Teaching Intensely with Technology: A Zero Sum Game?

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Years ago I was a leader of a teaching team in what was known as the Integrated First-Year Curriculum in Science, Engineering, and Mathematics (IFYCSEM) at Rose-Hulman Institute of Technology [1, 2]. I was drawn into this project out of frustration concerning students who were seeing the same idea or concept in different contexts and were not relating them, nor was the faculty who taught these ideas attempting to relate the concepts and build on student knowledge and understanding. For example, sophomores at the time were seeing the raw, basic definition of vector in graphics, statics, physics, and multivariable calculus. I saw this happen one afternoon on a gentle hall wandering exercise with ears open outside four different (by department) classrooms. What did the students think of us that we, as faculty, would subject them to concurrent introductions to a fundamental concept in all our languages and discourse – vector? Why not become efficient, introduce the concept once and then use it in context in all areas, building further because of this efficiency? Indeed, why not combine the disciplines into one course – team taught by disciplinarians inclined to attempt to understand and appreciate the views of the other disciplines and to look for common ground? Later that same week a young man came to my office and asked if he could use the "physics" formulae for projectile motion in his physics text book for the examples of parametric equations we were doing in our calculus class. Did he think "g" was different over there? Why should he have to ask? Was it permission or was it intellectual permission? I.e., was he uncertain that ideas could be in common, could be integrated, could migrate, and could be multitasking? It was then that IFYCSEM was launched in my mind to help students make the connections, to integrate the ideas and concepts from the disciplines.

The history of IFYCSEM is just that -- history. I am on a different page now; however, the chorus is the same, but the verses are slightly different – some harmony and some dissonance. I revel in the harmony, but I am upset by certain dissonances. Again, I fear the students are being caught in the middle, being left out of the equation, perhaps for the sake of "whiz bang" toys in the hands of technology-enabled faculty (I count myself as one here) or for the sake of pencil and paper (or possibly papyrus and clay tablet) curmudgeons who decry the advances claimed by technology users.

Once in IFYCSEM with my teaching partner from physics, several times over the years in conversations with physics or engineering faculty, and recently from a science colleague I get this same old story. “I asked my students to differentiate sin(ωt) today and they gave me cos(ωt), no ω out front, no awareness of the Chain Rule.” The fact is that some (most? all?) could not symbolically differentiate sin(ωt) on the spot, that the Chain Rule was not in their blood. Mathematics faculty get this all the time -- even before the dawn of technology; our clients can point to any number of things our students do not know. I appreciate this feedback at times, but much of the time I just shrug and think to myself, “Does this colleague understand the nature of learning, where a student sees a concept once, uses it a bit, but has to revisit it in other contexts to really learn it?” The student who just barely learned the Chain Rule in her calculus class needs to have the concept reinforced in its use then and there, not grilled for a lack of understanding. The science instructor has a chance to make points with the student, not create negative vibes at lunch with the mathematics colleague. This is the chance for the science colleague to reinforce the Chain Rule and discuss the importance of it, lest it kill some one.

Kill someone you say? Consider oscillating phenomena – in an engine with a vertical displacement A sin(ωt). The force this object can impart on something in its way is equal to its mass times its acceleration, thank you MR Newton! This means its force is m times A times the second derivative of displacement. Now let us say we have a fast moving object like a piston in an engine, with a frequency of $\omega = 1000$ radians/second. This means that (using the Chain Rule) the acceleration is on the order of mass*A*ω^2sin(ω t) where ω^2 = 1,000,000. So that failure to invoke the Chain Rule means the calculated force by the erring engineer yields a force that is off (less than actually present) by a factor of 1,000,000! where the ! is for emphasis not for factorial, which would really cause havoc! Now, having miscalculated something by a factor of 1,000,000 will get an engineer a reduction in pay – to ZERO! Moreover, if this engineer signed with his Professional Engineering (PE) signature it could get a huge fine and/or free room and board in one of a number of select institutions in our country for professional negligence.

