High-Performance Computing Technologies, and Pre-Service Teacher Preparation: Is There an Overlap? (Post-Evaluation Thoughts)

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Abstract: In this paper, we share our experience in the development of successful programs focused on promoting high performance computational tools in undergraduate science education, and among high school teachers. The two NSF-supported projects we will describe, are the Education Center on Computational Science and Engineering, established on the campus of SDSU two years ago, and STEP, the Supercomputer Teacher Enhancement Program. Both projects have been evaluated, using a variety of questionnaire surveys and interviews. This gave us the material to assess what worked and what didn't, and share the lessons we learned. Pre-service teachers fall in the gap between the target audiences of these two projects. We believe that some of the tried and proven techniques used in our two projects are applicable to pre-service teacher education, and argue for the need of a project focused on integrating high-performance computing technologies in teacher preparation. A replicable project of this nature would address the widening gap between the rapidly changing computing environment and needs of the marketplace, on the one hand, and the awareness of teachers and their students of such changes, on the other hand.

Background: High Performance Computing Technology in the Curriculum

Developing replicable and scalable examples of successful incorporation of advanced computing technologies in the curricula at various levels has always been one of the main priorities within the national effort of making high performance computing more accessible and more useful to as many people as possible. Since October 1997, NSF has channeled its support of high-performance computing in education through two National Supercomputing Partnerships, led by the San Diego Supercomputer Center (SDSC), University of California, San Diego, and the National Center for Supercomputing Applications (NCSA), University of Illinois at Urbana-Champaign. The two partnerships, namely the National Partnership for Advanced Computational Infrastructure, NPACI (NPACI 1999), and the National Computational Science Alliance (NCSA 1999), unite over a hundred leading research universities and national labs over shared use of high-performance computing resources, advanced compute-intensive research, and a variety of education and outreach efforts. These efforts focus, broadly speaking, on promoting computational science curriculum in K-12, undergraduate and graduate schools, and informal learning communities, on shortening the distance between research labs and classrooms, and developing learning tools that utilize the best modern scientific accomplishments (EOT-PACI 1999). As part of this effort, the NPACI Education Center on Computational Science and Engineering (Ed Center) (EC/CSE 1999) was created on the campus of San Diego State University, with the mission to promote the incorporation of NPACI-developed tools within the California State University system, and design relevant exemplar projects which could be replicated and scaled to the national level. The focused education and outreach efforts in the present NSF program are based, in part, on the experiences and successes of several previous programs, including STEP (Supercomputer Teacher Enhancement Program) (STEP 1997) originated from SDSC and UCSD with direct participation of one of the authors of this paper. Both STEP and Ed Center programs are described in details in subsequent sections. During the 1998/99 academic year the NPACI Ed Center program has been formally evaluated by an external group of experts (Foertsch & Alexander 1999). The STEP program was also evaluated (Stewart & Bowers 1997), its materials are now a part of Smithsonian permanent collection (Smithsonian 1996). While pre-service teachers are only a fraction of the clientele of the Ed Center program, and the STEP program is focused on in-service teachers, the evaluation results and literature review suggest that the challenges we faced are similar to those experienced in pre-service teacher education. Indeed, finding a meaningful integration of computer technologies in various curricula, convincing faculty that such innovations are effective from the standpoint of student learning, and establishing an environment conducive of change – remain the central challenges, despite the visible progress in technological infrastructure (Campus Computing 1998). At the same time, access to the Internet which quickly becomes ubiquitous, makes many resources of high-performance computing available to both undergraduate and K-12 faculty.

We believe that the strategies we have developed in the STEP and Ed Center programs, may prove useful for the pre-service teacher preparation in high-performance tools, such as advanced simulation, 3D visualization, web-based collaboration, access to large on-line data sources, etc. In the next two sections, we will briefly describe the two programs, and complete the paper by outlining the strategies appropriate in introducing high performance computing technologies to pre-service teachers, and ultimately - to broad populations of students.

