Computational Modeling Issues in and around Physics Courses: Why, What, How and Whither?

Introduction to the GIREP-2006 symposium on Computational Modeling Issues for Physics Courses

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I come here as the editor in chief of a technical magazine: *Computing in Science and Engineering* (*CiSE*). This is a co-publication of the **American Institute of Physics** (AIP) and the **Institute of Electrical Engineers** (IEEE), in particular its Computer Society, so *CiSE* is committed to serve a very broad range of professional constituencies. Let me explain why this "marriage" of professional interests is not so odd as it may seem at first, and further why we believe this GIREP-2006 meeting is an appropriate forum in which to present this symposium. In doing so I will both introduce the contributors to follow and also provide a context in which their presentations can be understood.

In my view physics is a universal "vocabulary" and computing a universal "methodology" that together underpin today's diverse scientific and engineering professions. As our first editor in chief, George Cybenko, put it eight years ago at our founding:

> "*CiSE* is setting up camp at the confluence of two great intellectual rivers—the physical sciences and the computational sciences. This camp will grow into a town and then a city but only if we learn each other's languages and trade in good faith."

Ideally then, *CiSE* is designed to be a conduit connecting diverse scientific, engineering, and computing fields. It is a place where both computational methodologies and computational applications to science and engineering can be published in forms understandable to all these communities.

Computational modeling and simulation are two of the most successful methodologies that have been applied to sciences and engineering research and development work. Unfortunately, undergraduate physics programs, at least in the United States, do not reflect this reality to the extent that computational modeling is not a substantial part of the curriculum in most schools.

What evidence is there that these programs are not doing an adequate job in computational areas? Take a look at this graph (Figure 1) that was compiled from the results of a survey of physics bachelor degree graduates conducted by the AIP's own Statistical Research Center a few

years ago. [“The Early Careers of Physics Bachelors” (August 2002) AIP Statistical Research Center report R-433 http://aip.org/statistics/trends/reports/bachplus5.pdf] I believe that these graphs indicate that training in scientific software and in computer programming suffer from the largest gaps between educational preparation and workplace importance.

Having read this report at the beginning of my editorship and recognizing in it a potential cause for *CiSE* to address, I took it to my editorial board and asked them if they felt this was a problem worth tackling. They agreed, and so I undertook creation of an editorial initiative, which I like to refer to as a "campaign."

I should reiterate at this point that *CiSE* is a magazine, and not a journal. An important difference is that a magazine can be an advocate because, in addition to considering unsolicited manuscripts for publication, unlike journals we can and do solicit them regularly both for our features and for our departments. Solicited papers form the majority of what we publish. So we can promote and support specific causes.

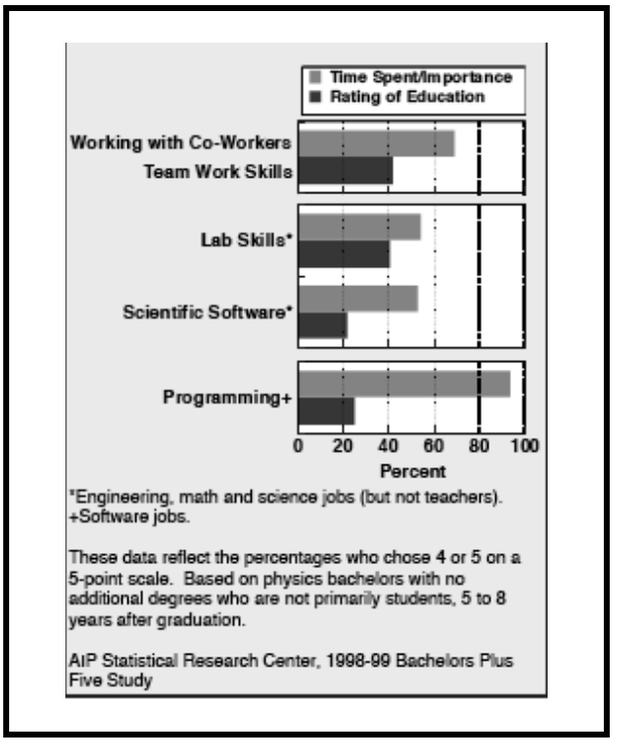

Figure 1: Time spent on tasks compared to rating of physics bachelor's educational preparation.

