A High School Curriculum Focused on Engagement

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In the moment versus the long haul? *Given we know that students' motivation and patterns of engagement are quite volatile, changing as they move from teacher to teacher, subject to subject, and activity to activity, how to effectively structure learning experiences at different levels of time-scale to promote long-term valuation of STEM subject matter is the central question of my academic life.*

In recent work, my colleagues and I examined the High School Longitudinal Study of 2009 (HSLS: 09), and subsequent follow-up surveys of high schoolers in the US. What we have found is that kids enter high school about evenly split into thirds: About are contemplating STEM careers, about 1/3 definitely *don't* want to continue in a STEM career, and about 1/3 are like most 9th graders. They haven't thought much about what they want to do 4 or 8 years down the road (Mangu, et al., 2016). Two years later, when these same students finished 10th grade, they were again about evenly split into the same thirds. BUT, we found that there were many students who we termed, "switchers," who originally aspired towards a STEM career but two years later *didn't* select STEM careers as potential future jobs. Moreover, there were many who originally *didn't* want to go into STEM as 9th graders who, two years later, *did* select STEM careers as their potential future options. Many from both categories became undecided while many of the undecided moved into selecting both STEM and NON-STEM careers as 11th graders. To probe into why this might be the case, we examined their motivational attitudes in 9th versus 11th grades. There was little to no correlation between students' responses in 9th grade and their responses in the 11th grade.

We interpret these findings to suggest that there is great variability in students' experiences in the early years of high school. This is following on a huge period of change (generally decline) in students' math and science motivation in the middle grades (Martin, Way, Bobis, & Anderson, 2015). Moreover, students' experiences are highly varied, depending on the teacher and the emotional and academic support provided (Alexander, Johnson, & Kelley, 2012). Some things are happening in between 9th and 11th grades that turn some kids on to mathematics and science, and some things turn other kids off, at a critical time in their academic development. Beyond about the 11th grade, there is little turning back: A student who opts out of STEM-related coursework will find little opportunity to opt back in in the future.

We are currently studying the development of mathematics engagement in high schoolers, beginning in the 9th grade and moving through the end of the 10th grade in several school districts in Arizona and Delaware (Middleton & Jansen, 2017). The role of the teacher and her/his emotional, academic, and personal support, the nature of the tasks given students and their perceptions of those tasks, the social structure of the classroom, and students' personal interests and predilections are being studied through mixed-methods, longitudinally. We are following the same kids individually as they move from 9th grade math through 10th grade, tracking the changes in their engagement in the subject matter.

A particular challenge we are finding is the irrelevance of mathematics tasks and experiences to the lives of students. As an example, polynomial functions are taught with little to no real connection to the world of work, or even quality fantasy contexts wherein the properties of these functions can be imagined as meaningful and useful. Often the science curriculum provides some remedy as mathematics is nearly always *used* in science in service to some important concept or investigation. Likewise, engineering provides utility for the mathematics. But the science, engineering and mathematics curricula are disarticulated in middle and high school. Science curricula, for example, focusing on exponential growth in biology, or statistical concepts such as correlation, uses mathematics concepts and skills that are not taught in mathematics until years later.

There is a good body of research on this issue of relevance. Two types of perceived utility (i.e., *instrumentality*) seem to make a difference in students' interest and self-efficacy related to math and science: *Exogenous instrumentality and Endogenous instrumentality.* Briefly, these aspects of utility focus first on whether or not the outcomes of what one is doing will impact the learner in the future. Endogenous instrumentality is a belief that what one is learning in-the-moment is valuable for one's future — e.g., whether or not knowing the end behavior of a 4^{th} degree polynomial will be important for me as a biologist. Exogenous instrumentality concerns the belief whether or not the *outcomes* of my effort (e.g., obtaining

grades or recognition—extrinsic contingencies) will contribute to one's future—e.g., whether or not my score of 73% on a polynomial chapter test will impact my ability to take AP Calculus (Husman & Lens, 1999). These two beliefs are tied to one's present and future goals in distinct ways: Kim (2016), studying 765 undergraduate engineering students, found that endogenous instrumentality was a stronger predictor of students' mastery goals and situational interest in the subject matter than exogenous instrumentality. In contrast, exogenous instrumentality weakened students' motivation and their achievement. This was especially apparent for students with low self-efficacy.

There isn't really a good exploitation of the large body of research on motivation, engagement, and utility in mathematics, science, or engineering curriculum design. Most attempts at motivating students appear to be surface level — embedding a task in a supposed occupation without really treating the concepts like the professional in that occupation would — or ancillary, focusing on games or music, or images that are not central to the science, or the mathematics being taught.

My dilemma is thus: What would a learning environment focused on truly engaging high school students in mathematics look like? How would dealing with relevance cause changes the ways students interact socially in the classroom? How might endogenously instrumental tasks enable students to develop interest in the subject matter? And, how would such a curriculum be woven together with science coursework and engineering experiences such that they each mutually support each other?

Venture

Building Endogenous Utility: Working Together to Fundamentally Change the High School Curriculum

As I reread *Project 2061*, and the *NGSS* and the NCTM *Principles and Standards for School Mathematics*, and much of the *Common Core*, I wonder at the inertia of a system that can't put these good ideas together to create a set of learning experiences that is more relevant and rewarding for students—authentic, if you will, to the fields that we love and call our own. What if we did just that? What if the broader learning trajectory of mathematics, biology, earth and space sciences, chemistry and physics, and engineering disciplines, were mapped out as a common (if vast) structure? What if the critically important ideas in each were identified, and the common ideas that support each discipline were *planned* together so that they could mutually support each other? I venture to say (see what I did there?) that with such a basis for instruction, the nature of teaching subjects would change dramatically. The tools for teaching would also probably change to be more useful over a longer period of time.

What I am proposing is the following. To: 1) Scrap current perceptions of the high school curriculum; Order of topics within and across courses, the distinct and separate nature of course, the notion of why we have content-specific courses at all, and time constraints and technologies should all be challenged such that the actual experience of learning STEM, and its trajectory over time, can be better envisioned; 2) Bring together subject matter experts and discipline-based researchers from each discipline to a common table to return to first principles, challenge those principles, and begin to build plausible learning progression(s) in STEM wherein ideas in one area follow from and contribute to, ideas in others. This is not necessarily curriculum integration, but careful, mutual, curriculum design; and 3) Develop tasks and learning experiences that would engage students by envisioning how their current experiences interconnect (or not), and lead to the fulfillment of their own intrinsic goals and motivation(s).

"Ideas," as Dewey wrote back in the 1920's "gain their meaning through use." I hypothesize that Endogenous instrumentality can come to rival Exogenous concerns, in turn, helping students develop interest and inclination to continue in STEM related pursuits, whether or not they end up being scientists or engineers. There are many reasons why students may turn on or turn off during high school mathematics and science. Changing curriculum has shown to be causal in changing teachers' beliefs, and more importantly, their teaching behaviors. As such a truly engaging curriculum may serve as an important lever for keeping more kids in the STEM pathway.