Technology and Curriculum Structuring

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Introduction

Technology has once again jarred the walls of education. This simply continues the trend begun many years ago with the introduction of pencils, mass-produced paper, the abacus, television, cameras, and hand-held calculators. As in the past, the proliferation of technology throughout our society alters the world view held by our young. Students are joining investment clubs in high school and actively trading securities on-line. They gravitate towards entrepreneurial endeavors, not expecting "cradle-to-grave" professional careers. They appear to be more comfortable with change as a constant presence than previous generations. More importantly, students are arriving at our institutions conditioned with a high level of expectation about what technology processes should be efficient and what should not, based largely on their experience to-date. This bias imposes additional pressure on educators because students tend to place learning into the category of what should be efficient, which, by its very nature is not.

As computing technology saturates our educational environment, we find ourselves constantly examining our mathematics curriculum, our teaching methods, and the very underpinnings of our teaching philosophy. I would like to share a collection of thoughts on the resulting impact on the way we do business, and to hopefully stimulate a few productive ideas on where we might look to formulate a strategy for successfully operating within this environment in the future. For convenience, I will define technology as electronic hardware devices and computer software applications, since these categories are the most common of those associated with mathematics reform. However, in our current era, "technology" could also easily include things such as wind tunnels, vehicles, robotics, aircraft, transportation and delivery systems, bio-mechanical devices, lasers, DNA sequencers, and the like.

The organization of this paper loosely follows the order of the questions posed to the Technology Group, while allowing for a wee bit of meandering in the process. To begin, let me state my position on technology up-front:

- The incorporation of technology into our pedagogy is not, has never been, and will never be, *efficient* from the point of view of comparing the amount of start-up effort expended by a faculty member to the results achieved by students when viewed using traditional assessment instruments (written tests, etc.). The assessment instruments must change if technology is going to be an essential component of learning.
- The use of technology will always be considered as adjunct to course content, a "fifth wheel" so to speak, so long as its use is orthogonal to the main effort of a course as perceived by students and faculty.
- Today's students appear to be clever enough to either (1) learn technology on their own, or (2) find seemingly efficient (yet unorthodox) means of minimizing their use of technology to the point of achieving an academic performance level they perceive is acceptable for themselves, whether this be high or low.
- Technology has the potential to free up class time by enabling material to be segmented into two tracks (see Figure 1): (1) material that a student should be able to learn on their own in which their own perspective characterizes the principal value-added dimension, and (2) material that contains subtleties best revealed through active discourse in which the instructor's perspective (either through experience or education) defines the value-added dimension.

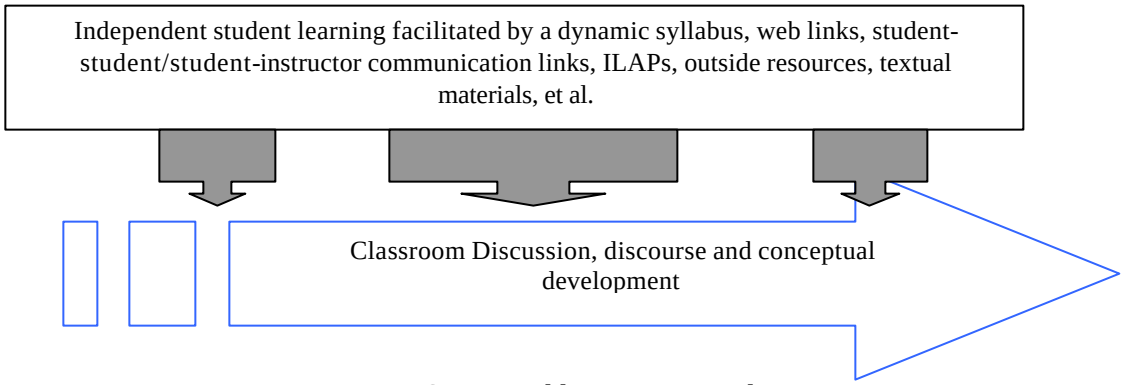

Figure 1. Segmented learning material.

