**Science Education in the Key of Gentle Empiricism**

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Let’s begin this thinking about science education at the beginning: with the very meaning of “science education.” Science education may mean instructing in or learning about scientific information, knowledge, and methods in various disciplines. The goal here would be to equip our students with requisite knowledge and skills to become scientists, technicians, and science and technology educators. Our current system of science education is replete with this way of teaching science. And we need this form of education to cultivate future generations of scientists, technicians, and workers in science-related careers.

Science education may also mean educating people to have ways of understanding and approaching the world with worldviews based in or influenced by science. When our school children protest to us that they are not going to become scientists or technicians and so they don’t want to and don’t need to study science, we might appeal to this second meaning and tell them that for them to function in today’s world, they have to have a certain level of scientific knowledge and understanding of the scientific method. If they press us further and ask us why we have to know science to function in today’s world, we will point to the degree to which the construction of our world depends on science and technology. These responses on our part would constitute a justification for not only including science and technology education but also underlying its central importance.

Now comes the troubling part. What if our students, well trained to ask critical questions, ask us this question: “So, you say that in today’s world everything is constructed by the modern scientific knowledge and technologies. But look how terribly troubled the world is today. You have been, in fact, telling us that according to many scientists, our world may not continue and cannot be sustained beyond the next few decades, at the rate we humans are consuming and destroying the world. If modern science and technology are what constructed such a world, then why should we continue to study them?” What would be our answer? “Oh, come on! Stop trying to avoid studying science. That won’t get you far.” Or, “Back to your work! Don’t ask such silly questions!” Or, “Your mom and dad want you to be successful, and for that, you need to study science (and math, etc.).” Answers such as these do not address the serious point raised by our students. However, our chapter shall do just that.

The starting point of our discussion on science education is the acknowledgment that science is a human enterprise. What does that mean? It means that what we think science should be bear our metaphysical (literally, going beyond the physical) assumptions about the world: what the world looks like to us humans or how it might look differently when we adopt a different lens of understanding and investigation, and what we value or ought to value. This is apparent when we examine the history of science. Historians and philosophers of science would readily confirm this. Even just in the history of Western civilization, we can point to a diverse set of scientific worldviews, closely aligned with or based on ontological or metaphysical and epistemological views of the world (Pepper, 1970). Moreover, when we add such views from other civilizations, we have a cornucopia of scientific worldviews, notwithstanding the debate, sometimes violent, about which ones are true of reality. We shall also note that our general tendency is to discredit the scientific views of other cultures, especially from the distant times, as untrue. Our main point of making these observations here is to emphasize that science is not independent from human values and views, commitments, sensibilities, aspirations and tastes of a given culture and people.

Of particular interest to us (the authors of this chapter) are the exploitative and even violent views, attitudes, and resulting conduct that define humans’ power relationship of domination over nature, integral to the West’s Enlightenment and Renaissance preceding it and Modernity proceeding it (Merchant, 2008). A central figure in this way of thinking about the relationship between nature and humanity is Francis Bacon who “invented” the modern scientific method of experiment that is the hallmark of empirical research to this day. Merchant states: “Distributed among many of Bacon’s works and often reappearing in slightly altered phraseology, these terms [such as, ‘penetrate,’ ‘shake,’ ‘shape,’ ‘squeeze,’ ‘subdue,’ ‘wrest,’ etc.] all connote some degree of violence toward nature” (p. 749). For emphasis, let us repeat: violence toward nature is built into the foundation of modern experimental science. So normalized is this understanding that we take it for granted and we think nothing of it. How else do we do science?

The question of ‘ought’ is always a wake-up call for the mind that thinks descriptively as in “that’s how it is,” or “that’s how it goes and how it’s done.” A master car thief may teach his apprentice, “Let me show you; this is how you steal a car.” The apprentice, suddenly waking up from her trance, may ask herself, “Wait a minute. *Should* I be stealing cars? *Ought* I continue to live a life of crime?” Similarly, many thoughtful people since Bacon’s time woke up from the Baconian trance and have been asking: *Ought* we think of nature as a female that needs to be “penetrated,” “squeezed” and so on to have “her” yield, give up “her secrets”? Secrets that will enable us to manipulate, alter, further violate “her”?

