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Fulfilling the Need for a STEM Platform

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Abstract

For students to grasp mathematical thinking and not merely secure behavioral responsiveness to standardized cues, they must be lured into viewing it as a conceptual wilderness that is exciting and open to new path-finding ways of thinking about math. By using the example of the Pythagorean theorem an example of how this can be done in practice is made palpably clear.

Keywords: Stem, platform, evolution, truth-securing, truth-seeking, understanding

1. Stemming Distractions from STEM Studies

Stem studies need to be fixed. There is nothing new to this claim. The Stem acronym has been around for more than a decade indicating a problem area in education. But even before that the famed Nation at Risk Report in the late nineties heralded dissatisfaction with STEM and other studies. One can even look back to the panic in the 1950's following the Russians launching of Sputnik into orbit. So, with close to seventy years of attention one would expect to see more satisfaction among the public, and for that matter students, with STEM education and its consequences for people seeking the rewards of a solid STEM education.

Perhaps continuing frustration with STEM studies is the result of a something less than complete and robust image of a proper platform for STEM. Imagine what a platform for STEM might look like. The platform would not itself be filled with scientific facts or algorithmic protocols for finding answers. Certainly, there are answers to be found. For example, after 350 years of work in mathematics, Fields medalist Andrew Wiles was to collect much of the previous work together to finally show a proof for Fermat's conjecture

(Singh, 1998). Physics thought work showed why ice is slippery. They had not. Not yet anyway. In just the past year scientists found that previous conclusions about the slipperiness of ice were wrong. A more accurate cause of ice and slipperiness is now known. These and all the facts and insights of STEM related studies come from researchers working from a common platform, though individuated in detail by discipline. This is to say, there is a foundation, a meaningful platform for addressing STEM in general. If there was not a plausible platform supporting STEM, STEM talk would be little more than ideological jargon. So, what is STEM?

Many studies include math and empirical observation. In fact nearly every discipline except literature can claim to be a STEM study and thus deserving of additional funding and special attention: history, business, philosophy, every social science, home economics; the list may be inexhaustible. Mostly however, people are content to limit STEM to the disciplines of mathematics, the physical sciences and engineering. Of course, that can be problematic. For example, technology and engineering in central ways are different from pure math and pure science. So should STEM be limited to SM, science and math? And what counts as science and math?

Mathematical application and empirical observation are not sufficient criteria for eliminating much of anything from STEM attention. Yet resources demand educators be discerning about the use of the term STEM both for funding efforts and for purpose of assessing and evaluation. For example, engineering is not pure math not even for a super abstract-thinking engineer such as Claude Shannon, the father of information theory. Similarly, engineering is not pure science. Pure science seeks truth or the best approximation thereof utilizing inference to the best explanation or ideally some more strategically deductive model. In contrast, engineering for all practical purposes is a much more pragmatic field. Engineering seeks solutions to problems in a definitive context. Of course, there are engineering specialists doing pure science at times and some scientists do applied work as well. But in general, the division between the two areas is evident to the curriculum pertinent when preparing candidate entry into each field.

A now classic real-world example illustrating the difference between these two pure and applied STEM sectors is found in the contribution of Alan Turing and Tommy Flowers to building Britain's BOMBE, the enigma code -breaking calculating machine in the Second World War. Turing was a mathematician who studied philosophy under Ludwig Wittgenstein for a time (Price, 2021). Turing's philosophical interest in mathematics led to thinking about formal structures of artificial intelligence. At Benchley Park it was largely Turing who came up with the Bayesian-driven model for breaking down the enigma code in more timely fashion giving code recovery operations greater utility than ever before (Hodges, 2014).

Turing knew what had to be done mathematically and in practical ways to get ahead of the Germans master code system enigma. Great. But there was a problem. Turing did not know how to build the needed machinery for the job at hand. The British recruited experienced engineer Tommy Flowers from the British postal system for the job! The two were not in a collaboration. Turing and his team knew what the machine had to do. Flowers and his team knew how to build machines capable of some specific, novel functions. The outcome of the two operations was symbiotic but never collaborative. Engineers and scientists typically have different foci in mind when engaging in their professional labors (Price, 2021).