With these thoughts in mind, let's proceed.

How should technology affect what and how we teach?

Let's first dissect the underlying structure to this question as posed. In an academic setting, there appears to be a natural tendency to not separate faculty and student perspectives. By and large, faculty perspectives on teaching are concerned with management issues: creating efficient methods for content delivery and course design, achieving the greatest "bang for the buck" in terms of effort expended for results (apparently) achieved, developing accurate assessment methodologies, integrating and coordinating curriculum across departments (partly for altruistic motives, partly for survival and continued perception of relevance within the academic institution), and so on.

On the other hand, the student perspective I have grown to appreciate is rather simply stated:

> *What students experience in a course should directly support what they choose to study for the remainder of their college experience, and simultaneously provide them with a measurable advantage in their career pursuit over someone choosing not to take that same course.*

I am not suggesting that every college topic be pragmatically measurable in a student's educational experience. However, I do submit that the tools introduced, the thought processes developed, and the tacit conditioning induced by the courses students take should matter, and matter in a substantial way as seen from the student perspective.

From a faculty perspective, "What should we teach?" is not necessarily the proper question d'entrée. Principally, we should teach what is in the students' best interest, both long and short term. A more appropriate question to ask is: "What mental constructs and abilities do students need to be equipped with in order to cope with and succeed in an increasingly technologically sophisticated world?" Asking "What should we teach?" leads one to examine the current content of Calculus as a baseline, subsequently determining what should be kept and what should be discarded. The failing of this approach is that it achieves a minimization of content variance over time while only tangentially addressing the underlying relevance issue. To its credit, this approach does seemingly protect the interests of those who have significant sunk costs into activities such as writing texts, producing videos, creating interactive websites, instituting nationwide standardized assessment instruments, or possessing a drawer full of accumulated materials and have (apparently) better things to do with their time that start over from scratch.

However, pursuing this approach is analogous to the situation in which an organization forecasts next year's budget based on the current year's expenditures: the result assumes the previous year's expenses were appropriate. Zero-based budgeting corrects for this assumption, but it is usually viewed as an arduous and painful experience. Consequently, there are not many advocates for starting course design with a clean slate, although I confess I am one, believing that modeling should form the backbone of a core mathematics program, not Calculus. But this is a topic for later discussion.

From the students' perspective, whatever material we teach should meet a set of minimal requirements:

- It should be *relevant* to their world view *now*, giving them a marked and measurable advantage in other courses they are taking, and set them up for success later.
- The focus should be the *problem*, not the tool. As such, it should make them better *problem solvers* in the most general definition of this term, not better tool manipulators. When the actual problem is the focus, the question of relevance is answered naturally.
- It should assist them in becoming discriminating users of information. They should develop a healthy skepticism toward information and be able to recognize bad information when they see it. This is especially valuable given the plethora of Internet resources.
- It should equip them to be better able to organize, extract information, and draw supportable and logical conclusions about increasingly complicated and sophisticated real world problems. Hence, what we teach should condition them to ask the right type of questions to accomplish these goals.
- It should help students to recognize when they are truly looking at a hard problem, as opposed to what their limited experience tells them is hard because of unfamiliarity with the course material or the task at hand.
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So what does this philosophy have to do with technology? Let me suggest a unifying conceptual framework involving technology within which one might intelligently seek answers to the content question. Technology plays a role in such a structure as the principal workbench for faculty and students alike. Its main function is to be able to rapidly present various alternative perspectives on ideas and material with the hope that one of these perspetives will appeal to the student. A corporate vice-president friend of mine who also happens to be a science fiction writer once stated to me that "[he] didn't see anything extraordinary about mental telepathy." With each story he wrote his challenge was essentially the same: induce the image in his mind for a particular scene in the mind of a person potentially thousands of miles away, possessing a dramatically different life experience, and perhaps very different world view, through the use of only a judicious selection of words and phrases. Imagine a student sitting in the middle of a polyhedron such as the one displayed in Figure 2. Now imagine that we, as faculty, exist outside the polyhedron, and each of the facets are significantly different ways of portraying a particular mathematical topic. Technology has increased both the number of facets at our disposal for use in education and the speed at which these can be created, presented, recalled, and manipulated. The educational challenge that persists despite technology is that the inside surface of each of these facets (the student's perspective) is not guaranteed to be the same as the outside surface (that faculty perspective).

