A Philosopher Looks at STEM Quality in Higher Education from a Liberal Arts and Sciences Perspective

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ABSTRACT

Higher education is at a pivotal crossroads. The federal government is looking more carefully at the practices and outcomes of colleges and universities. Businesses are becoming increasingly disappointed in the graduates of higher education institutions as noted in Richard Arum's and Josipa Roksa's 2011 *Academically Adrift*. Moreover, in terms of innovation, critical curriculum components are lacking as denoted by STEM: sciences, technology, engineering and mathematics.

The philosopher Aristotle was, like many philosophers, a scientist as well. He discussed the process of change in substances with respect to what he called the four causes. These causes are final cause, formal cause, efficient cause, and material cause. Further, in each category of cause, there is a state of potentiality and one of actuality. Also, one ought to be able to discern between accidental causes and proper or planned causes. From this theory, Aristotle created for philosophy a methodology for quality inquiry and improvement.

A review of what philosophers have known for two thousand years can provide insight into the fields of STEM and the liberal arts and sciences and offer tips for creating improvement and change in order to improve the status of STEM in higher education.
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INTRODUCTION

Most philosophy, mainly in the arena of epistemology, is rule governed and extremely complex. Many of these rules and complexities were generated by the philosophers themselves. What should be understood is that many of these epistemological philosophers were trained in math and science. For philosophers, this mathematic rule approach helped them form and strengthen their critical thinking through problems.

This is found to be true in the work of Plato and Aristotle. In fact, Plato had one particular admission requirement to his famous Athenian 'university.' Above the entry doors to the Academy, Plato had this inscribed, "Let no one ignorant of geometry enter." Plato's overall philosophy of the 'forms' was based on what he called the mathematical forms. One could never really understand the true forms of the things of this earth if one did not understand the forms of mathematics. Clearly, 'Truth' was on a higher plane than mathematics, but it couldn't be reached or understood if mathematics was not grasped.

Much of this belief was founded on the work of Plato's mentor, Socrates, who believed that people could intuitively know and understand mathematics. Geometry was a subject that we all knew but simply forgot. We only had to ask the right questions in order to have the student or pupil arrive at the correct answer. This exact tactic is demonstrated in the *Meno* as Socrates questions an uneducated slave boy who can, for the most part, correctly answer questions about geometry.

Truth be told, though, if anyone has taught geometry or anything like math, science, engineering, or technology, then it is well known that one cannot simply ask questions and expect students of any level to quickly respond as if they had only forgot they knew the answer already. So, this presents a genuine challenge to STEM (science, technology, engineering, and math). While these are some of the most important fields of study, they always appear to be overly difficult to teach and learn. Philosophers like Aristotle, though, did not necessarily put math and science on a higher plane than any other form of education or knowledge. Rather, they were forms of knowledge that could be and should be known and experienced in a very real way. Therefore, scientific experiments are performed and conducted. Math, and its linguistic sibling, logic, is demonstrated and performed and proved and reviewed. None of these matters were simple question and answer topics. In fact, if Plato had the first "admission requirement," Aristotle had the first "graduation requirement" in the form of student projects. Students were required to apply what they learned as a means of demonstrating that they understood their subjects (Frankena, 1965). This kind of applied experience should be the point of departure for examining STEM in higher education.

BACKGROUND METHODOLOGY

Philosophers, such as Aristotle, were also practicing or amateur scientists. History says that Aristotle's pupil Alexander the Great would send back animal and plant specimens so his mentor could study and catalog them. The importance here is that much of Aristotle's philosophy was influenced by his scientific endeavors and, moreover, Aristotle is considered by some to be the father of biology. Because of the unique status that Aristotle holds in the canon of philosophy, he is a perfect candidate for reviewing the problems in STEM education.

Aristotle, like other philosophers, had an approach to education that mirrored his particular philosophy. He wrote on numerous subjects such as metaphysics, ethics, politics, poetics, and biology. In the realm of the sciences, Aristotle attempted to answer what made things the way they were and, more importantly, how they change. Things as they simply existed were called substances with various properties. For instance, tigers are substances with properties such as stripes.

The more difficult question to be answered was to explain change in substances. Substances themselves were made up of material and a form or blueprint for what made it take the shape or have the characteristics that it had. In simple living things, the form is contained inside of it already, such as acorns having the blueprint for becoming an oak tree in it. Aristotle further identified this as also having within the acorn a final goal, or *telos*. This extremely simple example serves as a basis for examining nonliving things, how they are made, and how they are changed.

