undergraduate fluid mechanics course in a bioengineering curriculum. The approach will include frequent and constant integration of meditation and other described techniques as well as a conscious effort to make connections among the subject matter and in this case, the fluid mechanics of living systems. A research question is offered as is a theoretical foundation and methodology. If successful, that is, understanding is increased and can be documented; I shall integrate the contemplative pedagogy in all of my teaching. Maybe I can create a bit of anti-entropy. I encourage others among us to also consider the idea.

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