The Impact of the EOT-PACI Program on Partners, Projects, and Participants: A Summative Evaluation

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1. EOT-PACI: Its organizational structure, mission, and goals

The national program known as Education, Outreach and Training for the Partnership for Advanced Computational Infrastructure (EOT-PACI) was established in 1997 through grants from the National Science Foundation (NSF) to two supercomputing partnerships: the National Computational Science Alliance (NCSA, or “the Alliance”) and the National Partnership for Advanced Computational Infrastructure (NPACI). These two supercomputing partnerships, centered at the University of Illinois at Urbana-Champaign and the University of California-San Diego respectively, each had their own projects in the areas of computational science education, outreach, and training, but the NSF sought to bring their EOT projects together under one umbrella in order to increase their opportunities for leveraging, collaboration, and creative exchange. A few of the 27 projects or “partners” that made up the original membership of EOT-PACI receive funding from both NCSA and NPACI, but the vast majority of partners receive funding from just one partnership. A complete list of the current partners and projects associated with EOT-PACI may be seen in the Appendix.

Beginning with a planning and evaluation workshop held at the University of Wisconsin-Madison in September of 1997, EOT-PACI’s partners worked together to build a framework for national collaboration, dissemination, and scaling. For much of the six-year granting period, EOT-PACI’s projects were clustered into five action teams—Access and Inclusion, K-12 Education, Undergraduate Education, Government & New Communities, and Learning Technologies—overseen by the seven to nine members of the Leadership Team and supported by an Evaluation Team. Starting with that first workshop and continuing to the present day through an annual process of reflection and refinement, EOT-PACI’s diverse partners jointly developed the mission, goals, and strategies that would define and support this ambitious mutual endeavor.

The mission of EOT-PACI is to develop human resources to understand, formulate, and solve problems through the innovative use of emerging information technologies. The three goals of EOT-PACI that support this mission are:

- Demonstrating the use of PACI’s high-performance computing technologies and resources to diverse audiences and disciplinary communities.
- Increasing the participation of underrepresented groups—including women, ethnic minorities, and persons with disabilities—in the computational sciences, computer science, engineering, and information technology.
- Enabling broad national impact in education, science, government, business, and society through the scaling of successful, well-evaluated programs.

As this report will show, EOT-PACI has had a broad impact on science, math, engineering, and technology education at every level from K-12 to graduate, on the opportunities available to underrepresented groups in these disciplines, and on the integration of computational science into classrooms, labs, and new communities nationwide. In 2002-03 alone, EOT-PACI’s partners have delivered more than 85 workshops, made over 60 presentations in conferences, lecture series, and workshops, conducted 4 department-sponsored courses, and published 20 articles on their EOT-sponsored activities. These activities and partners’ annual projects have produced more than 75 new or updated online resources including curricular materials, guidelines, resource collections, and interactive tools for education or research. The more than 12,000 participants in this year’s EOT-leveraged or hosted events included over 8000 elementary students, 900 undergraduates, and 150 graduate students, 500 K-12 teachers, and 1000 faculty members and researchers from hundreds of colleges and universities, including 24 Minority-Serving Institutions (MSIs). Numerous new projects have developed out of EOT-PACI's collaborative efforts and supports for scaling, including Alliances for Graduate Education and the Professoriate (AGEP), Advanced Networking for Minority Serving Institutions (AN-MSI), the Computer Science Computing and Mentoring Partnership (CS-CAMP), Ed Grid, the National Computational Science Institute (NCSI), and TeacherTECH.

This summative evaluation report is intended to offer an overview of the impact of the EOT-PACI program on its partners and associated projects. The data reported here can help EOT-PACI's stakeholders to understand what the program and its numerous projects have accomplished over the last six years and what they have the potential to accomplish in the years to come. This report documents the impact of EOT-PACI's programmatic efforts (Section 3), discusses partners' feedback on the drawbacks and benefits of the current EOT-PACI program (Section 4), and summarizes what has been learned from extensive evaluations of twelve individual EOT-PACI projects conducted by the Evaluation Team at the UW-Madison's LEAD Center (section 5).

2. Summative evaluation methodology

Two different, but complimentary, efforts were undertaken to determine the impact of EOT-PACI over the past six years. One effort involved evaluating individual projects that received some or all of their funds from EOT-PACI. In many cases, these evaluations have been done by professional, third-party evaluators like those from the LEAD Center. A compilation of all the EOT-PACI-related evaluations that LEAD has conducted and a synthesis of the lessons learned from those evaluations are found in Sections 5.1. and 5.2 of this report. In other cases, partners conducted their own evaluations of projects or project components, as mentioned in Section 5.3. The data from all of these separate evaluations "summed" can give one a sense of EOT-PACI's documented national impact at the project level.