In the *Physics* and the *Metaphysics,* Aristotle explains change in substances through four separate types of causes: material cause, formal cause, final cause, and efficient cause. Each of these causes emphasizes a different aspect of substances and how they are changed. Material cause refers to the actual material something is made of, such as wood being the material cause for tables. Formal cause refers to the blue print or plans for making a particular item or substance, a set of instructions for putting together a table, for example. The final cause is simply the goal or objective in mind. That is, the material and plan to come together to become a table. The efficient cause is the mechanism which causes the change, namely the person or thing that makes the change. The best example for this is someone using a screw driver or hammer and nails to put the table together.

From these three points about substances, Aristotle can explain change in terms of four causes. The first cause asks why something is the way it is. That is, what is its goal, or *telos*? In the acorn, the goal is to become an oak tree. In artificial things, the goal can be something such as becoming a table or chair. Then, the question is what is to become a table or chair? The simple causal answer is whatever the material is whether it is metal or wood. Of course, a chair and table have distinctive properties that make them two different things even if made of the same material. Therefore, the third causal question of what makes something the way it is must be answered. What is its form? What is the blue print? If there was a pile of wood that was to be made into a table, then directions or instructions how to make the table would be necessary. Lastly, artificial items don't simply grow into their final goal like acorns to oak trees. Something or somebody has to do the work. In the case of the chair or table, a carpenter could be the 'efficient' cause of creating the change.

This seemingly simplistic model is actually perfect for discussing change management, improvement processes, and fixing STEM curriculum in higher education. In fact, with Aristotle's four causes model, it is essentially a model that focuses on the end result: the who, the what, and the how.

Regarding the end result from a liberal arts perspective, the running issue is whether or not new graduates can think critically. Further, there is general confusion here about how educators define critical thinking and how employers define critical thinking. Worse yet, some interchangeably call this process critical thinking and decision making. It appears that the agreed upon outcome for employers would be that newly graduated employees know how to arrive at sound judgments. Decision making is a skill that can be learned but, like critical thinking, many may find it difficult to teach or to incorporate into curriculum. Both can be done and are done in a quality STEM curriculum. From a 'classical' perspective, this ability to think critically made an individual a valuable citizen in society. Ultimately, this goal should not be neglected in the current STEM agenda discussions.

FINDINGS

By today's standards, Aristotle's four cause philosophy is a good approach for change processes, similar to lean. If lean looks at customer focus as the goal, eliminating material waste, never allowing a formal process to pass on a defect, and focusing on the people at work in the process, then we are essentially conducting change as Aristotle did. Aristotle, though, also referred to additional states in the four causes regarding accidental changes as opposed to proper, or planned, changes. In turn, then, each of these causes needs to be reviewed for planned change improving the quality of STEM education.

Final Cause

Oddly enough, while the goal of STEM education appears to be known, something has not been actualized. From an Aristotelian perspective, the specific goal of jobs may have been incidentally attached to STEM education. That is, education does prepare individuals for jobs but have academic programs developed for job procurement? Not necessarily as much of higher education is founded upon advancing knowledge in the field and disseminating that newly found knowledge. Many academics do not believe their charge to be job preparation. Clearly, though, education in engineering probably only will be applicable towards jobs in engineering and the same may be said for technology education. In the case of the sciences and math, however, there are skills that could be applied in arenas larger than just professions for mathematicians and scientists. Further, in the 'real world,' the vast majority of people would do well to really understand math and learn how to use and apply the scientific method. Higher education has not demonstrated that it is responding to this need, though.

More intention, more resources, and more support for teaching STEM skills and competencies in the arena of the liberal arts must be given. With pressure on universities and colleges to improve critical thinking, stressing the quality of critical thinking that comes with learning principles of engineering or learning how to trouble shoot in technology may properly approach this goal of quality in STEM. Therefore, in following Aristotle's approach to change with four causes, the final cause, or goal, of STEM education could be a planned approach to providing basic literacy in STEM, instructing critical thinking, as well as imparting specific skills for certain professions and industries. Additionally, by retaining these students and imparting these skill sets, higher education will be equipping people to be engaged members of society, which was truly the final goal and outcome for philosophers such as Plato and Aristotle.

Material Cause

Now, the material of STEM is not going to change by its mere definition. Teaching STEM 'properly' means serious thought must be given to teaching towards jobs and, more importantly, skills such as critical thinking. One possible approach to generating a planned approach to the material of STEM education would be to review the material of STEM curriculum alongside something like Lumina's Degree Skill Profile and determine the competencies and skills that should be generated from such an education.

