The computing community is only beginning to understand the wide variety of education challenges it faces. Our field lacks diversity, the general public misunderstands the nature and relevance of our field, and, as in many other fields, interest in undergraduate education often takes a back seat to research. This white paper focuses on common obstacles to the systematic improvement of teaching and learning in computing. Heavily borrowing former Carnegie Foundation president Ernest Boyer's ideas, I suggest taking a research-oriented approach to teaching and learning, in order to achieve lasting, positive impact on undergraduate education. Although I discuss this mostly in terms of what individual faculty members can do, I also suggest how educational institutions and research funding agencies can change to support faculty efforts.

Why don't more faculty pay more attention to the improvement of undergraduate education?

Many faculty want to improve their teaching but do not know where or how to begin. Others are not inclined to focus on teaching, because they feel their teaching is fine as is. Still other faculty associate teaching development with sacrificing autonomy, *e.g.*, being told how or (worse) *what* to teach. Perhaps the most significant challenge is the traditional separation between teaching and research. Not only do most faculty approach the two activities with different standards and processes, many consider teaching a burden that interferes with their research careers. To a great extent, the culture ("publish or perish") and policies (*e.g.*, "buying out" of teaching) of academia reinforce this clash between teaching and research, and teaching is usually the loser.

Some faculty prioritize teaching, particularly at smaller, liberal arts institutions and community colleges. Unfortunately, all too often, these efforts occur in small, isolated communities, neither building on past innovations nor propagating beyond the originating department (or even faculty member).

When you pick up your teaching hat, keep your research hat on!

There are no simple solutions to the above challenges, but there is a versatile, time-tested approach that we are all already very familiar with as faculty. Why not approach teaching and learning with the same kinds of standards, practices, and respect that we apply to our research in computing? This is essentially what Ernest Boyer advocated in his report, *Scholarship Reconsidered* (1990). Traditionally, professors have regarded teaching as an activity that is independent of or even mutually exclusive with research. Boyer encouraged faculty to expand their notions of scholarship to *include* teaching—to engage in the "scholarship of teaching and learning". Examples in the next three sections illustrate how a research orientation can help faculty face the challenges discussed above, as well as the support roles departments, institutions, and funding agencies can play.

Make teaching decisions based on theory and evidence.

In our traditional research work, we rarely make claims or decisions on the basis of intuition alone. We carefully scope the problem, we study related work, we identify goals and define measures of success, we accordingly design studies to validate our claims, and we try to justify and state explicitly what few assumptions we feel are necessary. Nothing precludes doing the same for our teaching decisions, *e.g.*, how to choose an appropriate in-class activity, how frequently to test the students, how to order the topics in a course.

All this is not to say that we must all engage in novel education research. We can all make teaching decisions in a more scholarly way by referring to the growing body of education research in computing and related fields. Particularly as computing researchers, we feel comfortable acting on theory and evidence. We might expect a research-oriented approach to teaching to be successful (if demanding) with faculty who dislike "being told what to do" in conventional teaching development settings.

Develop and share a research-based body of knowledge on computing education.

The scholarship of teaching and learning entails more than isolated faculty members making principled decisions, however. It also includes sharing and contributing to a body of computing education research, *e.g.*, on student learning and best practices in teaching. As with traditional research, peer review and publications can serve as mechanisms for collaboratively developing and archiving this body of research. An early example includes "another ICER", the International Computing Education Research Workshop, whose inaugural meeting took place last October [AFG05]. Publication fora like the ICER workshop can serve as a resource for faculty members and help disseminate new ideas on computing education.

This body of knowledge need not and indeed should not be built up from scratch. Rather than "reinvent the wheel", we should learn from the experiences of other communities who have gone ahead of us in researching education in their respective fields, *e.g.*, mathematics, physics, and the growing engineering education research

community. Even if their findings do not generalize to computing, we can learn much from the research questions they examine, the methods they use, and how they support and engage in education research as communities. For instance, what can SIGCSE learn from the extremely active and growing Educational Research and Methods division[1] of the American Society for Engineering Education?

Demand rigorous evaluation of teaching and learning.

