Technology And Instructional Reform In STEM Education: Beyond the Classroom

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Abstract: Research in postsecondary education has focused on the pedagogical effectiveness of technology in the classroom. Most relevant literature focuses on students' cognitive development, professional development of faculty members, and the translation of courses and curricula into digital platforms. The AAU Initiative for the Reform of Undergraduate Education shows that many of the factors affecting the successful sue of technology in STEM education lie beyond individual faculty members and students. Reward structures that influence faculty time allocation are set at the institutional level. Administrators select educational software to control costs rather than to maximize learning. This presentation draws on recent experience with the AAU Initiative to describe the variety of factors potentially affecting faculty and student use of technology in teaching and learning.

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INTRODUCTION

Most efforts to improve undergraduate STEM education, including the use of technology, have focused on the classroom—the teacher, students, course content, and so. The literature on evidence-based instruction is focused heavily on the micro-level with particular attention to assessing learning outcomes and on relating pedagogical changes to those outcomes.[1] Most relevant literature focuses on students' cognitive development, professional development of faculty members, and course and curricular translation into digital platforms.[2]

After more than 40 years of investment by the NSF, various associations, and individual institutions and their faculties, we can now say that we have developed and tested a variety of empirically-proven techniques that are clearly more engaging and more effective at helping students learn than the traditional expert-lecturer-transmitting- knowledge model.[3] Yet this body of evidence has not led to the hoped for magnitude of change in STEM pedagogy and the desired outcomes of those changes, including the widespread adoption of effective technologies accompanied by improved student learning and retention in the major.[4,5,6]

AN ALTERNATIVE PERSPECTIVE

This focus on the individual faculty member in her or his particular course or courses can (and often has) succeeded for that particular individual. That approach, however, is bound to fail in the long-term for 4 reasons: (1) it does not acknowledge nor take into account the distinction between intrinsic and extrinsic motivation by individual faculty members, (2) it often fails to find a role for efficiency in implementing pedagogical strategies, which is crucial to help faculty members negotiate the variety of claims on their time, (3) it assumes that evidence of effectiveness leads others to adopt the innovation (i.e., dissemination), and (4) it does not place reforms in the larger college and institutional cultures in which the faculty work. To achieve long-lasting and broadly disseminated educational reforms this micro-level focus must be expanded to address 3 additional questions:

(1) How do we address complex learning outcomes that go beyond a single course i.e., where the "unit" is a curriculum? (2) Why don't more faculty members make use of proven techniques in their classrooms *even if they are aware of the empirical knowledge about their effectiveness*?[7] (3) Why don't successful reforms with strong empirical evidence about the effectiveness "naturally" scale-up and lead to broad dissemination?

To answer each of these questions requires a larger view of educational reform in academia, one that includes the role of individual faculty and their students *and* takes into account curriculum scaffolding as well as institutional and disciplinary cultures. I start with the intrinsic/extrinsic motivation debate as it affects educational reform in higher education. Many pedagogical reforms in STEM appeal to the intrinsic motivation of the faculty, i.e., their desire to see their students learn. Yet as Dancy & Henderson show the

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appeal to intrinsic motivation ignores the larger context in which faculty work--rewards, structure, and culture. It is this larger context that helps explain the discrepancy between what faculty members know about teaching versus their instructional practice.

A crucial factor influencing the decisions that faculty members make about their teaching is the time involved in instructional reform.[8,9] The research on effective STEM teaching focuses mostly on the nature of evidence and size of effects. According to the NRC report it does a poor job of translating research results into *efficient* ways that faculty may modify their teaching. For example, it is rare to find studies on STEM education that focus on cost-benefits instead of simply benefits. A small but statistically significant benefit may be useful in advancing knowledge. But the cost in time and additional TAs to teach in that manner may not be worth it to a faculty member (or, equally important, to one's peers, department chair, and dean).

Trends in the evaluation of teaching reflect a shift from faculty inputs (teaching) to student outputs (learning).[10] Even though the limitations of student ratings are widely acknowledged, the alternatives have not gained wide-spread acceptance in part because they are more labor intensive.[11] These alternatives include c*lassroom observation*, t*eaching portfolios and artifacts*), *interviews with faculty members*, and *surveys and interviews with students* conducted by external evaluators.[12] The challenge lies both in finding transparent ways to document and evaluate teaching effectiveness—observation and competency-driven portfolios clearly can provide more detailed understanding of teaching and learning than traditional student ratings—*as well as* translating these approaches into efficient methods for the promotion and tenure process.

Ultimately faculty members respond to (and help define) what matters most at their institutions. As important as time constraints are annual reviews and especially promotion and tenure decisions.[13] Hence the role of the department (and institution) in faculty teaching is more than allocating teaching assignments and defining expectations; it lies also in making judgments about faculty achievements and weighting them in faculty rewards.

BROADER PERSPECTIVES ON REFORM

All of these issues point to the need for a more systemic view of reform, including understanding the system in which educational innovations, including the use of instructional technology, take place. As a real example of how to take the broader departmental and institutional cultures into account, the Association of American Universities (AAU), the top 60 American and 2 Canadian research universities, launched the AAU Initiative to Improve Undergraduate STEM Education provides guidelines for educational reforms efforts in STEM, including those based on technology. The AAU Initiative starts *from the beginning* with a focus on sustainable reform with changing the culture of education as its overreaching goal. According to AAU, "the overall objective of the initiative is to influence the culture of STEM departments at AAU institutions so that faculty are encouraged and supported to use teaching practices proven by research to be more effective in helping students learn and in better engaging students in STEM education. The goals of the AAU Initiative are to:

1. Develop an effective analytical framework for assessing and improving the quality of STEM teaching and learning;
2. Support project sites at a subset of AAU-member institutions to implement the framework;
3. Explore mechanisms that institutions and departments can use to train, recognize, and reward faculty members who want to improve the quality of their STEM teaching;
4. Work with federal research agencies to develop mechanisms for recognizing, rewarding, and promoting efforts to improve undergraduate learning; and
5. Develop effective means for sharing information about promising and effective undergraduate STEM education programs, approaches, methods, and pedagogies."[14]

The AAU framework provides a set of key institutional elements central to sustainable change. This framework embeds individual faculty instruction with a focus on pedagogy within the larger curriculum (scaffolding) and the institutional and departmental cultures. The intent is to overcome the institutional inertia to large-scale reform so evident in most prior efforts at improving STEM teaching and learning. To date AAU with grants from the Helmsley Foundation and the NSF funded 8 institutions to initiative multi-departmental reforms in STEM during the first two years of undergraduate instruction. Another 33 AAU institutions expressed interest in forming a larger network to promote these reforms.

SUMMARY

Let me conclude with some words about the AAU Initiative and why it's exciting. AAU primarily has been a lobbyist for research. Rarely has it engaged in reform of undergraduate education. That it is doing so now is in part a reflection that AAU presidents see the importance of showing their constituencies that they care about undergraduate students. Tuition at public 4-year institutions is the fastest rising sector of cost exceeding even health care. If our top institutions seem to not care about those students the political and potentially fiscal damage is onerous. Relatedly, all 62 AAU institutions have appointed a contact person for The Initiative. This again speaks to the importance of the effort by university presidents. The level of presidential support —in part out of necessity—is a missing ingredient from many past reforms at undergraduate education. Having an empirically-based framework for reform as part of The Initiative also may prove useful at the local level. It seems possible today that we have more of the important elements for reform aligned including a critical mass of faculty members on a single campus who are committed to these ideas.

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