The STEP Project, and its Evaluation

The goal of the NSF STEP program was to introduce in-service science teachers from San Diego area to computational science, connecting the high school classroom with the computational world outside, and enhancing the teaching of high school science. In the course of the program, which was funded between 1993 and 1997 (and still continues, through regular meetings), STEP teachers explored various computing platforms, from Macintosh and PC to UNIX mainframes, wrote their first Web pages, engaged in electronic communication, discussions and collaborations. For the advanced computing technologies to work well in the classroom, teachers had to be convinced that their use *significantly* aids students' learning, supporting conceptual understanding of the material and effective engagement. As Noblitt (1997) stressed, and as the STEP program experiences demonstrate, new classroom technologies, to be accepted, must work substantially better than, or provide a different kind of understanding than the traditional form of instruction. This is an additional justification for focusing the curriculum changes on high-performance computing techniques.

As the teachers were getting interested and involved in the advanced computing world, it was clear that this program would need institutional support to be sustainable. Thus, we emphasized the participation of local school administration in the program. Similar approaches proved viable in our subsequent Ed Center project described below. STEP teachers' experience showed that using advanced computing in the secondary classroom requires additional resources, sometimes not readily available at the individual school level. It is important that pre-service teachers willing to present state-of-the-art research tools to their students, are aware of the available support and computational resources. In the survey at the conclusion of the program (Stewart & Bowers 1997), the teachers indicated that involvement in STEP supported their professional and personal growth, and curriculum development, and was a valuable contribution to their schools. STEP teachers presented a series of workshops at their schools and districts. Turning project participants into enthusiastic "ambassadors" of curriculum change with advanced computing tools was perhaps the main accomplishment of the project, and a lesson for projects to come.

The Ed Center Project, and its Evaluation

With over 31,000 student body, SDSU is the largest university within the California State University (CSU) system, which in turn, is the largest and most diverse undergraduate system in the nation. This reflects the diversity of Southern Californian population - the likely future audience for students in SDSU teacher preparation program. In collaboration with the LEAD Center (Foertsch & Alexander 1999), we examined SDSU faculty expectations and practices in teaching with computers, based on a series of questionnaire surveys and interviews. Analysis of faculty use of the Web, use of computers in the classroom by students and instructors, and the use of high performance computing applications in the curricula, helped us develop Ed Center strategies of curriculum change. In (Stewart & Zaslavsky 1998), we described at least ten obstacles to a wider acceptance of computational science in undergraduate education, and came to the conclusion that a comprehensive educational infrastructure - human, technological and administrative - is needed for successful curriculum change. Thus, from Ed Center's inception its focus has been on building a comprehensive infrastructure to support the incorporation of high-performance computational science tools into undergraduate education. Addressing this problem, we have established an environment encouraging the curriculum enhancement in sciences and engineering with modern simulation and visualization technologies, through the campus-wide Faculty Fellows program, collaboration with NPACI and NCSA researchers, in-house project development, and various outreach efforts.

The rationale for the Faculty Fellows program initiated by the Ed Center is the fact observed by many researchers of educational change: curriculum innovations spread successfully through personal contacts with a respected colleague who has tried the innovation, and hands-on demonstrations (Foertsch et al 1997, Rogers 1995, Noblitt 1997). Therefore, the goal of our Faculty Fellows program is building a synergetic environment supporting such interaction between faculty members from various departments, sharing of ideas and hands-on experimentation. Each semester, the program has provided release time to two-three faculty members who worked on changing their regular undergraduate courses to include computational approaches. This support allowed them to use various compute-intensive approaches ranging from interpretation of satellite imagery and web-based collaborative visualization of large geological datasets, to the exploration of the Network of Workstations (NOW) distributed architecture implemented on a cluster of SUN workstations, to investigating new Web-based 3D visualization strategies for geographic data in an experimental class composed of geographers and computer scientists. Note that these technologies and functionality are almost entirely available on-line, i.e. can be accessed by K-12 teachers and students.

Creating on-line repositories of high performance computational tools, and introducing these tools to CSU faculty through focused presentations and workshops is another Ed Center "mission-critical" activity. However, early in the process we recognized that just presenting the tools is not sufficient. It is important to convincingly demonstrate how these tools can be used, and, possibly, have been used, in the curriculum. Thus, we have been experimenting with various computational techniques in our own teaching. Examples include group-based problem solving environments in our supercomputer classes, real-time distance teaching with Web-based collaborative software (featured as a Microsoft Case Study in Higher Education (Microsoft 1998)), etc. Yet another project, which has significant infrastructure impact, is the development of the Sociology Workbench (SWB 1999), a collection of on-line survey data analysis tools that can be used in various evaluation settings, as well as a teaching tool in classes that deal with sociological analysis. The Ed Center's external evaluation showed that the most successful, though time-consuming channels were through individual collaboration with faculty, and our own in-house curriculum experiments.

