Natural Sciences

As Taught in Great Hearts Academies

New Faculty Orientation - July 2016

Philosophy undergirding the GH pedagogy

I. What's our understanding of and general approach to the natural sciences?

- Nature and the cosmos are ordered, beautiful, and worthy of knowing for their own sake, apart from any practical applications. The sciences are a sure path to a state of wonder, and that experience must be cultivated.
- The natural sciences are the best path to knowledge about the physical and mechanical operations of nature. They complement and interact with other humane and liberal studies.
- The sciences are humane pursuits, with a human history of discovery, breakthroughs, errors, and 'paradigm shifts.' Our main emphasis is not the history of science, but we should teach students about its history alongside the study of the current state of scientific knowledge.
- Our students should explore the natural world through a) direct observation, b) demonstrations and experimentation, c) reading and lectures, and d) mediated observation (i.e. made possible through technological means).
- We want our students to learn what science is (and what it is not), not merely to master facts or "content knowledge." They must know the latter, but they must learn more than that: how to hypothesize, test, infer, construct models and theories, and see what the limits of the sciences are.

II. How do the natural sciences fit into a liberal arts education?

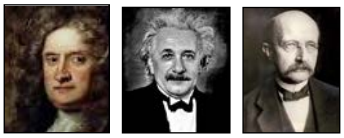
- The ancients and medievals placed the natural sciences that were known to them squarely in the canon of the liberal arts. In the education of the guardian class proposed by Socrates in the Republic, a blueprint for liberal education, physics (although not named yet) and astronomy are prescribed studies for the future philosophers and rulers; likewise does astronomy have its place in the medieval quadrivium of liberal studies. Aristotle was the founder of biology, meteorology, zoology, and physics.
- But we must be careful about the way in which we teach the natural sciences. Even in the Republic, (book VII), the tension between the liberal study of the sciences and the practical, utilitarian approach is on display: while Socrates prescribes science "for the sake of knowing" and "drawing the soul towards truth…leading it upward," the young Glaucon

is continually chastised by Socrates for only seeing the practical benefits of liberal studies: astronomy is good because it helps to predict weather and agricultural planting seasons, mathematics is good for business and military organization, etc.

- The practical, utilitarian pressure—a Faustian drive for power and control over nature through the application of scientific knowledge—has never been stronger in Western history than now. It is more necessary than ever to be vigilant in the way we teach the natural sciences, to ensure that we do so "for the sake of knowing" nature and the natural order, the splendor of its variety and diversity, the beauty and harmony of its laws.

III. Why do we study the natural sciences at Great Hearts?

- In grades K-5, we teach our students to be attentive, knowledgeable observers of the natural world and of natural phenomena. We also outfit them with an array of basic knowledge of the workings of life, the ecosystem, the earth, and the cosmos, from deep space to the atom.
- In middle and high school, we teach the foundations of all the major sciences: biology, astronomy, chemistry, and physics. We do so in a way that does two complementary things: it prepares our graduates for specialized university studies AND it provides all students a robust foundational understanding of the disciplines that is often superior to university requirements for non-science majors.



Curricular Guidelines to Teach Students to Know and Understand, Practice, and Love the Natural Sciences

I. What curricular choices has GH made based on the notes above? Is there a path/progression in the discipline of the natural sciences?

- Deep conceptual understanding and profound appreciation of beauty is more important than a wide coverage of facts (depth over breadth).
- Students should learn the current scientific consensus but also genuinely appreciate the essential historical research and thinking which laid the groundwork/forged the path to our most current understanding.
- Moments of purposeful wonder and curiosity are critical, and should drive the lesson - its pace, sequence, scope, and topical emphases.
- The natural overlap of topics within the different science courses necessitates coordination and intentional placement of concepts as well as level of rigor/detail, such that the content of the courses establishes, complements, and reinforces the most essential ideas/themes of the discipline (e.g. structure/function, forms of energy, properties of matter, cycles, organizational systems, modeling, etc.)

II. How do we go about teaching this based on what we believe about it and its purpose?

- Our pedagogical approach to the sciences should be primarily (though not exclusively) Socratic. We begin with the thing itself - the phenomenon, structure, etc. being observed in shared experience (via readings, diagrams, demos, labs), and guide the students through a series of carefully crafted questions and prompts to help reveal truths (and mysteries), and develop in the students a genuine understanding of the object of our study.
- Technology is used in the classroom as a tool to enhance our understanding (e.g. microscopes to view hydra nematocysts in biology, or graphing software to track acceleration in physics). Technology itself is not the object of study, nor the daily focus/core of activity in the classroom.
- Primary readings should be used where appropriate. The cogent reflections of a naturalist or researcher are typically more thought-provoking than textbook summaries.
- The manner and sequence in which students encounter new information is important. Textbook “pre-reading” can often deprive students of the opportunity to speculate and reason thoughtfully about how something might work, or what might be true. Textbook

readings are best deployed as resources for review, consolidation, and summary; the introduction and primary learning occurs through the active conversation of the classroom through the carefully constructed lesson of the teacher.

