2010 Final Report for NSF Project (4/2/11)

"Resparking Innovation in Computing Education"

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NSF Grant 0720999
Period of Performance June 2007 through June 2010

Participants

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Purposes of the Project

The PI was designated a CISE Education Fellow (in June 2007) and given a charter to stimulate innovation in computing curricula. The PI sought a new way of looking at computer science that would be more attractive to young people and to practitioners in other fields who use computing in their work.

This was to be accomplished by two workshops, one to develop the Great Principles of Computing framework (greatprinciples.org), and the other to identify and help innovative faculty achieve adoption of their proposals for reforms. The PI would also speak up frequently in public forums where he was highly visible.

We soon concluded that we would have a better chance to produce an innovation in the community by organizing a large summit instead of two small workshops. The NSF program manager (Harriet Taylor) concurred with this shift of emphasis of execution. A major activity was the planning, execution, and follow up of the summit.

These outcomes are summarized in the remainder of this report.

Partner Organizations

ASSOCIATION FOR COMPUTING MACHINERY, INC.: In-kind Support

ACM Education Board and ACM SIGCSE executive committee endorsed the Rebooting Computing summit held January 12-14, 2009. ACM provided access to a listserv for communications within the summit design team and among the summit participants. ACM entered into an "in cooperation with" agreement that incurred no financial or other obligations on either side but allowed us to use the ACM logo and the listserv facility.

NPS FOUNDATION: Financial Support; In-kind Support

Handled private contributions that supported parts of the Rebooting Computing Summit.

COMPUTER SCIENCE TEACHERS ASSOCIATION (CSTA): Advice

Provided advice on teachers to invite to the Rebooting Computing Summit.

Other Collaborators

They were numerous. Of special note is our 19-person design team for the Rebooting Computing Summit. Each brought access to a network that needed to be represented in the summit. They were:

Peter Denning (chair), NPS
Frank Barret, NPS (facilitator)
Tim Bell, University of Canterbury, NZ
Geoff Brown, M2MI at Moffet Field
Vint Cerf, Google
Robb Cutler, Tutor Crossing
John Dunnion, University College Dublin
Ron Fry, Case Western (facilitator)
Susanne Hambrusch, Purdue
Susan Higgins, NPS
Alan Kay, Viewpoints Research Institute
Leonard Kleinrock, UCLA
Joshua Kroll, Harvard Student
Craig Martell, NPS
Andrew McGettrick, University of Strathclyde, Scotland, UK
Jeff Moser, Interactive Intelligence
Peter Neumann, SRI
Richard Snodgrass, University of Arizona
Larry Snyder, University of Washington

Research and Education Activities

Much of the project time and effort was focused on organizing and executing the Rebooting Computing Summit, held January 12-14, 2009, at the Computer History Museum in Mountain View, California. About 220 people from diverse sectors of the computing field attended. The attendees included about 70 women (35%), 20 students (from K-12 to PhD candidates), 25 industry, 20 K-12 teachers, and 30 international. The international attendance was especially gratifying;

attendees came from far places including Australia, Singapore, Japan, Scandanavia, Germany, United Kingdom, Italy, and Dubai. They were particularly effective at reminding the majority (US) that there are other views of computing out there.

The summit produced two principal outcomes:

1. Generating new conversations and relationships between communities who have not normally talked to one another – e.g., K-12 teachers and university faculty.
2. A set of 20 action groups formed by the participants around projects they wanted to continue working on after the summit, to promote the mission of the summit.

The 20 action groups formed after a lengthy discussion of the problems faced by computing education. Although we were gratified at the expanse of their interests, we had no illusion that all would be successful. The participants would have to find time in their schedules for these new projects and many of them did not have adequate follow-up support. We would have been satisfied if only three or four groups accomplished its goals.

To find out how these groups fared, we conducted follow-up surveys of the group leaders in December 2010 and March 2011. Much to our delight, we found considerably more than four had produced results.

These eight projects continued on and most are still contributing as of March 2011. Note that two of the listed projects formed from mergers of Summit groups (a two-way and a three-way merge); therefore, this list accounts for eleven of the original action groups:

1. *Recruiting women and minorities in CS*

   David Klappholz ran a Google-sponsored CS4HS workshop on the topic of Real Projects for Real Clients Courses (RPRCCs). This is his approach to attracting more girls and young women to the computing realm.