In more straightforward terms, to help achieve the goal or final cause of intentional STEM education, consideration needs to be applied to what are the core competencies that accompany science, technology, engineering, and math. As noted earlier, this can be more easily done with technology and engineering but something significant is missing if the same skill competency present in math and science cannot be demonstrated. So, with respect to Lumina's Degree Skill Profile, it should be determined if STEM is being taught as a matter of broad knowledge, or as an intellectual skill, or is it a matter of specific, specialized knowledge.

Essentially, the matching of STEM curricula to potential jobs must account for not just major coursework but also general education courses and electives. That is, specialized outcomes and skills are typically indicative of major coursework but students will only arrive at this curriculum if the broad and intellectual competencies sufficiently prepare them for success in more advanced coursework. Moreover, this broad approach should provide enough literacy in the concepts and language of math and science that this knowledge can be applied in nearly any career or vocation.

Considering that success can be found with teaching STEM concepts integrated with other disciplines, interdisciplinary coursework should identify an appropriate level of math needed in order to be successful, for example. Even in majors such as psychology and business management, it is not uncommon for statistics courses to be required. There is an assumption that students are truly ready for such advanced material after meeting general education requirements. Such a broad approach to STEM material in general education courses doubtfully prepares students for more advanced courses such as statistics and business calculus. These are highly specialized fields of knowledge that are really within the realm of STEM more than psychology or business management. Perhaps, there ought to be an intellectual field of knowledge to help develop students' understanding from broad concepts to more specialized material. With supporting evidence of success of STEM curriculum in other disciplines and in the developing of cognitive competencies, support and resources could be garnered more easily.

This is reflected in classical thought, as philosophers such as Plato understood the importance of subjects like geometry in preparation for vocations. Yet, it was the ability to think mathematically that made individuals able to understand the forms of things and even the moral forms. In some sense, the philosophers were using a cross disciplinary approach to education and the utilization of math and science as subjects of study.

Formal Cause

The next point regarding Aristotle's view of education is that different levels of teaching should be appropriate for different learners. Unfortunately, in the ancient Greek culture, many of these different learners were identified by class or race rather than ability. Still, the varying classification of education is appropriate for us to explore. In fact, some of these practices are already being utilized today.

After a basic childhood education, which included play and socialization, women, according to Aristotle, could and should learn the basics in maintaining a household. One might call this "home ec." Slaves could learn traditional trade work or attend a vocational technical school. Men from the aristocracy, though, would actually obtain higher education on par with philosophy and the sciences (Frankena, 1965).

Plato had a similar approach to education in the *Republic*. Students would begin with trade work and vocational training. Those who wanted to pursue those endeavors could leave and enter the 'business world.' Those who stayed were training in physical education and those who stopped after that would enter the military. Finally, those who remained behind would actually obtain training in philosophy and mathematics (Barrow, 1976).

These structures point to an area of policy that can be changed in universities and colleges to help students become successful in STEM courses. These policies may be admission requirements or remedial coursework requirements, just to name a couple of examples. The benefit to a policy approach is that it can be implemented possibly with little or no cost. Also, the workforce necessary may only extend as far as an organization's policy committee. As lack of resources can be a major obstacle to the STEM agenda, an approach for measuring success will be needed for justification.

Efficient Cause

Finally, the efficient cause must be evaluated with respect to the instructor. Aristotle's approach to change is based on his understanding of the physical sciences. His approach to philosophy was informed by the same belief system. And, ultimately, his approach to teaching and educating was based on the same findings.

After the students' understanding of the material is identified, then the instructor is to move on to demonstration of the material. In demonstrating the subject matter, the proper form of how the material is to be understood and manipulated is illustrated. So, one should be cognizant if she is teaching STEM concepts to basic learners who only need literacy in the field or if she teaching the material to students who need to apply the knowledge to another field such as business or psychology. Of course, one also needs to account for those who she is teaching to go further in the field and advance the depth of knowledge through research.

Cooperative education and internships are standard in most colleges and universities now, but Aristotle was perhaps the first faculty to employ such practices. It is said that at the Lyceum, students did continuous scientific research, which Aristotle used for some of his own research and philosophy. Moreover, the students were encouraged to take responsibility for the governance of the Lyceum. As such, they were able to utilize real experience in both research practices and professional settings. This was an inherent part of Aristotle's approach.