Equally disturbing is the reduction of nature to the order of the inanimate. In recent decades, many thinkers (e.g., Erazim Kohak and R. D. Laing) from diverse but interconnected fields of philosophy, psychology, ecology, and health have all spoken about contemporary humanity living out the worldview of the mechanical universe that the 17th century Western philosophers like Thomas Hobbs and Rene Descartes championed. If the universe, including our planet, is basically made up of inanimate matter (“stuffs”), then there is nothing that would prevent us from hacking and destroying it to satisfy our insatiable desires for consumable goods and services.

The role of science, however, goes deeper than supporting the enactment of the mechanical universe. The process of rendering the universe to the order of the inanimate could not be accomplished without simultaneously numbing our psyche so that we don’t feel the pain of snuffing life out of the animate universe. Neil Evernden (1993) speaks of the practice in which lab scientists would cut the vocal cord of animals that they were vivisecting, for the pain of hearing the animals howling in pain is extremely disturbing. By shutting down our senses and sensibility, we dehumanize our selves; for, it’s only in hearing, seeing, and feeling the pain of others that our empathy and compassion are exercised. With all this in mind, we may continue to consider how contemporary science education in North America (and all over the world as the modernist worldview has spread globally) plays a vital two-fold role of continuing to render the world to be an order of the inanimate and simultaneously accomplishing psychic numbing and, hence, dehumanizing. And, against this backdrop of considerations, we may also re-envision a science that heals our psychic numbing and releases us from the practice of dehumanization.

**Science that Heals: The Goethean Approach**

The gift of postmodernism – the era we have been in for the last few decades – is its massive questioning of the *grand narrative* and replacing it with many narratives. Monologue is being replaced with dialogue; fundamentalism, by pluralism; hierarchical ordering by rhizomatic networking, and so on. As part of this invitation to seeing in multiplicity and ecological complexity, we can also entertain different paradigms of science. Since, as we saw earlier, our interest in doing science differently ultimately stems from ethical values, such as wanting to see less suffering and more flourishing, less pain and more joy, and in general more support for all beings and their wellbeing, we are searching for a science that heals and vivifies all beings, including, of course, human beings. It is in this context that we would like to introduce the Goethean “gentle empiricism,” zarte Empirie.

Johann Wolfgang von Goethe was a celebrated writer, statesman, and scientist, and prospered during the Romantic era where holism, wonder, science and philosophy could belong to a single discipline (Richards, 2002). He wrote poetry and prose, inspired morphology as a new scientific discipline, and devised an alternative approach to scientific methodology. His “conscious-process-participation” (Wahl, 2005, p. 59) involved prolonged looking, direct attention, and deep empathy, with an “emphasis on the metamorphosis of the scientist” (Robbins, 2005, p. 115). This holistic and participatory approach, when adapted to the contemporary context of science education, offers an alternative way to understand and be immersed in the world’s phenomena. Whether studying climate change, biodiversity, plant growth, or other biological or physical entities, zarte Empirie engages the scientist in a relational yet still precise scientific methodology.

Incorporating Goethean science in today’s science classrooms requires us to step beyond the limits of the conventional reductionist science methodology that follows the predominant subject-object-separation epistemology and move toward a conscious-process-participation epistemology. In this Goethean approach, the learner provides space for the phenomenon to show up and for the learner to receive from the phenomenon under study, mobilizes his/her imagination as a tool to understand the varied qualities of a phenomenon, and employs intuition in order to more fully comprehend the object’s outer and inner contents. By incorporating a science of qualities rather than *only* a science of quantities (Goodwin, 2000), we engage in a reciprocal relationship more inclined to reveal our mutual interdependence with other life phenomena. The alternate paradigm of Goethean science recognizes the importance of two-way perception where the scientist both perceives and receives and helps us to “recover the life that once pulsed through knowledge” (Reynolds, 2007, p. 160).