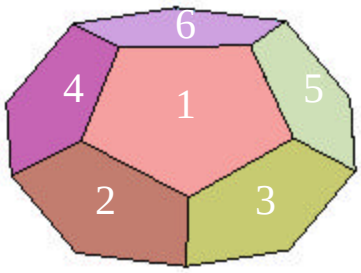

Figure 2. Perspetive facets.

Instead, there is a non-uniform probability of match associated with each facet whose distribution depends solely upon the student sitting inside the polyhedron. Technology should effect how we teach by better equipping us to cycle through the various facets in a decreasing order of match probability in an attempt to assist a student in formulating a view of the material that, if it does not match ours, at least is consistent with ours in the sense that it is a correct representation of the abstract structure associated with a particular mathematical topic. In other words, the picture a student formulates to understand a mathematical idea does not have to match the one that works for us individually; it simply has to be consistently correct.

- **What are the strengths and drawbacks of different technology choices, and how to match technology choices to specific audiences?**

Whoever said "Beauty is in the eyes of the beholder" could easily have been referring to technology choices in academics. At USMA, we have progressed through various experimental phases culminating in the situation we presently find ourselves in. Although each phase provided clues as to how best to proceed and adapt our technology strategy to achieve our academic goals, none have illuminated a globally optimal solution. And certainly, not all variations have been embraced by either the student body or the faculty. For example, we learned that dictating "every instructor will bring a computer to the classroom" in the late 1980's didn't work, as only about 5-10% of our faculty possessed sufficient visionary insights on how to use this capability effectively. With permanent computers and projection devices in our classrooms that are all linked to internal network, the number of faculty willing to experiment has risen substantially.

Ultimately, we recognize that our institution needs a unifying philosophy that enables us to look at an emerging technology and be able to state: "It's a great technology that someone, somewhere will be able to use, but it doesn't fit within our learning environment framework." Of all the technology efforts we've made to date, having this ability has been the most significant byproduct by far because it prevents us from investing in technology for technology's sake.

Our current learning model recognizes that the greatest proportion of student learning occurs in a situation in which they have ample time for exploration, discovery, reflection and iteration. This is clearly not the 55 minutes of classroom time allotted for our mathematics classes. For USMA, this time occurs when the students are back in their rooms since 100% of our student population is resident on-campus. Consequently, USMA equips each student desktop with the most powerful computing platform available, connecting it to an unrestricted conduit to information on the Internet. Student portability of these resources, which points toward notebook computers and the like, is not an indigenous characteristic of this design. Thus, we are not currently pursuing portable technologies whereas other institutions are.

Two observations are worth noting which directly result from our technology-enhanced learning environment. Technology affords a natural counter to student tendencies of perceiving their USMA education as physically isolated. Foreign language classes can connect to distant newspapers to view the latest cultural events occurring in the Baltic region, France, Spain, and others. Political sciences and sociology classes link to many sites around the globe to provide supporting material for their studies. Outside research laboratories, government and civilian organizations, and professional societies all have a footprint in our mathematics courses as a result of the technologies we have adopted. Students visiting these supporting sites get a preview of potential career fields as well as augmentation sources for course work. As teachers, we no longer are the sole source of information for our students, and neither is the course textbook. Because not all web sites are quality information sources, we want our students to become discriminating users of information.