By allowing practice, we trust the student to experiment and possibly make mistakes. In almost any level student, this practice must be valuable with some form of 'real world' application. Most students do not come to STEM courses with an internal drive or motivation to master the concepts. Rather, they simply want to get through it. As a result, these students never perform at the level that we see fitting of the STEM agenda. While some students do have the 'heart' for STEM, instructors must take care to provide meaningful experiences to the remainder of the student body who would benefit from seeing the value of STEM skills and competencies in application. From a teaching perspective, real-world, situation based examples would be greatly beneficial. Realistically, this approach is teaching a new kind of skill or competency but it works as many students truly learn by doing or learn by experience that is meaningful.

SUMMARY

In addition to evaluating change from the perspective of planned versus accidental, Aristotle also viewed change in terms of the transition from a potential state to an actualized state. The STEM quality agenda is in a state of potentiality. It has not been actualized fully. If Aristotle's four cause theory is used and reviewed with attention to intentional change and actualization, then the true work will be obvious.

The ancient Greeks, perhaps the first faculty of western civilization, not only had strong philosophical foundations for their views on education and development; they also enacted and practiced what they taught. The crux of what should be done today for STEM education is to return to these ancient practices and strengthen current practices that improve STEM education quality.

First, the varying approaches to education and outcomes that underpinned the Academy and the Lyceum should be adopted. Next, Aristotle's philosophy on the four causes in addressing process, policy, procedure, and practice improvements should be utilized. Lastly, Aristotle's pedagogical practices can be used to improve the quality of STEM education.

SUGGESTIONS FOR BEST PRACTICE

In applying Aristotle's process for change to STEM quality in higher education, the following list of suggestions comes directly from the four cause approach for change.

Formal Cause

A significant challenge facing students and universities alike is the lack of preparation of students to perform in college level STEM courses. In fact, this particular issue has challenged a number of colleges and universities to revisit their specific policies. Effectively, due to the high demand for resources across all academic channels, a policy approach can often afford a cost beneficial resolution to some of these difficulties in advancing the STEM agenda. For example, admission requirements could be the first issue to be addressed in order to not only get jobs but to think critically. This could also be repaired through policy changes that can help students such as making Becoming a Master Student courses or Principles of Learning courses mandatory for returning adult and/ or new students who also need remedial coursework.

Further, to ensure that the change desired can be affected in the quality of STEM education, there needs to be additional funding for professional teaching development, tutoring resources, and possibly additional workforce to assist in the overall process.

Efficient and Material Causes

At the level of efficient and material causes, the instruction of faculty and adjuncts need review and evaluation. The final cause being the performance of our students requires the evaluation of actions performed in attaining that goal.

Full time faculty, akin to the model of Plato's Academy, must acknowledge when they are instructing future educators in the field and when they are teaching skills and competencies to those who wish to apply the knowledge to different fields of study and practice. Aristotle taught by asking Socratic type questions, demonstrating the proper method, allowing students to practice, and then reviewed the entire subject again as a wrap up. Individually, these pedagogical points all connect to science and philosophy. Students must be questioned to see where their understanding is at: how much they know already or not. There is no belief that they already know the subject inside and out before instruction, but there could be some surprise regarding what they may already know. In some manner, the weight of this is on identifying how much material is already present with which to work (Frankena, 1965).

Additionally, instructors must use life and experience to help in the "what's in it for me" category for students. A genuine problem may be that this is easier with adult students, who have experience, but a similar approach can be taken with traditional aged students by providing service learning or community based experiential learning (Gelmon et al, 2009). By building partnerships with non-profit community organizations, real experience can be found for students that make the material more tangible. For example, in *Using Quality Benchmarks for Assessing* and *Developing Undergraduate Programs*, the authors specifically note that 'STEM disciplines are rife with opportunities to infuse service learning systematically into the curriculum (Dunn et al, 2011).'

Final Cause

The majority of STEM discussions focus on jobs and performance. By taking a similar approach using badges, stackable certificates, and traditional degrees in combination with degrees such as associates to bachelors, masters, and so on, the focus on jobs and performance can be matched. Moreover, another aspect to consider from the liberal arts perspective is that this kind of learning and critical thinking is how citizens become functioning members of society (Gelmon et al, 2009).

If the STEM agenda is to be advanced in education and the workplace, then the skills and competencies that accompany STEM must be properly understood against the backdrop of how those skills are beneficial to society overall. In both Plato's Academy and Aristotle's Lyceum, the goal of education was to instruct the citizens of the polis. Jobs were actually the secondary consideration. The primary focus was on instructing the public on how to think and how to do so critically.