Another problem with determining a proper range of what should properly be called STEM studies involves what to do with medicine. Practicing medical doctors are not scientists. They are much more akin to engineers. They utilize scientific information in order to address a unique problem in an immediate context (Williams, 2022). And as with some engineering scholars some physicians become scientists. When medical doctors and engineering professors do genuine scientific work they are in the minority within their field. In fact, a close look at medical advances often shows there are far more Ph.D.'s. involved in the basic science leading to medical advance than M.D.s. M.D.s are often required on grants when there is to be patient experimentation with products designed by the scientists. So, what should the focus of STEM curricula be without being neither too inexplicit on the one hand nor too explicitly limiting on the other hand?

2. Is There Anything to STEM Studies beyond a Clever Acronym?

Obviously, one can list science, technology, engineering, and math among numerous other subjects as parts of STEM. But if STEM is to be understood robustly by educators and classroom teachers in general there must be more to it than contrived lists and rubrics of disciplinary sectors each comprising its own knowledge silo. Instead, there must be an understanding of what constitutes a platform for the entire collection of STEM sectors. This is a tall order but it is not insurmountable.

3. The STEM Platform

For a serviceable image of STEM, consider the visual of a three-legged stool as a platform. The platform described herein accommodates engineering and medicine along with standard sciences and advanced mathematics and a bit more as will be explained shortly.

One leg of the stool consists of facts, theorems, and well-known algorithms for both experimentation and decision-making. For example, students must know that natural selection and Krebs' cycles are key to understanding evolution (Lane, 2022). Curricula and lesson plans along with methods of assessment and evaluation should reveal that students have reached a threshold (Wagner, 2018) understanding of conventional theories and undisputed facts that have resisted persistent attempts at falsification over an extended period of time.

A second leg of this STEM Platform is "hands -on" preparation. For example, in this leg of STEM students work math problems, code computers, do experiments, create operative electronic sequencing circuits, build physical constructs to some pragmatic purpose and so on. The purpose here is to give students an affective affiliation with the processes managing human recovery of data and its aggregation into summaries that can be shared with other hands-on experienced researchers (Wagner & Fair, 2020; ch.3).

Both these "legs" of the STEM platform have been well studied by educational researchers.

There are many successful programs teachers are currently using to advance student knowledge and technical skill suitable for both these platform supports (Wagner, Johnson, Fasko & Fair, 2018, 2017). So, what more could there be?

Students may pass multiple-choice tests pertaining to Evolution. They can identify *natural selection* as the heart of evolution. Yet they may still not understand what natural selection means. Natural selection means that through random genetic mutations and contextual change, nature exhibits creativeness sustaining what is of use to a future generation of a species, eliminating what seems less suitable and increasing likelihood of survival for recipients of beneficial modifications. Understanding natural selection means being able to discuss the robustness of natural selection and employ apt examples of its creativeness when doing so. Merely recognizing an apt selection to associate with a multiple-choice test stem shows next to nothing (Wagner & Fair, 2020).

Similarly, in geometry recognizing an apt selection that pairs with a test item stem is not reliable confirmation that the student knows how to measure the angles of a triangle even in plane geometry. Still less does such pairing recognition show the student has considered all depends on the nature of the space involved: planes or curved. In plane geometry the degrees of a triangle add up to 180 degrees. In curved space, the degrees add up to more or less than a 180 degrees but never exactly to 180 degrees as in plane geometry (Wagner & Fair, 2022).

If students come to think natural selection whittles away at species making each generation better suited for survival, they miss the point of natural selection. Nature does not care about the future of any species. Instead, natural selection blindly eliminates the lethal and does so by mere chance alone! Nature is blindly at work. Mutations are always chance occurrences. Most mutations are harmful and most of these are edited out by the DNA repetition mechanisms of most species' DNA. Some mutations are inconsequential and may survive generation after generation indefinitely. Evolutionists call such inconsequential mutations *spandrels*. These inconsequential genetic mutations are analogous to architectural spandrels. Architectural spandrels are unnecessary adornments to structures both in buildings and in species physiology. They are not necessary for preserving either structural integrity or, function (Tattersall, 2022; Gould, 2002: 155-159; Eldridge, 1995). For example, the human chin is commonly described as a physiological spandrel. It is not especially useful in any way and yet neither is it costly. As a consequence, it remains across many generations. If a trait becomes too expensive to preserve, natural selection becomes more than chance and mutation, it also eliminates traits, including sometimes entire species. Because species' history is responsive over time to environment, significant environmental changes can lead to subsequent disfavor of previously favored physiological traits.

Disfavored traits tend to disappear over a span of generations. If the species does not have genetic resources to accommodate environmental changes, nature edits the species out of nature's economy. In short, lacking resources to address environmental changes leads not only to shifting properties across generations within a species but can lead also to species demise altogether. Natural selection eliminates species unfit in the context of changing environments.