Today’s scientific method that formulates questions, gathers data, interprets results, makes conclusions, and then formulates new hypotheses, is a precise methodology often documented in a lab report. The most coveted section of a lab report is the results section, “the centerpiece of your report” (Pechenik, 2016, p. 151), providing key data findings, including numbers, statistical parameters, and other relevant observations shown in figures, tables and written text. This is deemed the most important section of a lab report because it presents findings without “reflecting the author’s biases, hopes and opinions” (p. 158), without interpretation or analysis, and certainly without subjectivity. In other words, it lacks the qualities that make us human. To a Newtonian scientist, this logical-rationalistic approach removes human folly from the equation and all the subjectivities that might infiltrate the conclusions made in the report. Although human-made, their observations via one or more of their senses, their higher faculties – and all of the prejudices and partialities therein – are not to be trusted. The data is seen as eternal, unchangeable, and what future researchers will reference. Ethically, scientists should report any bias involved in their experiments. In reality, the pressure to publish may increase scientific bias (Fanelli, 2010). To a Goethean scientist, however, prizing raw data so highly neglects the fact that all scientists are human and disregards the reciprocal relationship between the observer and the observed, whether the latter is electrons or electric eels.

In her paper on Goethean science education, Sherrie Reynolds (2011) asks: “Is it necessary to eliminate spirit in order that children may learn science?” (p. 160). The use of the word ‘spirit’ will give many scientists consternation, for how can you measure or analyze such an ethereal entity (if indeed it’s an entity) objectively? But her question is pertinent, for her use of the word ‘spirit’ is connoted with passion, ethics, curiosity and attentiveness in an educational context rather than a religious one. Spirit is a phenomenon, not a substance. When science is taught through a mathematical, positivist, formula-driven lens, this can alienate some learners whose primary inquiry in science is qualitative observation, curiosity with how things work, cognitive problem-solving on a meta level, or a fascination with the natural world.

Conventional K-12 science education occurs inside a classroom and focuses largely on the classification, measurement, and manipulation of phenomena. Kindergarten students are encouraged to explore using multiple senses, but by grade 7, in a slow progression that removes creative expression and any degree of open exploration, the dominant focus becomes variables, controls, and hypotheses. In each lesson a clear learning outcome is usually being sought, one that brings clarity for understanding a certain phenomenon, which can discount the pursuit of science as an ongoing and holistic journey where phenomena are examined over time and from multiple frameworks. In later grades, creativity and purposeful unstructured exploration is supplanted by a strict and vigorous scientific methodology that wants us to forget our humanness and the reality of all of the other beings with which we share our planet. Cartesian-Newtonian science does afford us an important way to gather unbiased data and understanding about the world, and all of the atomistic mechanisms that underlie phenomena, but there is an opportunity for its limitations to be complemented by Goethean science.

The four stages of the Goethean approach, as outlined by Isis Brook (1998) and developed by The Life Science Trust, can be listed as follows: (1) exact sense perception, (2) exact sensorial imagination, (3) seeing is beholding, and (4) being one with the object. These stages, detailed below (with examples of how to implement and facilitate each stage), cultivate a relational engagement with the phenomenon being observed over a prolonged spatial-temporal study. The distinct features of Goethean science include “rigorous attention to direct experience, empathy, intuition and imagination” (Wahl, 2005, p. 60), fostering a sense of wonder, incorporating philosophy and ethics in science, using emotional awareness and creativity to fully engage with phenomena, and contemplating the myriad interrelations among phenomena. The observer also becomes the observed, and is immersed, at different times, in direct sense engagement, creative expression, contemplative practice, and finding “unity in variety” (Bronowski, 1956/1972, p. 20) by tying together common themes that underlie seemingly divergent realms; in other words, the observer employs many of the most prized qualities of his/her humanness. “Goethe asserted that the human body is the greatest instrument to evaluate empirical experience because it permits an understanding of nature from the inside out” (Mason, 2014, p. 62), and this holistic understanding is what we are after.