III. Is there is a language of the discipline that we help kids understand during their course of study? (optional)

- Narrative description of processes, structures, relationships, etc. is the essential indicator of and mechanism for student comprehension. To think "scientifically" is to be able to communicate something about the natural world.
- Precision of vocabulary - sometimes terminology which is new, detailed, and unique to the discipline, sometimes terminology which is familiar/commonly used but with a specific/new meaning in the discipline.
- The language used in scientific vocabulary often reflects an intrinsic order that makes sense of and represents an internal logic/order in the natural phenomena being described (etymology, Latin/Greek roots, etc.)

IV. What big questions will/should students be asking in their course of study?

- What order exists in the natural world?
- In what ways can energy be transformed, and what are the effects of energy?
- How does structure affect function?
- How does matter interact?
- What are the various influences/effects of time in natural processes (from axon firing to geological erosion to generational evolution)
- What are the variety of ways which living organisms (or molecules, cells) solve environmental challenges/problems?
- How do we best capture meaningful information about the natural world? What is the process of reconciling sense perception/observation with other mechanisms of data tracking/collection?

V. What skills and habits should students develop through studying it?

- Observation and clear articulation/communication
- Spatial imagination and conception of scale
- Recognition of patterns
- Ability to draw logical connections, properly contextualize discrete ideas/data

- Systematically approach new situations, based upon previous experience and knowledge, making reasonable predictions .
- Organize and represent data in order to discern trends, draw conclusions, and translate information from one form to another (numbers/graphs/words/etc.)

Epilogue

Science and Other Forms of Inquiry
Found in the faculty handbook

21st century Western culture is often susceptible to two contrary errors in thinking about the natural sciences, each view a partial truth that has become a falsehood through exaggeration. Great Hearts teaches the natural sciences in the humane, classical tradition, and as such, navigates a straight and narrow path through the contraries. The teacher of the sciences cannot keep his/her head down about these questions, and he/she must be aware of the competing claims about knowledge and truth in science, a contention that would either enthrone science as an absolute despot over all knowledge, or render it a serf on the estate of a great medieval landowner.

To an extraordinary extent, present-day Western culture is in thrall to a worldview which we might call scientism. Often unacknowledged by its devotees, the assumptions of scientism are that the natural sciences tell us everything that there is to know about everything, and thus that if there is anything that science and its methods cannot discover, then that something simply does not exist or cannot be an object of rational knowledge. Other conclusions following from the premises of scientism and incompatible with a classical, liberal arts education include aesthetic matters are entirely subjective, or explainable as nothing but the results of evolutionary biology; no ethical/moral propositions possess any validity unless they are research-based assertions about causality and correlation, such as “studies show that married people live slightly longer on average than unmarried people”; claims by philosophy and theology are pseudo-sciences like alchemy and phrenology; questions about the meaning of life and about the existence of God/gods are unscientific and thus absurd. The worldview of scientism, if scrupulously adhered to, would reject a large portion of the Western intellectual tradition as nonsense.

Another problem inherent in the ideology of scientism is that it often blinds its adherents to their own non-scientific premises and imperatives in social and philosophical matters. There are few things more harmful to civil discourse and common political life than unacknowledged moral or political premises presenting themselves as self-evident truths.

A close contemporary of the scientistic worldview, ubiquitous in the 21st century West, and similarly incompatible with the classical tradition, is the STEM-utilitarian view, which holds that studying science (and mathematics) has as its purpose practical, technological utility; that science in schools ought to be taught specifically as preparation for careers in practical sciences such as engineering and medicine; that school curricula in the sciences ought to be continually revised to keep pace with pressing social needs that call for technological solutions. This is not our approach. Since all of the subjects that we teach can be put to some practical, professionally useful purpose by those who have learned them well—Latin and Greek will be tremendously ‘useful’ to the future teacher of Classical languages—we teach all of the subjects not for the sake of some practical utility to be accessed only by some in particular careers, but for the sake of their worthiness as objects of knowledge for all educated persons in a free society. Here we see a direct application of our commitment to liberal education, as opposed to servile/mechanical training.

But in the classical tradition of the West, the natural sciences are viewed as several among other disciplines that lead to truth, certainly not superior to those other disciplines, nor separable from them. In this classical view, natural science is the path to a certain kind of knowledge about certain natural objects; history yields truth about other kinds of things; mutatis mutandis with mathematics, logic, and philosophy. And while each discipline has its own autonomous methods and particular objects, the classical view also holds that the separate disciplines are never completely independent of each other; since truth is ONE, no conclusions of one study can possibly contradict any other truths found in other disciplines; furthermore, every separate field of inquiry can and ought to be informed by the findings of the others. This exchange is always mutual and never unilateral: to give one example, microbiology can be fruitfully informed by the findings of history, i.e. ancient and medieval descriptions of plague—and in turn, modern knowledge about infection can and has shed light upon the historical understanding of the Black Death. Similarly, philosophy cannot tell us the entire truth about humanity—and neither can history, economics, biology, chemistry, psychology, or philology. ALL the disciplines have something to contribute.