2. *Tools for Fun and beauty + CS FUNdamentals*

   The group identified two goals:
   a. Create a reference-standard site for technologies and tools for CS Educators. This group partnered with TECH, a similar project task force of the ACM Education Council.
   b. Create a page that can be used for informal learners, after-school teachers, etc. who are leaning to program for the first time. This goal was not completed.

3. *Recruiting 10,000 new CS teachers by 2018*

   Calvin Lin, a project lead, indicated that the group became involved with others seeking to recruit CS teachers. They helped establish a UTeach CS Program to train CS majors to become teachers, and received a small NSF planning grant to fund this effort. As of December 2010, the group was in the process of submitting a larger grant proposal to NSF's CE21 program.

Their project would increase the number of high school students who take CS courses in Texas and the number of high school CS teachers in Texas.

4. *Socially relevant computer science*

   Several group members collaborated on grants and workshops focused on similar goals as those defined during the Summit. They received funding from NSF, DoE, and California in support of developing curriculum materials demonstrating how computer science can help solve social issues.

5. *Extensions to CS Unplugged*

   This group, led by Tim Bell, co-authored a paper for ITICSE09. They examined means to create moderated and commented collections of computer science teaching materials. Tim Bell created a guide for teachers in New Zealand that contains hundreds of pages of links to resources.

6. *Computing field guide + Science of computation + Defining Computing*

   These three groups combined and wrote a joint concept paper. Peter Denning and Rick Snodgrass then wrote a pair of collaborative CPATH Proposals, which were funded by NSF. Several members of the original groups joined the project steering committee. Further information on this is included below.

7. *Computing ontology*

   The Computing Ontology project, led by Boots Cassel, already existed prior to the Summit. A group formed around this topic at the Summit, and directed their efforts to help the Ontology Project. The Summit provided new volunteer help and increased interest.

8. *Computer Science in LabRats*

   Shawn Carlson recruited several computer science people to his LabRats project, which aims to provide a Scouts-like after-school community for kids to learn the purposes and ways of science.

The remaining nine groups dissolved without results. However, two of them provided feedback that indicated they made significant partial progress:

1. *Computing discipline model*
   Group Lead Jim Brown wrote a CPATH proposal. It got excellent reviews but was not funded because it section on evaluation section was deemed inadequate by the review panel.
2. *Image of computing*
   The group discovered that many of the things they were trying to accomplish were already being done by other organizations, most notably the ACM/NSF/WGBH project on New Image of Computing. They decided it would be more productive to help those efforts rather than create new, similar projects.

Because they did not respond to our follow-up surveys, we concluded that these seven groups lost their momenta and dissolved:

1. Foundations of disciplinary identity
2. Future computing requirements in vertical sectors
3. Essential K-12 curriculum
4. Parallel Worlds Initiative (Multicore computing)
5. Multi-disciplinary collaboration
6. Open artifacts and recombinant systems
7. Project based learning in Grades 7-14

We set up a Rebooting Community Web site (`rebootingcomputing.org`) to enable the groups formed at the summit to continue their conversations and invite other people into the discussions. This web site provided a communication center for the groups to discuss their work.

Project Findings

(1) Nearly half the participants at the Summit rallied around the notion of "defining computing". There was a deeply felt sense that the field lacked a clear definition, and that was causing confusion within the field and outside. The theme of defining computing runs through several of the continuing projects listed above. There was strong feeling of urgency to develop a coherent definition of computing and its role in the world.

(2) With the concurrence of our program manager, we refocused all the workshop resources of the project from two small workshops to one large meeting, the Rebooting Computing Summit. We thought this would be a most unusual form of intervention, focused on getting disparate groups within computing to meet each other, talk together, and initiate projects together.

(3) We expected that about 20% the action groups would remain active because of time demands in their normal lives and lack of funding for follow-on work. We were therefore gratified at the 50% rate reported above. (We conducted a survey of the group leaders in December 2010 with follow-up in March 2011 to confirm these outcomes.)

(4) We received a notice that a teachers group in Singapore was undertaking a major revision of their K-12 curricula based on inspirations they received at the summit. (Singapore sent 7 people.)

(5) Our partner WGBH, working with ACM, produced a major report on the attitudes of high school students toward computing majors and careers (`http://www.acm.org/membership/NIC.pdf`). They later focused on development of a program to attract young women to computing (`dotdiva.org`) One of their findings is that many high school students have a lot of respect for the computing field and think it is a great career choice for other people -- but they do not choose the field for their own careers. This finding corroborated a sense at the summit, that people see substance in the field but not excitement, magic, and beauty.