 Prior to the numbered steps below is a preparatory stage where the observer makes a note of first impressions and shares these preconceptions about the object of study. If “[w]e all have a history as observers and have formed ideas about the world, which influence what and how we perceive” (Wahl, 2005, p. 62), then acknowledging these formed ideas places us in an important context that emphasizes how our personal history and current state of being may influence our observations. This preparatory stage serves as an individual foundation often absent from current scientific study.

**Exact sense perception**

During this stage the observer steps back from the object of study and, by way of his/her ordinary senses, lists all of the facts and specific data perceivable from the object. Like Newtonian science, the observer is objective in his/her approach, doing his/her best to suspend judgement, evaluation, and personal interpretation. In encountering the phenomenon as it is, the Goethean scientist is present to its patterns, colors, shapes and other details. As Reynolds (2007) contends, “for many natural phenomena, the measuring, mathematical approach is blind to quality” (p. 163); during exact sense perception, qualities are recognized as pertinent observations.

 We can apply this to elementary school students by having them go outside and use the five primary senses to perceive a single phenomenon, such as a fern. After the preparatory stage where they can write and share about who they are, how they are feeling right now, and their first impression of the phenomena, students will “remain within the realm of phenomena and concentrate on form, color, pattern, and behavior” (Reynolds, 2007, p. 168). The teacher will avoid classifying the phenomena (e.g., the fern) and let students use their own words to describe it. Drawing is an appropriate method here, both in the moment and later from memory (Brook, 1998), the latter as a way to emphasize the parts of the fern the student may have forgotten. Students can also make note of other phenomena interacting with the fern, such as a spider scurrying underneath the fern frond; such interrelations will be focused on in a later stage.

 Another example, more suited to middle grade students, would be to have students observe an amoeba under the microscope. While the visual sense would obviously dominate here, this does not preclude learners from smelling the pond water from which the amoeba came, or using their imagination to make observations on how the amoeba touches with its pseudopodia, and what we might hear if the amoeba were large enough to make audible sounds. Students would record cellular patterns, shapes and structures in written form, and also make multiple drawings of their amoeba at different times or under different conditions (e.g., light intensity, slide mounting medium, time of day). They could also carefully observe, under the microscope, the way an amoeba ingests food, known as phagocytosis: how it surrounds and engulfs, with its pseudopodia, live prey like a protist or bacterium. It is a most fascinating process that students may enjoy drawing and even dance to enact its shape-altering ability.

**Exact sensorial imagination**

This stage involves shifting from a static view of phenomena toward an understanding of transition and metamorphosis. Now, the imagination can be employed to understand the temporal dimension of phenomena. We come to see that the object has a history. It is important here to move beyond the exact sense perception stage, which provided useful observations that are now frozen in time. Imagination is used to bring movement, development and transition to the phenomena, so that, as Daniel Wahl (2005) explains, “we can wilfully imagine a different sequence of transformation than the one that emerged based on our engagement in stage one” (p. 63).

 To continue with our fern example, we can have students draw the fern frond and its leaflets as they might appear when the particular frond they examined was younger, and when this particular frond will be older. In the first stage the drawing provided a static image of the fern; now, students imaginatively draw a sequence of development. This alternate epistemology, rather than showing students a textbook figure or a time-lapse film, allows for students to imagine and reason for themselves.