However, EOT-PACI's total impact is literally "more than just a sum of its parts." NSF created this nationwide partnership with the expectation that there would be additional benefits—or a "multiplier effect"—in bringing together under one umbrella so many different education, outreach, and training projects. Hence, a second task in determining the full impact of the EOT-PACI program is to assess the degree to which the collaborative aspects of EOT-PACI produced outcomes *above and beyond* those that the projects would have produced by themselves with individual grants from the NSF. This assessment involves documenting how the collaborative aspects of EOT-PACI helped partners to: (1) improve and expand their projects in ways that they wouldn't have otherwise; (2) improve and expand their knowledge and capabilities as individuals; and (3) create new projects and collaborative efforts with other partners.

In 2002-03, the LEAD Center conducted a summative evaluation of the EOT program as a whole using two data-collection methods:

(1) Interviews with partners to illuminate how being a member of EOT-PACI has affected them and their projects and to collect feedback on EOT's programmatic efforts and strategies.
(2) Surveys of partners to collect details on the evaluation of their projects and the obstacles to collecting certain types of evaluation data.

This summative program evaluation builds upon the formative and summative project evaluations that LEAD conducted for twelve EOT-PACI-related efforts between 1995 and 2003 (see Section 5.1). Some EOT-PACI partners also performed their own assessments during this period, but data from those assessments are not reported here. For more information on the project assessments performed by EOT-PACI partners, see each individual project's website, as listed in the Appendix.

3. The EOT-PACI community and its impact on projects and partners

3.1. A wide-reaching collaborative community of computational scientists and educators

Over the past six years, the EOT-PACI program has become a wide-reaching collaborative community that provides its members with numerous benefits at both the project level and the individual level. In this section, we summarize what the 26 partners interviewed as part of the summative evaluation had to say about the EOT-PACI community and its impact on them and their projects.

Most partners described EOT-PACI as a community or network of individuals from different areas of research and education who are working towards the same goals. As one partner said, EOT-PACI facilitates connections:

> "…by having an actual partnership in which you share funds and you have an organization. That means that when you have annual meetings you already know you have some common ground. You are working toward the same goal. And so it means that you know you'll have a productive relationship with the people or with this organization. It makes your efforts to go beyond your own state or your own locale more productive because you have this group working toward common goals."

Of particular note was that most EOT-PACI partners had never worked together prior to the formation of the program. In our evaluation interviews, partner after partner described how they became aware of, and had the opportunity to talk and work with, individuals who they never would have met if it hadn't have been for this organization. Of course, partners' collaborations with others in EOT-PACI varied in their degree and their eventual outcomes. For many partners, these collaborations created a synergy that was unusually productive and with outcomes that were described as "more than the sum of the parts." One such partner stated that, without EOT-PACI:

> "I don't think that I would have had the opportunity to develop these relationships that we have developed, and build on the knowledge that we bring to the table, and put the pie together. Without [EOT-PACI], it would just be the pieces."

Many of the partners described how there were very few people in their universities, schools, or research centers who were working on the same types of goals as EOT-PACI. Hence, one of the primary benefits of EOT-PACI was that it brought widely scattered computational science educators and researchers together into one organization. Computational scientists who had felt relatively isolated in pursuing various educational reforms suddenly realized there were many others nationwide who shared the same goals. By banding together and working collaboratively, the chance of each partner meeting their goals increased. As one partner put it, "it has been valuable to draw a small national community together so we can reach a critical mass."

The EOT-PACI community was described as unusual in this respect, particularly for partners in university settings:

> "One of the problems in universities in general is that everybody is sort of an island of their own and they're always reinventing the wheel. So when you get into a community where you have some common goals and objectives and it turns out to be a community which facilitates your work, that's a real plus."

Some of the partners felt that one of the things that created the synergy and productivity within EOT-PACI was bringing together a disparate group of educators and researchers who could communicate and collaborate. One partner described her experience as follows:

> "I think that it's been extremely valuable to have the mix of people from the university community and from the K-12 community in this partnership, because you don't often understand what's going on at a level different from your own. And to have an organization where you can bridge those barriers really contributes to making the educational experience for the students so much better."

The many partners of EOT-PACI varied in how much they participated in the larger EOT-PACI community. This resulted in differences in the type and degree of its impact on partners. However, all of the partners felt that their programs had experienced a positive impact through their participation in the EOT-PACI collaborative community.