(6) Some of the language of the Summit, notably around the joy, magic, and beauty of computing has filtered into other activities, most notably the ETS/NSF project to create a new course on computing principles for Advanced Placement (csprinciples.org).

Field Guide Follow-on Project

Peter Denning volunteered at the summit to coordinate the actions of the several groups interested in the "definition of computing" question, including the development of a field guide to computing. Rick Snodgrass volunteered to lead a group examining the science of computation. The two of them teamed up to submit a collaborative proposal to the second round of the CPATH initiative. The project, *A Field Guide to the Science of Computing*, combined these efforts. The proposal successfully passed review. The three-year project began at their two institutions in October 2009. Their project summary follows.

Project Objectives. Many scientists, engineers, and students see computing as a technology field but not a field of science or engineering. This project's long-range objective is to replace this with a new understanding, that computing is great domain of science, on par with the physical, life, and social sciences. This new understanding will make the field more attractive for students and science collaborators.

This project directly supports the three main CPATH goals. (1) It contributes to US competitiveness by providing a scientific framework for computing, which will advance technology development and attract many more bright students, including more women and underrepresented groups. (2) It increases the number of students developing computational thinking by offering new learning possibilities, for undergraduates as well as for pre-college students. (3) It is transformative because it brings forward a science framework for computing, which has not been done before.

Project Approach. Our plan is to develop a **body of content** that presents the deep insights of scientific theories of computing, attuned by field-testing to a broad range of students, from middle school through graduate school. We will structure this content as a service, the **Field Guide to the Science of Computation**, which organizes the scientific theories in a framework of seven categories – computation, communication, coordination, recollection, automation, evaluation, and design. In addition to the seven categories, the field guide will support two orientations (end-use and instruction), three perspectives (mathematics, science, and engineering), and four levels of entry (beginner, intermediate, advanced, and research). The content will be developed, tested, evaluated, delivered, and sustained over time by a **collaboration network** that includes the lead institutions (Naval Postgraduate School and University of Arizona), their local education partners (BASIS and Hartnell College), the ACM Education Board, the Computer Science Teachers Association (CSTA), LabRats, and CS Unplugged. An **external evaluator** will measure the effectiveness of the content and field guide to attain the project goals.

Our network includes representatives of pre-college age groups because we want to influence computational thinking not only in present undergraduate programs and students, but in future programs and the students. ACM reaches deeply into the all the sectors, especially college. CSTA has reaches deeply into

the K-12 school system. LabRats and CS Unplugged are well-regarded grass roots approaches that involve kids in computation and science. We will also work with ACM to host the field guide and to bring the science framework to its body of knowledge for computing.

Intellectual Merit. The project brings to the forefront an underappreciated side of computing: that it is a great domain of science based on sound scientific theories and first principles. Computation science offers deep insights and surprising predictions, and an experimental method to validate predictions and make discoveries.

Broader Impacts. By reaching out from hard-core computer science to representatives of different age groups, the project will find ways to convey the science message to many generations. It also provides solid grounding for other scientists to interact with computer scientists as peers in the search for new discoveries.

Training and Development

We have greater contact with teachers and students in K12 and have become acquainted with many of their interests and concerns.

We have found a network of others who are interested in articulating the broad view of computing as a great domain of science.

We have formed a new team to continue the work started at the summit on the field guide.

Outreach Activities

We reached out to people in many sectors of the field and invited them to the summit. The acceptance rate was around 90%.

With help from the CSTA (computer science teachers association) we invited students and teachers to the summit and got scholarship funding so that they could attend.

We partnered with ACM (especially the education board and SIGCSE).

We partnered with the WGBH "new image of computing" project.

Publications

We spoke out numerous times on topics relating to innovation in computing education and computing as a great domain of science. These publications appeared during the duration of the grant (6/2007 to 6/2010):

1. Denning, Peter. Computing is a Natural Science. ACM *Comm. 50*, 7 (July 2007), 13-18.
2. Denning, Peter. Voices of Computing. ACM *Comm. 51*, 8 (August 2008), 19-21.
3. Denning, Peter, and Richard Riehle. Is software engineering engineering? ACM *Comm. 52* (March 2009).
4. Denning, Peter. Beyond computational thinking. ACM *Comm. 52* (June 2009).