**Seeing is beholding**

In this stage the observer enters a state of “receptive attentiveness” (Brook, 1998, p. 56) and receives from the phenomena with an open mind. The phenomenon is allowed to “articulate in its own way” (p. 56) while the observer closes down his/her own perception. As the recipient, the observer gives the phenomenon some of our humanness and conscious awareness, and therefore a way to express its gesture. Since “Goethe does not study nature from an observer’s view seeking a reason for its existence outside itself, but as an entity that has its own reason to be” (Reynolds, 2007, p. 166) this stage is vital in revealing the phenomenon’s purpose and intention in existence.

The observer expresses his/her observations in emotional language. This practice can lead to unexpected insights and the development of “new organs of perception” (Goethe as cited in Brook, 1998, p. 56). We would like to point out that this way of observing the world and coming to know it has a long, time-honored tradition, known as what we now call “wisdom traditions” of the world. These traditions bear ancient roots, reaching back thousands of years into antiquity and beyond, and still bearing abundant fruits on contemporary branches. One of the well-known wisdom traditions – there are many, throughout the world – is yoga in Hinduism, and here, the practice of devotion (bhakti) is central to yoga practice and philosophy (Scott & Bai, in-press). It is through the practice of devotion that our organs of perception become attuned precisely and clearly to the exacting beauty and wonder of the world. Devotional practice enlarges and deepens our love for all, enabling us to participate in the phenomenology of life and cosmos. Through devotion, we become lovers, not destroyers, of life. Through devotion, we become part of, not apart from, the world. Our point here is that Goethean science education, too, engenders this profound love of and for the world.

 To return to the seeing-is-beholding stage of science education: When students engage with the fern during this stage, they can do so in an extended period of silence. Questions such as “What does the fern possess that you haven’t noticed before?” and “How would the thing studied describe itself if it had the ability to speak?” (Reynolds, 2007, p. 168) can help guide this practice for younger learners. Afterward, students can paint, write poetry, or partake in other arts-based expression that fosters an alternate understanding of the phenomena, and perhaps leading to a “morally responsive obligation to the observed” (Robbins, 2005, p. 113).

**Being one with the object**

This last step of science education is really the fruit-bearing stage. Through this stage, we come to taste the fruit of our labor: full integration with and participation in the world. Thus, we come to realize the truth of ecology: that we humans are interconnected through and through, and that our presence interpenetrates all other phenomena. In knowing this, not just theoretically, but in our senses and heart, in our body, we truly become ethical beings. The manner of our being in the world and our actions we take would be in alignment with the welfare of the world. We would become healing, protecting, and nurturing agents: not the rampant consumers and destroyers that we witness in today’s mainstream humanity.

 Here, too, this notion of being one with the object has time-honored roots in the wisdom traditions of the world, and is well-known in contemplative arts and science, attesting to the integrative function of arts, science, and spirituality. The habit of separating science from arts and spirituality is typically modernist. Hence, Goethean science education offers an integrative function that can unite all disciplines of learning. Our science students, educated in a Goethean paradigm of science, would be polymaths, well versed in both arts and sciences. (Later, in the concluding section, we will also make the point that specialization in separate branches of sciences is not incompatible with our Goethean science education approach.)

 Phenomenologically speaking, this idea of being one with the object is not some spiritualist talk. The phenomenon is eminently verifiable by undertaking the practice and seeing how it works in our consciousness. Anyone who has spent enough time with an object in concentrated attention can verify how a sense of intimacy grows with respect to the object. This phenomenon, known in some circles as engrossment or in others as participation or in Buddhism as non-duality, goes beyond the disciplinary boundaries and belongs squarely in the phenomenology of human consciousness. Human beings are so constituted that, given an opportunity of modeling and practice, will experience being-one-with, or in contemporary neurobiology, attunement and resonance (Siegel, 2010). It is also known as intersubjectivity in philosophy and psychology (Gunnlaugson et al., in press).