The second STEM platform alluded to above is the “hands on” STEM leg. This leg is exemplified by students learning to do math, code algorithms and arrange experiments structured to recover, aggregate and finally reveal physical realities. For example, students learn to solve geometric problems using the Pythagorean Theorem $a^2 + b^2 = c^2$. Their ability to solve problems using this theorem are tested for in standardized tests. All well and good. Both these legs seem to cover all that practicing Stem workers do, right?

So why the need for attention to a third leg?

The reason for attention to a third leg for the STEM platform is about more than securing a certain aesthetic stability for the image of a platform. The third leg unifies a set of technical disciplines reflecting rigorous thinking practices across technical, disciplinary specialties. The third leg of the platform is as integral to student success in STEM studies as is achievement in either of the other two legs.

4. Is there a Philosophy of Stem Subjects that needs attention in the Stem Curriculum?

The first leg of the proposed STEM platform consists of curricula and teaching strategies inducting students into appropriate background knowledge. The second leg introduces students to hands on manipulation of both symbols and technical apparatus. Both are critical to eventual efforts at further truth-seeking in the STEM world. But what about the need for students to develop truth – securing skills, i.e. understanding of what is learned?

The third leg of the Platform may be most important of all. This is the leg that represents the history and philosophy of STEM specializations. This is the truth-securing leg. Without the truth-securing leg advancement in truth-seeking slows to a crawl or may end altogether.

Teaching brings information and investigatory protocols to mind. In truth-seeking what is brought to mind is new. No one seeks what they already know. Seeking requires memory, imagination and risk-taking in building hypotheses and new theories. In contrast, truth-securing is about taking what has been taught or otherwise learned and subjecting it to critical evaluation. It is the practice and process of critical evaluation (philosophical analysis) that in the end determines what learners should retain if there is to be further advance in understanding. Through truth-securing, philosophy pulls back the curtain on practices and accumulated data revealing the heart of math, science and technological enterprises generally. Three standard philosophical questions frame the truth-securing enterprise. To secure truth, always ask:

1) How do you know what you claim to know?
2) What do you mean by critically central terms in your descriptions?
3) (The tolerance question) What is the least amount of evidence you can imagine that if

It turned out to be true would cause you to give up your previous conclusion?

With these the questions of epistemology, ontology, logic and philosophy of language at hand evaluations of knowledge claims become revealing and transparent. In the absence of these three questions, opinion, mere persuasion and social power tend to direct the attention of further investigation of any kind. As biophysicist Nick Lane explains, "Many a beautiful idea have been killed by ugly facts. (Lane, p.117; 2022)."

The three philosophical questions above when adequately answered, secure truth – as much as possible. For this reason, these three questions structure every course Wagner, Johnson, Fair and Fasko teach (2017, 2018). Again, as Lane explains, answering the question "How do we go about knowing?" is critical for further successful truth-seeking in every science (Lane, p117; 2022).

5. Philosophical Muscle in Stem Education and Emerging curricular Strategies

In practice, every STEM area should seek to advance further student innovation by advancing beyond past knowledge or application of standard algorithms. The third leg of the proposed STEM platform centers on truth-securing practices. Truth-securing practices are evaluative. They focus on justification offered in support of ideas, conclusions, data management, semantic clarity, interpretation and so on. More than any individuating technique, truth-securing practices exhibit the personality of each STEM discipline and the collective of STEM studies generally (Wagner & Fair, 2022). Generalized, truth-securing practices are what psychologist Steven Pinker (2021) describes as general rationality across the board of all problem-solving activities.

Understanding how to secure truth claims within a STEM study involves intimacy of understanding of what goes on within the specific STEM discipline with the truth – securing goal of all STEM studies clearly in mind. This third leg of truth-securing understanding is presumably what the founders of the increasingly popular UTeach STEM advocates now allude to as the core element when teaching students the spirit of each and every STEM subject.

This third leg focus on critical thinking, namely, history and philosophy aims at developing in students a deeper understanding of a STEM area by developing their ability to evaluate the merit of a claim or hypothesis. This focus requires creating in students skills and dispositions of exacting evaluation. For example, as noted above, thinking natural selection is about nature's intention to whittle an improved species from the resources of the current generation is misleading. Nature has no intentions.

