The Development of a More Interdisciplinary Academic Culture

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It is our position that we are moving (ever slowly) toward a culture that accepts interdisciplinary approaches to teaching what has been traditionally disciplinary material. There are obstacles. Some are high, some are superficial, but nevertheless real, e.g., inertia of a system, fiefs and turfs, distance between offices, tenured dead wood, cynics, publish or perish syndromes focused on narrow results, etc. However, the evidence that the movement is growing is seen in the programs offered and accepted by supporting agencies, National Science Foundation, private foundations, and local faculty governance mechanisms; the number of articles written about and sessions at national and regional meetings on interdisciplinary efforts; and the ever present awareness of how engineering and science works in the real world with teams from different disciplines.

It is not easy to move forward for it takes energy and time and it is all too easy to slip back into the comfortable past we cherished, the disciplinary turtle shells which most of us have known all our lives. We address some of the issues outlined by the conference organizers to support our contention that it is both good and appropriate to move in the direction of an interdisciplinary culture. Indeed, Barbara Olds, a member of the EPICS program and an English teacher at Colorado School of Mines, some years ago wrote an end piece article in the ASEE journal, *PRISM*, in which she offered her own "modest proposal" to do away with all departments. We do not see that happening any time soon (unfortunately), but we do see more and more contacts being establish. Hopefully, these contacts will weave a web of connection and then identity among disciplines. This will make an effective teaching environment, which can then produce a powerful, broadly educated, richly exampled, student body – a student body, emerging with skills and experiences to solve tough interdisciplinary problems which face our societies.

What is the impact of mathematics reform on the partner disciplines?

Our colleagues outside the department of mathematics have stood by and watched how calculus reform has torn apart our department; alienated collegial friends; produced students who cannot differentiate sin(x) by hand; increased mathematics budgets for computers and thus cut into their own department's revenue stream; and caused students to say, "I can't learn calculus with a computer." Or "What do you mean write an essay – this is math class!"

Yet significant reform has taken place in physics, chemistry, and engineering. Chemistry is supported with an NSF funded initiative, modeled after the calculus reform effort and physics on its own within its community when the physicist discovered that after all their equationing the students just did not get it. Students continued to believe in the "Road Runner" physics they were conditioned by on Saturday morning TV. The mathematics reform which has stressed use of technology has been very attractive to some engineering and science colleagues, for they are proponents of "get on with it" engineering and have an interest in playing with parameters to address "what if" questions. Computer algebra systems support these investigations very well and the non-mathematics faculty are meeting mathematics faculty on a common ground in using this software to permit discovery and analysis of more complex systems.

Engineering education has been supported by NSF heavily and new curricula have emerged. As an example consider the Integrated First-Year Curriculum in Science, Engineering, and Mathematics (IFYCSEM) developed at Rose-Hulman Institute of Technology in the late 80's in which all the science, engineering, and mathematics course content is wrapped up into three 12 credit quarter courses in which a team of 8 faculty from science, engineering, and mathematics teach a cohort of some 90 students. This IFYCSEM has served as a model and has been modified by other institutions (e.g., Texas A&M University and University of Alabama) in the Foundation Coalition, one of several multi-million dollar engineering education coalitions sponsored by NSF.

Furthermore, mathematics faculty are visiting with engineering and science faculty for ideas to enrich their class and applications to present as projects, These are not just visits to see what they want us to do in mathematics, but rather true collegial exchanges. An example of this is our own work with Ed Mottel, chemistry professor at Rose-Hulman Institute or Technology in which Prof Mottel outlined a number of experiments which give rise to various differential equation models, $dy/dt = - k y^n$, $y(0) = y0$, of order n to model kinetics. These included sublimation of CO_2 and evaporation of acetone in various shaped vessels (petri dish or funnel) as well as traditional zeroth, first, and second order reaction kinetics in chemistry. Mathematics faculty are reading *and writing* more widely, searching for examples of illustrations for their own classes and seeking places where they can direct their students to witness mathematics in use and where their students can reach out and touch an application of mathematics.

How should science education reforms affect mathematics instruction (and vice-versa)?

The collection of real data in the field and its appropriate use to motivate/affirm a mathematical model is one example of how reform in science education can affect mathematics instruction. This data is often used to permit the student to build/assemble a personal model of some phenomenon. Consider the example of constructivism in science education offered by David T. Crowder (Faculty in Science Education at University of Nevada-Reno) in his article, "Cooperating with Constructivism," which appeared in the September/October 1999 issue of *the Journal of College Science Teaching*. The five main principles of constructivism, according to J. and M. Brooks in their text, *The Case for a Constructivism Classroom*, published in 1993, by ASCD in Alexandria VA are "(1) Use the problem's relevance to students in instruction. (2) Structure learning around primary concepts. (3) Value students' points of view. (4) Adapt curriculum to address students' suppositions. (5) Assess students learning in the context of teaching." As an aside, on (4) – valuing students' points of view, how many of us have heard (or even engendered an atmosphere in our class which would permit) "well, it seems to me . . . ?"

Prof. Crowder has his students "measuring the slope and velocity of bowling balls down constructed ramps" at the local bowling alley. Making reform in science education is relating science to activities with which students are familiar. This is not just in your "physics for poets" classes, but rather in main line science courses and introductory engineering design classes offered by many engineering curricula to foster and keep engineering students interested in the field. It is meeting students where they are "at" and working with them. Some folks in mathematics instruction are doing just that in modest ways. An example of this is the team of Bruce Pollack-Johnson and Audrey Borchardt of Villanova University. In their newly designed business calculus course they require student generated projects, i.e., students decide what they want to study and then build their own project using the mathematics at hand.