My point here is that colleagues need to take advantage of opportunities to support other colleagues not badger them. I cannot tell you how many times I have asked a student in an engineering mathematics class to build a differential equation model with a Free Body Diagram (knowing that the students have taken statics, dynamics, and mechanics) and found blanks in their eyes and minds. I cannot tell you how many times with these same students I have had them look at me with a blank stare when I ask them about moments (one group calls them torque, one calls them moments) in a discourse about center of mass. Did these students not see these concepts? NO. Did these students not learn these concepts? NO. Did the science and engineering faculty fail them? NO. Are the science and engineering faculty inadequate? Are they tied up in a battle over slide rule vs. Napier's rods for logarithms? Are they forcing something on these students? NONE OF THE ABOVE. The students just forgot, they did not use the skill in a while, they were not sure of it out of the context in which they first learned it, and as with our initial students they were tied to differentiating sin (3x) and were thrown with sin(ω t) symbolism, etc. These things happen.

What really gets to me is that such criticisms of technology-enabled learning and doing mathematics mask the opportunity that these client faculty have to build on what students from such a technology rich environment actually know. For such faculty continue to stipulate that the incoming students are inadequate because they do not possess the hand manipulating skills we all grew up with as young aspiring professor types. I say, "Get over it." I do not think that our students will ever attain and retain that skill that we had, certainly not the vast majority of students we mathematics instructors send out to the sciences. If not these skills then what skills? Well, they would have handled data more. No, they might not be able to plot log-logged data by hand. Indeed, some (and I hear this often too) might not even be able to take a set of data and plot it by hand on a sheet of graph paper – determining scale, assessing range, labeling, etc., but they could probably get a spreadsheet to do that for them and then estimate a parameter using a trend line or fit notion in the software with a short essay to follow on what is important in this study. The students coming from our technology rich classes would have practice at modeling, be it motion, growth, change, etc. They would have concentrated on the big picture, the meaning of mathematics AT THE EXPENSE of the manipulation of the mathematics. Yet colleagues concentrate on the inadequacies of students' hand manipulation of the mathematics, often losing sight of the big picture themselves. I had one chemistry professor tell me one time that a student could not understand what an integral is, what the integration process is all about, unless she could find the anti-derivative and evaluate at upper limit and lower limit, subtracting to get a number. Imagine, thinking that evaluating an integral is understanding it. But that is where some of our colleagues "over there" are and we have to move them, or rather our students have to move them. Our students who benefit (and I believe they DO benefit) from technology have to be given the chance to show what they can do, but faculty who receive them often deny them uses of technology, indeed, a prestigious school I know has every student purchase a laptop computer, use it profusely in mathematics instruction with a rich computer algebra and spreadsheet environment, while the sciences deny use of this technology on the where the "money is" for students – on exams. Indeed, one of these science departments makes the students purchase a purposely limited calculator and restricts their exam technology to that while their mathematics instruction tries to show them the benefits of a more open use of technology in all aspects of learning and testing. So what are these students to think? I believe I know what they think. They think we have not got our act together – and they are right! Students can get hurt in such an environment. Sure they know how to "act" in each professor's class. This one is a stickler for lab write-ups, this one wants essays, this one wants four place accuracy, this one wants the name in the upper right, this one says, "whatever" concerning form and substance even, etc. They can adapt – we did!!! That is not the issue.

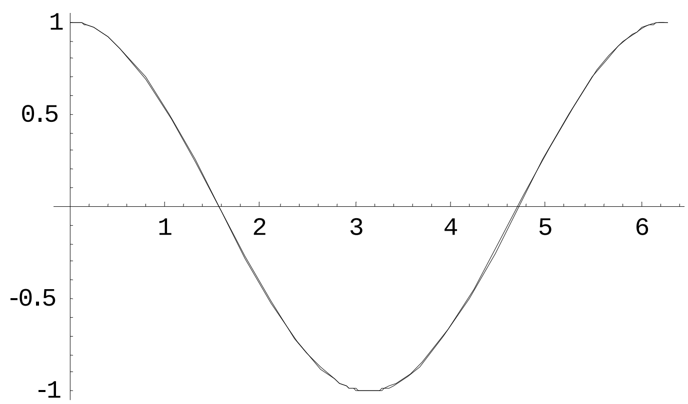
The real issue is we are losing out on a marvelous opportunity in the downstream and cognate courses from mathematics instruction that uses technology to build terrific problem solving abilities using that (and other) technology, to foster serious exploration through numerical and symbolic simulations, to concentrate on bigger modeling issues and less on symbol manipulation by hand, and to create more mature learners with rich tools for doing AND learning. These faculty are not preparing themselves to take advantage of what their students offer them, they are mired in a limited (albeit rich in tradition) way of solving problems and, in turn, they are truly limiting the students who come to them. I once had two students who had solved a complicated, data filled, numerically intense problem in their upper level physics course using the rich manipulative abilities of a computer algebra system with named variables instead of the problem offered numbers in the solution strategy. When the complete general analysis was done THEN they put the numbers in as a special case and "shook the tree" of their computer system for this solution to fall out, trivially. The instructor graded them down, saying this approach was unacceptable. What do you think they thought of that instructor? That instructor was not practicing what we preach, namely preparing for life-long learning. That instructor was practicing, "Be like me, of the past."