What are the rationales for assuming that *CiSE* has any business pursuing this cause at this or any other point in time? First, computational modeling is a cross-disciplinary issue; and our constituents are distributed across many disciplines. Second, education is one of our venues - CiSE publishes an education department article in each issue; but also our role as a conduit among disciplines gives us a tutorial function. Third, the time for doing this is now. Numerical modeling is now a predominant part of science and engineering work. Schools have unprecedented computing

power available accessible right from the desktop. And cross-disciplinary problems are rapidly becoming both common and pressing. Finally, as incoming editor-in chief of *CiSE* last year, I happened to have a blend of professional experiences that suited me to manage such a task. Trained as an experimental physicist, I had been in succession a physics professor, then a science researcher, and finally an engineering researcher in several different fields.

With this background in mind, I now wish to move back to the notion of a campaign whose objectives are to advocate and support the integration of computation into undergraduate physics courses. This campaign has three parts:

Partner with professional associations

Provide a voice and platform to air relevant issues and discussion

Host refereed, broad-spectrum articles in this area

Let me outline what we have done thus far leading up to and including this symposium.

In the summer of 2005, CiSE partnered with the American Association of Physics Teachers (AAPT) – a rough equivalent of the GIREP – to sponsor an informal discussion on the state of computation in undergraduate physics courses at the AAPT national meeting at the University of Utah. The concept of this discussion was to gather together a small group of physics professors that we knew to be early and dedicated developers of computational practice at their institutions. As such we specifically invited ten of such instructors to what otherwise was a gathering open to any of the meeting attendees. In all about twenty participated representing a blend of old and new faces. The "grass roots" discussion that ensued thus represented a blend of established and new wisdom. There emerged two conclusions to which all could agree. One was that we needed a broader national discussion on the issues. The other was that we needed a concrete data sample on actual computational physics practices in courses nationwide.

As the editor of CiSE, I was able to commission a national survey of current practices, which took place in the autumn of 2005. Just after I finish, Professor Robert Fuller will describe this survey and present his analysis of the data collected.

On the basis of this survey, we were able to identify individuals in over 250 colleges and universities in the US who were sufficiently concerned about computations in physics courses to tell us what they were, and in some cases what they wish they were, doing in this area. Further, we were able to identify four major paradigms for the degrees and quality of computational uses in undergraduate courses. After Fuller, Professor David Winch will describe these paradigmatic classes and list examples of participants that were placed in each.

Using these paradigms as a guide to segregate survey participants, we placed each into one of four classes. Then we selected one person from each class for invitation to describe her/his work at the summer 2006

AAPT summer meeting at Syracuse University. Moreover, we solicited an article from each of these to include in a *CiSE* special issue on the theme of "Computation in Physics Courses," published coincidently at the time of this GIREP meeting in the *CiSE* September/October issue. There should have been a copy of this issue included in each of the registration packets for this GIREP meeting. Both Fuller's and Winch's papers in that issue are the bases for, and good references to, their respective presentations in this symposium.

In addition to the four Syracuse University presentations, we invited twenty more of those survey respondents who appeared to be really committed to redress the underuse of computation in physics courses to present posters that would be grouped at this meeting. Both the invited speakers and the invited poster presenters were invited to a working dinner on the eve of their presentations. At this dinner, in keeping with the second consensual item of the previous summer's gathering, we arranged to have structured discussions to extend the deliberations of the previous summer and hence enlarge the airing of relevant issues.

This discussion provided an extraordinary perspective from which we could interpret our survey data. Among other realizations was an indication of a strong desire to shape a national agenda for developing and disseminating materials that embed computation into the standard canon for undergraduate physics. The participants felt that this would legitimate their efforts to do so and thus give professional credit for working in this area. Such credit is already granted by a small number of institutions but needs to be expanded to others if we are to have a rich variety of types and approaches of validated materials.

Yet "one size fits all" is not likely to be a solution to the wide range of contexts into which computation in physics curricula in the coming generation must fit. While we are sorting out a new canon, we need media in which peer refereed work may be published so that appropriate professional credit can be given to competent offerings. We also need some leadership and forums to present, debate, and refine developments in the area of computational physics education.

This symposium is one effort to provide such a forum. By inviting two distinguished leaders of efforts to conduct computational physics education to this symposium, we are framing two ends of the discussion that have yet to be addressed. Professor Cees Mulder will present a perspective on what is being done in the Netherlands to implement a computational physics model for pre-university contexts. One should keep in mind that the educational systems in Europe and the US are not synchronized so that his remarks can apply to the first year undergraduate programs in the US as well. After that, Professor Hans Bungartz from the Technical University in München will describe his efforts to provide meaningful post-graduate education in computational science that, in a sense, represent a model post-university implementation of computational physics.

I hope that this combination of US and EU examples will provide a fruitful basis for furthering efforts to improve computational physics in both regimes. I can say personally that I am looking forward to this symposium for this purpose, and am grateful for all the contributions of all the presenters and for the opportunity that GIREP has provided us for this "cross-cultural" exchange.
Thank you!