When we spend attentive time with an object, we come to appreciate its intrinsic value, that is, we come to appreciate its being for its own sake, not as a mere means to meeting our desire and design: “When we spend time in deep contemplation of the structure of a plant, for instance, we come to appreciate the plant as an end in itself rather than a mere means” (Robbins, 2005, p. 123). Again, we can see right away how this kind of science learning is one-piece with ethics learning and practice. Ethics, unlike considerations of prudence, demands us to approach and treat the world intrinsically. The world is not there just to serve us and do our bidding. We, educated in Goethean science, would not exploit, violate, and damage the world. For, the world is our beloved, and we are the lovers, caring about and being devoted to its wellbeing and flourishing.

Goethean science education, being aligned with contemplative arts and sciences traditions, can be supported by learning and practices in arts just as equally as in science. Mindfulness practice, which is frequently being introduced now in schools in North America, can be harnessed to support Goethean science education. Mindfulness, as is practiced in schools, has become an anxiety relief and behavior management tool, which, while beneficial, is a limited practice, and not doing full justice to its rich and important educational potential. Since there is a great deal written about contemplative practices in support of ‘being one with object,’ we will not go into its scholarship here but simply refer the interested reader to such scholarship (e.g., in Zen tradition, Bai, 2003, 2002, 1997).

**Concluding Thoughts**

Goethe’s approach to science offers a foundation of ethical thinking, mutuality, and “a more appreciative, qualitative, meaningful and participatory engagement with nature” (Wahl, 2005, p. 60). As Robbins (2005) acknowledges, “the observation of nature is always also a process of self-discovery” (p. 125). In this way the scientist is also changed or transformed. Goethe (1790/2009) saw the need for imagination as complementary to empiricism, allowing the observed to see nature as “complete and unified as both creator and creation” (p. 106). This is also what we propose: that is, a pluralistic approach to K-12 (especially K-9) science education.

 Goethean science, with its sensorial engagement, creative expression, and holistic exploration, fits well with elementary school science curricula. Instead of students dissecting frogs the classroom can be moved outside into a place-based learning environment, where frogs are part of the ecosystem. One can imagine a very different lesson being taught by those students given a dead frog and a scalpel, and those who discover this living and breathing amphibian in its own environment, and gaining intimate knowledge about this frog through delicate empiricism. The former focuses on anatomy and physiology, the latter on ecology and habitat, shifting from anthropocentric to ecocentric attitudes. In later grades, dissection can be a topic of conversation rather than a compulsory exercise left unquestioned, and Cartesian-Newtonian science can supplement Goethean science with more technical training.

The pertinence of disciplines working together in science research (Van Noorden, 2015) is well suited to the holistic and unifying approach of delicate empiricism. “The problem,” Reynolds (2007) contends, “is not that positivism has not led to useful science, but that it has substituted for all other forms of knowledge” (p. 164). The wide-ranging implications of climate change, for instance, necessitates an interdisciplinary study, while the Goethean approach ensures ethics and relationality are recognized as not only important but vital ingredients in this study. The largely abstract, and seemingly invisible, science fields such as molecular genetics or quantum physics may seem incongruent to Goethean methodology. How can you use the sense of smell to sequence genes or use intuition to understand atomic particles of matter? However, delicate empiricism is still essential and relevant here for instilling wonder, doing ethical science, and witnessing the interrelation and interdependence among varied phenomena. Goethe himself applied his approach to physics in his study of light and colour.

 There are core science disciplines best suited to Cartesian-Newtonian science, such as those involved with specialized medical practice. Cartesian-Newtonian science helps us gather data with limited bias, ensure that our findings are statistically significant, and has provided a prolific and profitable database of information on universal phenomena. Such empirical knowledge has produced innumerable rewards for human health and safety. However, this does not preclude Goethean science from supplementing the more technical scientific fields. If delicate empiricism can “help restore spirit to science education by reuniting a world that we have artificially fractured” (Reynolds, 2007, p. 166), then we need to seriously reconsider how we teach our children and young adolescents science. We can look to Goethean science, and other holistic science education models, such as Indigenous Science (Cajete, 1994), which are increasingly practiced in schools, as models that are compatible with most, if not all, branches of science.

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