An important lesson we learned is that the target audience of curriculum change efforts should be carefully selected. Over ¾ of surveyed faculty have used WWW *often* or *sometimes* in 1997[1], however there is still a big step to being able to effectively use advanced computing techniques in instruction, or even being receptive to technology-induced curricular changes. Many obstacles – including lack of time, tenure and review considerations, lack of awareness about existing tools, etc. may prevent faculty from curriculum innovations even if they believe in their usefulness. A telling graph (Fig. 1) demonstrates how the faculty use of computers in the classroom depended on his/her number of years as a faculty: the difference between those who *never* use computers in the classroom, and those who do this *often*, is the largest for untenured faculty, with the largest gap towards the time of tenure review.

Though advanced computing applications can make a difference in student learning in “any discipline which uses mathematical formulas to examine and understand relationships in complex systems” (Foertsch & Alexander 1999, p.12), only 12% of SDSU faculty respondents[2] saw themselves as having a use for high-performance computing applications in their courses (this number is higher for the colleges of Science: 17.1%, and Engineering: 20.0%). At the same time, 11% of the responding faculty indicated that their students *often* worked with computer models in SDSU courses (16% in the College of Sciences and 22% in the College of Engineering), 23% had students *often* use computers “hands-on” in the classroom (33% and 17% by the two Colleges, respectively), and 18% had students *often* use the Internet in courses (15% and 9% by the two Colleges). As experts in pedagogical reform noted (Hutchinson & Huberman 1993), and our experience confirmed, the best strategy is to focus on most enthusiastic and technically advanced instructors who are

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[1] This telephone survey of SDSU faculty was conducted by the Social Science Research Lab at SDSU in the Fall of 1997. The number of faculty who responded to the survey was 402.

[2] The cited survey of SDSU faculty was conducted by the LEAD Center in the course of its evaluation of EC/CSE in the Fall of 1998. Of the 461 faculty surveyed, 175 responded (38% response rate). The sample was representative of the total faculty population in colleges of Arts & Letters, Engineering, and Sciences, in terms of gender, years teaching, and tenure status (Foertsch & Alexander 1999)

already using computing and modeling in their classes, since they are most capable of producing a lasting curricular change (Foertsch & Alexander 1999).