5. Denning, Peter, and Paul Rosenbloom. Computing: The fourth great domain of science. ACM *Comm. 52*, 9 (September 2009).
6. Denning, Peter, and Peter Freeman. Computing's Paradigm. ACM *Comm. 5*, 12 (December 2009).

And these publications appeared later, inspired by themes begun in the grant period:

7. Denning, Peter, Fernando Flores, and Peter Luzmore. Orchestrating Coordination in Pluralistic Networks. ACM *Comm. 53*, 3 (March 2010), 30-32.
8. Denning, Peter. The Great Principles of Computing. *American Scientist 98* (Sep-Oct 2010), 369-372.
9. Denning, Peter. What is Computation? Opening statement for ACM *Ubiquity* symposium (Nov 2010), http://ubiquity.acm.org/article.cfm?id=1880067
10. Denning, Peter. Getting Your Ideas Adopted. *The Bent* of Tau Beta Pi (March 2011), 21-24.
11. Denning, Peter. Computer Science: An Interview (by Neville Holmes). *Computer* (March 2011).
12. Denning, Peter. Managing Time. ACM *Comm. 54*, 3 (March 2011).
13. Denning, Peter. Wrapping It Up. Closing Statement for ACM *Ubiquity* symposium (April 2011), to appear.
14. Denning, Peter, and Dennis Frailey. Who Are We Now? ACM *Comm. 54*, 6 (June 2011), to appear.

Internet Dissemination

`rebootingcomputing.org`

This is the home site for the summit process. It contains the Rebooting Manifesto, the design committee, and a link to the Rebooting Community.

`rebootingcommunity.org/community`

This is the home base for all the discussions and discussion groups surrounding the summit. It contains all the items posted to the ACM listserv. It has discussion areas for each of the 20 project action groups, together with methods for others to join the discussions and the groups.

`cs.gmu.edu/cne/pjd/cpath`

This is Peter Denning's information site for the project.

`greatprinciples.org`

This is the home base for the Great Principles of Computing Project. It lays out in detail a principles-based framework for computer science and engineering and compares the new framework with the traditional technology framework for the field. The GP project gave us the confidence that there are new, exciting ways to look at the field and appreciate its depth and richness. The GP project is the starting point for the current project.

Contributions

The purpose of the overall project was to respark innovation in computing curricula. The computing field has reached its greatest heights when it has been at its most innovative. A resurgence of innovation can help resolve the doldrums of identity and attractiveness and make lasting contributions in the future.

The Rebooting Computing summit was conceived as the most effective means to jolt the field, producing movement among those who are feeling stuck. The summit invited a diverse group representing all sectors of the field and its clients, to discuss the magic and beauty of the field as it appears in their lives, to find common ground among their diverse concerns, and to organize and commit to project actions teams that will intervene in the overall problem. Over half the 20 action groups produced results. This is much better than the 3-4 successful action groups we predicted at the end of the summit.

If all this succeeds, many more people in the field will be in touch with the magic and beauty of the field. They will communicate it effectively to potential students and collaborators. They will attract more good students from more diverse populations to the field. They will enter into more collaborations with other sciences and engineering. The academics will engage in more curriculum innovation and make their departments exciting places to study computing.

Contributions to Other Disciplines

A concern behind the summit and the project was to communicate the extraordinary depth and breadth of the computing discourse to people in other sciences and engineering. The better we become at offering our expertise, the more we will contribute to developments in other fields. This will be good for computing and will help attract young people. It will also demonstrate the ubiquity of computation in the deep structures of all fields.

Contributions to Human Resource Development

A concern behind the project and summit was to increase the participation by women and minorities in computing. The strategy was to expose the magic and beauty of what attracted us and to appeal to a similar sense in young people, in their teachers, and in potential collaborators.

Contributions to Resources for Research and Education

Several of the summit project action teams aim to develop resources. One team developed a repository of tools that can help people learn and apply computational methods, and have fun in the process. Another is specifying a "field guide" that will help people understand the structure and nature of the field and find answers to specific questions they have about how things work.

Contributions Beyond Science and Engineering

Computing pervades many fields of science, engineering, economics, and humanities. This is why we have concluded that computing is not just a field or a discipline; it is a great domain of science. The better we get at expressing how computing can help and impact other fields, the greater the positive influence.