Again Nick Lane notes, "It could have happened" is a far cry from "shown to have happened (2022; p.117)." Truth-seeking in STEM must be complimented by truth-securing applications. And these, applications have been learned throughout centuries in the history and philosophy of science and math.

Natural selection is understood by evolutionary scientists as eliminating the lethal and not creating the promising. This elimination protocol is the source of natural selection's creativity as well as the source for species' demise (Gould, 2002; 155-159). This deep account of evolution's function is standard history and philosophy for the scientific understanding of evolution. Unfortunately, this insight into natural selection is too seldom developed in public K-12 evolution education. But this can be changed easily enough. When attention is paid to third leg skills and disposition for accurate evaluation and therefore understanding, student-building is the result of these complimentary skills and dispositions of truth-seeking and truth-securing.

6. STEM is about Student-Building

Student-building within a subject occurs when students increasingly become more the master of their own further learning within the discipline (Wagner & Frank, 2020: 127-129). Student – building in science education occurs when each student has a platform for understanding the range of STEM securing practices (Wagner & Fair, 2020; 135).

Finally, consider again, the example above involving the Pythagorean theorem. The Pythagorean Theorem works in plane geometry but only in plane geometry. The multidimensional world of physics describes a world of curved space. Does the Pythagorean Theorem work just as well in curved space as when laying carpet or replacing shingles on a roof on a plane?

It does not.

Even within plane geometry, instead of programing students to reiterate that when the triangle's sides are predictably 3 and 4 then the hypotenuse is 5, more is required to student-build understanding of the Theorem even as applied to plane surfaces (Wagner & Fair, 2022; 104).

What if a = 1 and b = 1 what should c=? How does a teacher explain or lead students through the applicable mathematical philosophy? How has this philosophical problem of math been addressed historically? To succeed in building better students these questions should be framed in third leg constructions. Third leg constructions focus attention beyond memory capacity or mirroring behavioral mechanics. Third leg constructions are for bringing students through thresholds of discovery to where their performance reflects lawful-like attention to figuring things out pursuing intellectual adventure further (Wagner, 2018;50-51).

A student may propose that "c" in the above Euclidean plane geometry case, is equal (or nearly equal) to 1.41….

Close but not a winner. The square root of 2 is an irrational number. The number goes on infinitely. So, is there truly a square root of 2? Can you find it – exactly- on the number line or only more closely approximate it seemingly hidden, in some opaque location? Does this endless hiddenness signal the theorem simply fails in such cases? How can one secure an answer to such questions?

Questions endemic to the third leg of the proposed STEM platform pull back the curtain revealing a world of intellectual complexity too often ignored.

Rather than subservience to a rubric that ends bluntly in right or wrong evaluation, students are challenged through examples such as contemplating when and if the location of an irrational number is identifiable, to think about the reliability of the theorem and moreover of math itself. Skillful third leg constructions of STEM lessons are meant to lead to thresholds of new understanding. These thresholds are brought into view by showing that, "Doubt liberates thinkers from intellectual complacency (Wagner & Fair, 2020; 11). If a rational number cannot be "found" determinately then does it exist at all?

What makes mathematical sense and why does it make sense?

Are there revealing counterfactuals about how things in fact must be?

7. The Third Leg of the Proposed STEM Platform is the Muscle of Emerging Curricular Strategies

When truth-securing questions are entertained in any STEM subject, student advance in rational understanding generally and as applied to a specific sector of STEM improves.

Learning facts about a STEM study in addition to hands – on experience and prompts to ponder why things are as they seem and could be otherwise together serve as the three-legged platform from which students can experience a threshold of inquiry into various STEM studies. Take away any one of the three legs and like any physical stool, the platform tips over destabilizing opportunity to get a fix on new grounds for insight.

The UTeach program instituted by The University of Texas – Austin and now in operation at more than forty teacher training programs show a robust approach to student-building using a platform situating all STEM programs collectively. Hopefully, Uteach and other pre-service and in-service programs are developing that center not on one or another STEM study in isolation but in building a foundational platform for all STEM search for truth-seeking, truth-securing and understanding generally. Student-building has been increasingly acknowledged as the purpose of education. Teaching and learning are tools for fulfilling this purpose. Students can be taught to torture kittens and learn to abuse drugs but such things while products of teaching and learning have no place in education. Educational purpose is what distinguishes education from other teacher/learning activities. Educational purpose is about student-building (Wagner, Johnson, Fasko, Fair, 2018; Wagner & Fair, 2020: Wagner & Fair, 2022).

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