Looking inward, technology holds great potential to counter student tendencies to view their academic courses as being modular, mutually exclusive experiences. We've exploited this

concept to complement our interdisciplinary efforts over time, especially with regard to the creation and use of Integrated Lively Applications and cross-departmental teaching. Moreover, technology allows us to actively link syllabi across the web, thus facilitating cross departmental awareness of course content and teaching methods, enhancing research, and making real progress beyond rhetoric towards achieving a coordinated curriculum.

Our focus in the classroom is on the human dimension of learning: engaging in discourse, exploring conceptual ideas, conducting student presentations, and helping students to form efficient frameworks within which to view course material. The resulting increased interaction with students greatly complements our efforts in mentoring future leaders. Within this framework, we also needed to have a practical workbench available in the classroom that could communicate key pictures and be able to reach out from the classroom to obtain the right resource at the right time. Thus, it was a natural fit to put both networked computers and projection technology into every classroom.

The drawbacks to our commitment to technology are few, but significant. West Point came to the realization quickly that we have committed to a lifetime of maintenance activities involving both hardware and software upgrades on a periodic basis. These are two sliding scales whose timing of events is never synchronized or convenient. We standardized the suite of software used by staff, faculty and students, and then unwittingly became dependent upon Microsoft and all its licensing nuances. Critical computing jobs are hard to fill, tough to keep filled once you fill them, and are a never-ending source of system weakness. Planned support for educational technologies is segmented by needed response times, and these tend not to follow organizational charts. When response times exceed tolerance, departments create in-house expertise to facilitate effective support. Departmental expertise in computing technologies waxes and wanes as the years progress, and this causes departments to incur additional administrative burdens to maintain continuity of talent in this area. Faculty must also be cautious to not develop an over-dependency on this technology functioning correctly, as computer crashes, network switch failures and general software conflicts occur on a schedule apparently set by Murphy's Law. Our students have a diminished time window of tolerance for technology in that, if they do not get the results they expect (perhaps unrealistically) from a particular application, or if it has a relatively steep learning curve, they are quick to dismiss it. This impatience is related to students' expectation of efficiency noted earlier.

The faculty at USMA have only begun to scratch the surface in making full use of technology within our mathematics curriculum. We, nor anyone else for that matter, appear to have discovered the real Holy Grail that sends our student population buzzing with excitement and yearning for more mathematics. Students and faculty that have invested the time and effort to experiment within this technology structure become enthusiastic advocates. The less adventurous manage to "sit and wait" on the sidelines, and the naysayers continue to attach their opinions to a small number of unfortunate data points, concluding that technology is an evil beast to be slayed.

How to match technology with an audience depends directly upon the institution's anticipated learning environment for their audience. Is it a classroom on-campus? A laboratory? A home office connected via WAN? A remote experimental site in the wilderness? What is the minimum technology assumption imbedded in the design of supporting materials? Will a low speed connection facilitate exploration and discovery? Or is the imagery and visual material too extensive for reasonable transmission time? Must the learning curve associated with this technology be experienced by the audience in order to shape their conceptual understanding of the material? Or, can it be eliminated altogether? Which sensory material supports this learning environment the best? Visual, auditory, tactile? Is an instructor "presence" required at all times?

Or, will occasional interactive sessions be enough? In what dimension does the instructor present the most value-added effect? Who is going to create and maintain the supporting materials? Is security an issue? How will the audience's learning be assessed?

I suspect that the eventual solution to effectively incorporating technology into education is one that reverses the fundamental roles of who is teaching and who is learning. Perhaps it does away with these roles entirely, making education a two-way cooperative venture in which the faculty have equal expectations of learning from the younger generation as the students have from the experienced generation of the resident faculty. In any case, it must be a dynamic, adaptable strategy that embraces constant change, not one that looks for stability in static components.