CONCLUSION

The largest disconnect between higher education and the business community is how competencies such as critical thinking are taught or trained. Truthfully, experiential learning is a great way to examine the steps in critical thinking and decision making but sometimes it is difficult to create such experiences in the classroom. If business leaders are concerned that critical thinking is lacking in college graduates, then more attention and intention must be directed to the STEM agenda.

FUTURE RESEARCH/WORK

This final section is additional application of Aristotle's change process but specifically to work done at my college, which is an adult and professional college. There have been two main areas of emphasis in the past two years: college policies and adjunct performance.

Formal Changes in Policy

With returning adults, the lack of preparation is compounded by the number of years a student has been out of school. Moreover, due to accreditation policies, remedial courses no longer count for credit. Effectively, this creates a disincentive for returning students to take necessary courses to be successful in classes such as college algebra. Part of what needs to be imparted to these struggling students is a kind of STEM literacy. The concepts simply do not make sense as the words themselves may be difficult to understand and many adults have grown up, literally, with the belief that no one uses math and biology in the 'real world.'

Regarding the issues of remedial course policies, my college is considering packaging a set of classes for those who test into remedial courses including a returning student course, a basic math course, and a fundamental writing course that would be mandated for all remedial students. The result is not doing away completely with remedial courses as some other universities have opted to do, which would be detrimental to returning adult students. These courses already exist in our college but have not been put together as a package to assist our returning students. Ultimately, critical thinking must be viewed as not just a linguistic faculty but a mathematical one as well.

In our package of remedial courses, we are also going to attach an assessment 'pre-test' to evaluate the level of competency. Along the student's academic career, there will be another course used to collect 'post-test' data to evaluate competency and cognitive skills that tie to professional standards, which really is a best practice (Dunn et al, 2011). Of course, the goal is to see improvement and this will be reported at an annual assessment meeting held on campus. At this time, we do not have any data collected as this process is being reviewed as our response to this STEM/remedial coursework problem.

Efficient Changes for Instruction and Evaluation

With respect to instructor evaluations, another philosopher by the name of Jeremy Bentham may be worth studying. In chapter four of *Introduction to the Principles of Morals and Legislation*, Bentham created a quantitative measure for moral decision making, which could be a talking point for creating a qualitative measure for instruction. Consider his seven points and the application question added to each one:

- *Intensity* (**I**)--How intense is the "good"?
  - For adjunct assessment, how high are the survey scores?
- *Duration* (**D**)--How long does the "good" last?
  - Are these high (or low) survey evaluation scores only satisfaction scores or are additional aspects of instruction being measured?
- *Certainty* (**C**)--What is the probability that "good" will occur?
  - Do these instructor evaluation results match competency assessment results?
- *Propinquity* (nearness or remoteness) (**N**)--How far off in the future is the "good"?
  - Do students only recall information for next day use or do we have evidence that they are applying it to later projects?
- *Extent* (**E**)--How many persons are affected by the "good"?
  - Who does this decision affect? Instructor? Administration? Policy?
- *Fecundity* (**F**)--What is the probability that this "good" will lead to other "goods"?
  - Does high satisfaction or generally high survey evaluation scores lead to future, consistent competency performance?
- *Purity* (**P**)--What is the probability that the "good" will not lead to other "goods"?
  - Is this only a satisfaction result that has no connection to competency performance? (Bentham, 1907)

These seven points compose Bentham's hedonic calculus, which was a mathematical formula for determining an appropriate response to a moral dilemma or question. While this generates a quantitative measure, a similar approach could be used to create a qualitative response for instructor effectiveness in STEM courses. To be honest, this is in its nascent stages at our collage and this particular kind of performance measure does not appear to be utilized at any other institution as it appears most faculty and instructor evaluation foci also captures service and research, not just teaching (Dunn et al, 2011).

Currently, we do compile a set of evaluation and assessment data to try to mimic this kind of qualitative evaluation. We collect course evaluations, grade distribution data, class attendance data, and track adjunct training and professional development attendance as well. While these are quantitative data, a more composite qualitative picture of adjunct performance can be gleaned from these numbers, which help inform our class assignment decisions and professional development agenda.

While these two areas of future work have actually been areas of focus in my college, there is tremendous opportunity for creating community based experiential learning opportunities, particularly with a focus on performance in STEM subjects. Perhaps the best assessment will be utilizing the community based experiential learning initiatives and determine how these partnerships impact career and job transitions.

In sum, from a 'classical' perspective, the ability to think critically makes an individual a valuable citizen in society. While the STEM agenda seeks to help in career preparation and performance, ultimately, this goal of critical thinking for all members of society should not be neglected in the current STEM agenda discussions.

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