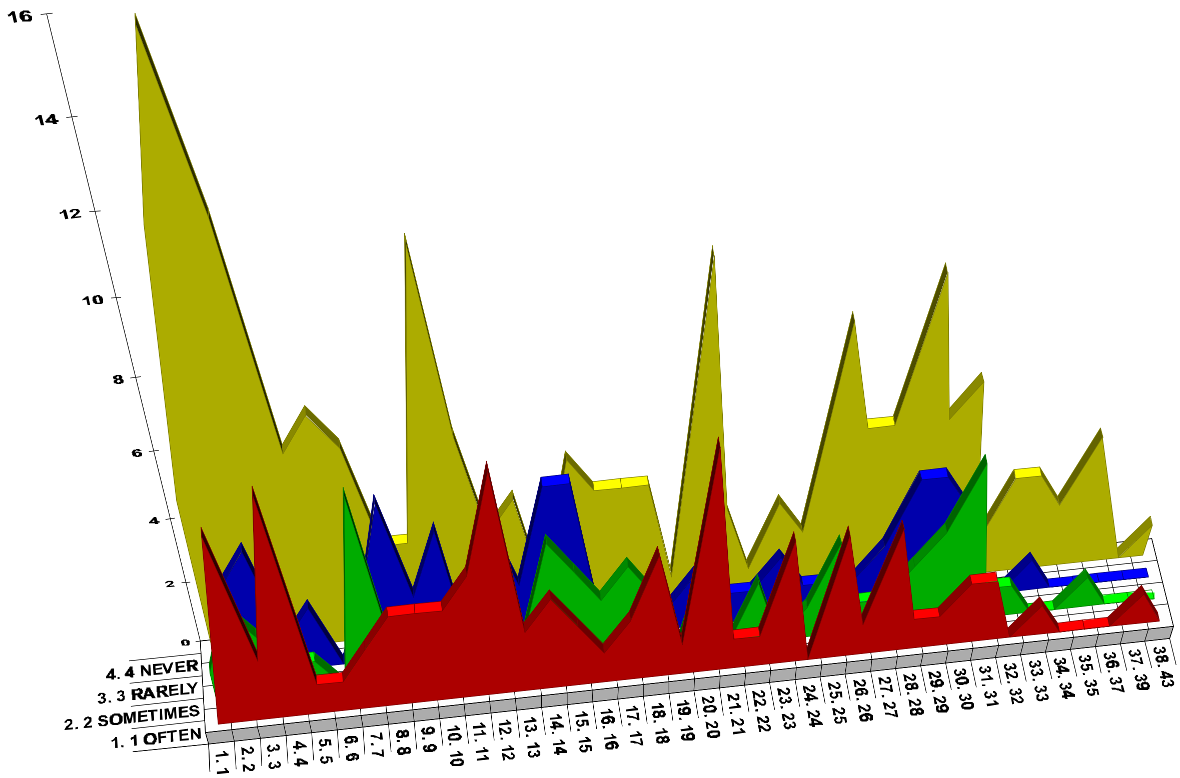

Figure 1. Using computers in the classroom versus number of years as a faculty member. Source: SDSU Faculty Survey, Fall'97.

Channels for influencing pre-service teacher preparation

The pool of undergraduate students at CSU, which is the target audience of the Ed Center, includes large number of future teachers, at various stages of getting their teaching credentials. The following are the major channels for influencing these groups of students, making high performance computing tools accessible and attractive to them:

- The use of advanced computing modules in general education courses. For example, Geol 303 "Natural Hazards" traditionally attracts a number of future teachers. Targeting this student group, the Ed Center sponsored an instructor for this course through the Faculty Fellows program. We hope that this will lead to a wider exposure of future teachers to novel simulation and visualization techniques, specifically new ways of modeling El Nino effects, earthquakes, and pollution.

- Cooperation with College of Education faculty and students, especially those specializing in Education Technology, on various projects which involve experimentation with new technologies and exploration of their use in the curriculum. To promote and support this effort, we organize SDSU Computational Science Olympics (CSO 1999), a competition of student projects focused on various aspects of computational science. Successful student projects are likely to be used again by instructors, eventually becoming a part of curriculum. This "bottom-up" development of computational science modules complements the traditional trajectory of curriculum change.

- Establishing regular meetings with in-service teachers who have been exposed to advanced computing techniques and used them in teaching. STEP teachers are an invaluable source of experiences, willing to share them with future colleagues.

- Providing on-line assessment technologies. Without accessible and relatively simple technologies for classroom assessments and evaluations, it is difficult to demonstrate positive impacts of curriculum changes. *Sociology Workbench* (SWB), a collection of on-line computational tools and resources for social scientists, is one of such technologies developed at the Ed Center. The SWB allows faculty and students to share and analyze social science data (questionnaire surveys, public opinion polls, and similar data) on the Web. In essence, it is a free on-line statistical package implementing a unique data analysis methodology. It emphasizes exploratory social data analysis, integration with other resources available on the Web, convenience of the user interface, and transparency of the analytical approaches. In teacher training, SWB can be used as a convenient instrument for sharing and analyzing student surveys, developing evaluation metrics, comparing results from various surveys, etc. At SDSU, the software has already been used for analysis of faculty surveys and student surveys in several classes. You are welcome to analyze your surveys with SWB, it is accessible from http://edcenter.sdsu.edu.

Conclusion

Within the two programs we described, several successful strategies for the incorporation of advanced computing in classroom teaching have been developed and evaluated. We believe that the tried and proven technologies can be extrapolated to the needs of pre-service teacher education, and outline the steps we are already taking to influence this group of students. As with any curriculum change, a successful integration of advanced computing in the standard curriculum is likely to take years (Green & Gilbert 1995), and result from a focus on most enthusiastic and technically-advanced instructors. We believe that our two programs created the necessary prerequisites for a successful undertaking focused directly on pre-service teacher education.

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