How is mathematics effectively integrated into the undergraduate curriculum?

Frankly, we do not believe mathematics is effectively integrated in the undergraduate curriculum. If it were, physics profs would not have to reinvent Fourier series for the students in optics, the students would remember this from their work in separation of variables strategies in solving partial differential equations; chemistry textbooks would not hide the "facts" of the differential equations describing chemical kinetics in the appendix; physics instructors would not be restricted to only the symmetric cases and encourage students to select the right boxed formula from their algorithmic physics texts; and engineering course work would not plod through old graphical approaches when students could use spreadsheets or computer algebra systems they learned to use effectively in mathematics courses.

There are probably several reasons for this lack of integration of mathematics into science and engineering curricula – and we believe it applies even more to the integration of mathematics into the social sciences. First, we have not done the best job in preparing students for the rough and tumble world of applications of the mathematics. Sure, our students can manipulate a bit, they can do the problem if they know the section of the book from which it comes, and they can push a bit, but not too far, with analysis. At times we have used different terminology, e.g., moment about a point and torque are used in engineering and physics and we need to tell our students they are the same when we first introduce cross product to define torque. However, students cannot bring their mathematical tool kit to the problem when it is out of the context of *that* mathematics. This may be because they are not truly familiar with what they have in their tool kit. More likely, it is because they have not practiced their mathematics out of the context in which they learned it, i.e., simple, one-step applications, as opposed to a timely use in the middle of a complicated situation.

Second, the way (order, logic, notation, motivation, etc.) we did the mathematics needed by the engineering and science faculty may not be suitable for their needs. It may be too general and thus need more refinement or it may not be encompassing enough and thus need expansion. Or it could just be that the professor of science or engineering who needs the mathematics we teach just does not like the way we did it and the students need to see it from the new discipline's point of view. Most often this is done without feedback or consultation with the mathematics faculty.

The way to integrate mathematics successfully is dialogue. Talk about what mathematics we do and *how* we do that mathematics. Throw in a healthy dose of *why* as well. Certainly, support and release-time help, but one-on-one conversation can kindle a great deal, visiting classes can help, and using each other's texts as source material (e.g., take your data set from the physics lab manual, your current students' lab reports, or the chemistry text book). Faculty "in the trenches" have to be comfortable in the other discipline, not totally versed, but comfortable, and confident their new-found colleague can bail them out when they get in over their heads – which will happen! All the programs, all the funding, all the initiatives can work only if faculty will but talk to each other and they will do that if they believe there is gain for students and for them professionally. The external forces and actions exist to support faculty dialogue and motion – and talk and action are out there more than ever. Thus we are hopeful.

When should calculus be taught and what other courses are needed?

Perhaps calculus should never be taught!!! Perhaps what is needed is a modeling course in which rates of change and accumulation are the themes and perhaps we should call it "Rates and Accumulation with Application." This certainly sounds less scary than the Calculus, with the big C. We need to know the clientele, their background, their anxieties, their desires, and their goals

in learning this mathematics. Faculty in other disciplines may not actually want to use anything we offer, just show it to their students. It is almost certain that these non-mathematics folks do not want their students to take our mathematics courses so their students can see how mathematicians think, or so they can learn to think like mathematicians. They have their own objectives in requiring our mathematics.

In the 70's we conducted workshops on microcomputer models for life sciences. We used BASIC as the language of simulation, instruction, and presentation to both high school and college life science faculty. We never used the words "differential equation," but always used the words "rate equation." Indeed, we used a simple Euler step method to say "change" and "update" to our new value from the old value. We would change our step size and note the better approximation because the plots would look more reasonable, not because of some epsilonics, but because of our understanding of the modeled phenomena. We relate this here because at times we can truly scare off our colleagues with all sorts of high-powered mathematical or technical terms, e.g., first-order, non-linear, ordinary differential equations. Think about "first-order, non-linear, ordinary differential equations" and then say it out loud. Now say, "rate equations." Then get on with the exciting part for the scientist, modeling and "what if"-ing. This is what the client wants, not an opening chapter on classification of differential equations.

How is on-going involvement of the partner disciplines maintained?

At some expense to both parties! Do not deceive yourself. It takes energy and time and these cost money. In each field new pedagogies are emerging, and in some cases in different ways. Cooperative learning in a mathematics class where one is trying to discover an underlying principle might be very different than in the class on truss building. Expectations are changing in each field. Data analysis in one field can be viewed quite differently in another. For example, traditionally in chemistry and chemical engineering one linearizes the functional model, usually by logging the data, and then fits a straight line. However, in calculus optimization applications one may directly fit modeling functions to data through a minimization of least square sums, thus avoiding the entire activity of linearizing and plotting logged data to see if the "transformed" model fits a straight line and then backing out the parameters from eyeballed slope and intercept information.

There are practical considerations too. Consider how one could benefit from a colleague's professional society meetings. What would you go to at the ASEE or APT meeting if you had never been there before? And who would pay your way? Approach your chair and say you need extra money for the other discipline's meeting where you want to go and visit and listen, not even present a paper. See what happens.

Conclusion

We believe there is hope for creating an interdisciplinary culture in undergraduate education. There is energy and light in this area already. It is appropriate to move in this direction in many schools. Faculty want to join with other faculty to learn more about other disciplinary views and methods and to share this new interdisciplinary paradigm with students. As a society of educators we can offer support, both financially and temporally, and we can lead ourselves, but we have to have patience and prudence in our efforts. For to push too hard creates some backlash, certainly some resistance, and we need to understand the sensitive human interaction which takes place along with the intermingling of science, engineering, and mathematics. We are confident the future will be one that reflects the broad view offered by interdisciplinary approaches.