At Great Hearts, our view of the relationship between the separate disciplines (in 19th-century parlance, the sciences, plural, both natural and humane) is well-expressed by the great John Henry Newman (1801-1890), writing in The Idea of a University, Discourse III:

These various partial views (of reality) or abstractions, by means of which the mind looks out upon its object, are called sciences, and embrace respectively larger or smaller portions of the field of knowledge; sometimes extending far and wide, but superficially, sometimes with exactness over particular departments…Thus Optics has for its subject the whole visible creation, so far forth as it is merely visible; Mental Philosophy has a narrower province, but a richer one. Astronomy, plane and physical, each has the same subject-matter, but views it or treats it differently; lastly, Geology and Comparative Anatomy have subject matters partly the same, partly distinct. Now these views or sciences, as being abstractions, have far more to do with the relations of things than with things themselves, They tell us what things are, only or principally by telling us their relations, or assigning predicates to subjects; and therefore they never tell us all that can be said about a thing, even when they tell us something, nor do they bring it before us, as the senses do…We may view (man) in relation to the material elements of his body, or to his mental constitution, or to his household and family, or to the community in which he lives, or to the Being who made him; and in consequence we treat of him respectively as physiologists, or as moral philosophers, or as writers of economics, or of politics, or as theologians…On the other hand, according as we are only physiologists, or only politicians, or only moralists, so is our idea of man more or less unreal; we do not take in the whole of him, and the defect is greater or less, in proportion as the relation is, or is not, important, which is omitted…Were I a mere chemist, I should deny the influence of the mind upon bodily health; and so on, as regards the devotees of any science, or family of sciences, to the exclusion of all others; they necessarily become bigots and quacks, scorning all principles and reported facts which do not belong to their own pursuit, and thinking to effect everything without aid from any other quarter. (emphasis added)

Contrary to the scientistic view, and less prevalent in late modernity, though perhaps to be found in somewhat greater proportion amongst the classically and liberally educated, as well as among intellectually consistent postmodernists, than among the general population, is an understanding of modern science that would marginalize or relativize its truth claims. While contemporary know-nothing flat-earthers and geocentrists are more the stuff of comic legend than of living presence among us, there exists a more intellectually robust kind of philosophical (sometimes theologically-driven) anti-scientism which is not compatible with the Great Hearts mission. Such anti-scientism might be inclined to:

- cast layman's aspersions upon the findings of any of the natural sciences
  Example: to disparage evolutionary biology as "just a theory, not a fact", an assertion which betrays a serious misunderstanding of the nature of scientific theory

- blur the lines between natural science and philosophy
  Example: to criticize science for not being able to provide a philosophical or logical account of cause and effect, or an empirical justification for its own premises of empiricism; essentially, to criticize science for not being philosophy

- relativize the importance of the modern natural sciences
  Example: to assert expressly or implicitly by the allocation of classroom time that the findings of pre-modern science are equivalent to those of the modern natural sciences
  Example: to assert that modern (Western) science is nothing but another mythos, a "narrative" with no more or less validity than non-Western creation stories

- discredit the natural sciences by historical ad hominem attacks
  Example: to over-emphasize the mistakes that great modern scientific minds have made, such as Newton's devotion to alchemy, Darwin's arguments for the mental inferiority of the female sex, or a detailed account of 20th-century racialist pseudo-science

In brief, while the ideology of scientism can be viewed as an over-extension of the natural sciences, a hostile violation of non-scientific airspace or territory, the above-depicted anti-scientism is no less an aggressive incursion into the domains of the natural sciences. It is a false response to an equally false scientistic ideology. The solution, rather, is SCIENCE, properly understood and properly taught as a way to a particular kind of knowledge about a part of reality. And our assumption is that, since reality is one, truth must of necessity be one; scientific truth cannot contradict nor be contradicted by philosophical truth; if there is contradiction, then one or the other or both must be in error.

While most know Aristotle as a philosopher, his work as a natural scientist—writing treatises of biology, psychology, and meteorology, among other things— is often completely unknown. No doubt this is because so many of the findings of his research have been corrected by millennia of natural science since the 4th century BCE. It is nonetheless a travesty to lop off or overlook this dimension of his intellectual work; it is not the content of his scientific work that matters as much as the form of his universal intellectual pursuits. Like Aristotle, a Great Hearts academy is devoted to the cultivation of the natural sciences AND the pursuit of philosophical wisdom. Though the former is highly progressive and ever-adapting and the latter tends towards the stable, perennial, and traditional, both are at home under our roof.