Be reasonable, you say. Well, there are legitimate concerns. For example chemistry faculty need to know their students know and can use the nomenclature of chemistry and some, therefore, do not want the students to have access to computers for exams. Do not throw out the baby with the water. Test them on nomenclature to your heart's content, but when it comes to the meat, to the substantive applications, do not deny students access to the power of technology to solve problems and, more importantly, do not deny yourselves (as faculty) the ability to question students deeper with more complex models and situations which could not be considered without technology. Better yet take advantage of the immediacy of the offerings of technology, e.g., I am looking at *Mathematica*'s Chemical Elements routines, simply amazing what they offer, all in one place, all in relation to the computer algebra system the students learn, use, and know in their mathematics coursework here at the Academy currently. Not every problem in physics has to be solved using the utterances, "By symmetry." Technology can permit explorations of asymmetric cases, can permit "what if" gaming on the very parameters that cause asymmetry! Let students continue (for they are doing so in their mathematics instruction) to explore, to be efficient. Yes they will forget things. I have forgotten – and during the 1950's I was schooled in the square root algorithm, I was schooled in interpolation of logarithms and trigonometric tables, I was schooled in polynomial divisions, etc. Why continue to do this to our students when machines can do all this for them, freeing them to think at a higher level, stimulated by graphical output from technology for example, and we can raise their sights to higher aspirations? Sure some will not make the journey. Do we think theses same students would make the journey if we withheld the "drug" of technology? Who are we kidding? Indeed, it may be BECAUSE of the technology that some will make it who did not make it before and make it with understanding. Think about this. Which is better at "convincing" a student of the derivative rule for sin(x)

(1) the derivation using the fraction (sin(x+h) – sin(x))/h with the standard pinching limit theorem applied to some obscure (to the student)sine of a sum of angles identity

OR

(2) plotting the fraction function (sin(x+.01) – sin(x))/.01 on the same axis – a trivial exercise with computer algebra systems. See the outcome below.



“Wait a minute,” you say. “There is only one plot shown.” Point made! And it will be made for the students. They will say the limiting value of (sin(x+h) – sin(x))/h as h approaches 0 will be cos(x) because of picture. Sure there are the pathology critics that will say, “Well they can be lead astray by such picturing, consider this pathology.” Anyone can nit, anyone can pick. We want to support student growth and discovery of some big concepts and technology can help that cause if used properly and with prudence. I argue that such learning should be continued beyond the technology rich mathematics classes we offer if the students and the faculty are to benefit in the future.

I say this to my colleagues who receive our students from technology rich mathematics classes. Embrace the students and the knowledge of technology they bring. Continue to relax when a student does not know a specific fact on the spot, perhaps let the student use the technology to recall, unearth, or discover the truth you want for them. The other night I used Google to help me decide – I have the capability of being a professorial forgetter – whether to use further or farther. My technology helped me. We all have our own epiphany on technology. Mine came a long time ago when I got a chance to use the powerful computer algebra system Maple on a VAX Workstation almost 20 years ago – WOW! Some colleagues used it to check by-hand answers, I used it to push beyond by-hand problems and open new worlds for my students. I would hope that once the new world is open, once Pandora’s box has been opened, once they have seen “Paris” that we will not try to keep them down on the non-technological farm. Huah! Go for it! Just do it!

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