As teachers, we frequently make assumptions about our teaching and our students' learning, *e.g.*, whether our students understand a concept, whether our students are motivated, how much time our students spend on our courses. A scholarly approach to teaching entails testing these assumptions, recognizing that most course evaluations are too crude, too limited and too late (after the term is over) as a formative measure of success. Excellent, easy-to-implement examples are Classroom Assessment Techniques (CATs) [AC93], which VanDeGrift *et al.* adapted for computing instruction [SV03]. These short, in-class activities provide both the professor and student a "reality check" on the level of student understanding.

SIGCSE and other communities devoted to computing education must also recognize the need to move beyond (but not necessary abandon) informal, personal accounts. Although labor- and resource-intensive, carefully designed research studies provide the detailed evidence necessary to assess the effectiveness and limitations of teaching innovations. Learning takes place in complex, social contexts, not a controlled, lab environment. Education research can help us understand how context affects the success of a given teaching practice. This enables a faculty member considering adopting (and possibly adapting) the teaching practice to make an informed decision based on their local situation.

Not just for the faculty alone...

Many changes are necessary to cultivate scholarship of teaching and learning in computing. While the general research orientation is familiar, most computing faculty lack the specific research methods, background, time, and support necessary to even be informed consumers (let alone producers) of computing education research. This highlights the importance of departments, institutions, and research funding agencies—all parties who substantially influence the support and incentive structures that affect faculty.

Departments and institutions will need to do more than simply provide their faculty with the time and resources needed to treat teaching as a scholarly activity on par with traditional research. They must reconsider hiring, promotion, and tenure criteria that set up an imbalanced incentive structure, effectively discouraging the scholarship of teaching and learning in favor of promoting traditional research.

Funding agencies can also play a role by demanding more rigorous evaluation of the teaching innovations and academic support programs they support. For example, many funding programs for K–12 outreach do not require grantees to allocate sufficient resources to rigorously evaluating funded activities and outcomes, not to mention dissemination of findings. If evaluation continues to be treated as an afterthought or optional component, the impact of these funding programs are doomed to remain local and unreplicated.

Funding agencies and departments alike could also support interdisciplinary collaboration with social scientists and education researchers, facilitating high-quality scholarship in computing education. Rigorous evaluation and other aspects of computing education research require both our knowledge of the field *and* the methodological expertise of other fields. In the long run, perhaps computing education will respected and supported as a specialization, building on the pioneering experiences of engineering education doctorate programs at Purdue University and the Virginia Institute of Technology. Meanwhile, there are already examples of successful collaborations with and contributions from social scientists (*e.g.*, in the area of gender and computing [MF01, Coh01, GB05]).

This white paper provides only glimpses of how the scholarship of teaching and learning can help us advance beyond isolated, ad-hoc efforts and toward a community of researchers collaborating on systematic, rigorous improvements in computing education. Faculty from computing might be the critical agents in this change, but other fields, departments, institutions, and funding agencies will have to actively support their efforts.

[1] http://fie.engrng.pitt.edu/erm/

REFERENCES

[AFG05] R. Anderson, S.A. Fincher, and M. Guzdial, eds. (2005). *Proceedings of the 2005 International Workshop on Computing Education Research*. New York, NY: ACM Press.
see also: http://icer2005.cs.washington.edu/

[AC93] T.A. Angelo and K.P. Cross (1993). *Classrooom Assessment Techniques: A Handbook for College Teachers*. San Francisco, CA: Jossey-Bass Publishers, Inc.

[Boy90] E.L. Boyer (1990). *Scholarship Reconsidered: Priorities of the Professoriate.* Princeton, NJ: Carnegie Foundation for the Advancement of Teaching.

[Coh01] J.M. Cohoon (2001). Toward improving female retention in the computer science major. *Communications of the ACM*, 44(5):108–114.

[GB05] K. Garvin-Doxas and L.J. Barker (2005). Communication in computer science classrooms: understanding defensive climates as a means of creating supportive behaviors. *Journal on Educational Resources in Computing*, 4(1):1–18.

[MF01] J. Margolis and A. Fisher (2001). Unlocking the Clubhouse: Women in Computing. MIT Press.

[SV03] S. Schwarm and T. VanDeGrift (2003). Making connections: Using classroom assessment to elicit students' prior knowledge and construction of concepts. In *Proceedings of ITiCSE 2003*.

Submitted for the northwest regional ICER workshop at Stanford University, 27–28 Jan. 2006.

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