3.2. Key outcomes of the EOT-PACI community

Interviewees discussed numerous outcomes that resulted from being a member of the EOT-PACI community. As part of these interviews, partners were asked how the program affected their projects and their own professional development. In this section, we discuss the major outcomes of the EOT-PACI community that emerged from our analysis of partner interviews. Briefly, those outcomes were:

1. **Increased knowledge of best practices** in education, outreach, and training through interactions with diverse researchers and educators.
2. **Enriched project and tool development** through collaboration with partners.
3. **Enhanced dissemination pathways** for existing curricula, tools, and projects through connections with other partners.
4. **Increased scaling of projects** through connections with other partners' institutions and organizations.
5. **Access to computational science researchers at supercomputing centers**.
6. **Increased likelihood of receiving additional grants** through leveraging
7. **Increased professional development opportunities** for EOT-PACI partners

3.2.1. Increased knowledge of best practices in education, outreach, and training through interactions with diverse researchers and educators:

EOT-PACI provided partners with opportunities to learn about the work of other partners through group discussions and posters at every All Hands Meeting (two per year), through the EOT-PACI website at http://www.eot.org/, and through various PACI publications. There were also numerous efforts in the first several years to encourage partners on the same teams to meet regularly by phone or at conferences and explore collaborative possibilities. As a result, EOT-PACI partners were exposed to the expertise of other educators and researchers whose work had relevance to their own. According to interviewees, this provided fertile ground for exchanges of information, sharing of best practices, and the possibility of collaborations. Most of the interviewed partners said that, before EOT-PACI, they had never had so many opportunities for interactions with individuals from different areas working together toward similar goals.

Many partners gave examples of how they had turned to other partners for information and advice on numerous issues including:

- running workshops for teachers,
- creating undergraduate research programs for students,
- setting up new organizations,
- disseminating information about their programs, and
- creating new curricula for workshops and students.

Many partners viewed other partners as a resource base that they could turn to for expertise in a multiplicity of areas. For example, organizations that were part of the EOT partnership would hold their meetings at the same time so that they could share ideas and expertise with one another. One partner stated that this allowed members of her organization to "connect with other people with similar goals." Another partner discussed how through EOT-PACI connections she had "all these partners that I can email and ask questions and advice from, and they're eager to share their expertise. And that's just been fantastic."

Best practices and project strategies were also disseminated from partner to partner through annual meetings, evaluation results, and written documents. For example, one partner got the idea of creating software for an information-access design tool through learning about the creation of scientific workbenches in PACI and EOT-PACI. This partner said, "We probably would have never thought of it if it had not been for our involvement in EOT-PACI." Another partner discussed how their program benefited through a second partner's knowledge of other EOT-PACI programs:

> "For us we can say that the relationship [with EOT-PACI] has helped us to mature as an organization. We have been able to see other programs and how they work, and benefit from that knowledge, and transfer that knowledge to our program."

Another example comes from the area of best practices in scaling programs. The EOT-PACI leadership made special efforts to encourage partners to share information on scaling with each other through numerous discussions during meetings, including special sessions on scaling at All Hands Meetings. One partner discussed how she was working on trying to scale her program in ways that allowed maximum impact on the largest possible audience. Through EOT-PACI, she became aware of another partner's strategy of running her science enrichment program through the Girl Scouts of America's national organization. This provided her with a model that inspired her to partner with a national organization conducting teacher technology training and "layer" her gender equity training within that organization's workshops:

> "So I hear about this [EOT-PACI partner] having an absolute stroke of genius when she developed this thing with the Girl Scouts….[In my program], we already leverage big time when we work with teachers. But see, she took it to another order, because she goes and does one-week training sessions with these people that go out and work with 5,000 girls in Girl Scouts. I just thought that was really savvy, and I thought, okay, what organization do I know that's training teachers where I could go and say to them, 'You have your training. Let me come and layer this in.' I think this is a phenomenal

> way to do gender equity training, because all over this country, there are teacher professional development technology workshops. So all you would have to do is go to them and say, ‘Can I come and do two hours?’ I can at least make teachers aware of the fact that women are so underrepresented in technology, and they can go back and make a difference. And so this is the idea that I got from [another partner] and I don’t think I would have ever gotten it if I hadn’t heard of [her] using the Girl Scouts.”

Another method of diffusion of best practices was through evaluation of programs and dissemination of the outcomes. Interviewees noted that they got ideas for how to better run their programs by reading the LEAD Center evaluation reports of other partners or hearing presentations about these evaluations at All Hands Meetings. In addition, the Evaluation Team shared best practices they had learned from previous partner evaluations when they worked with other partners later.

Based on our interviews with numerous partners, the EOT-PACI community appears to have been a very effective mechanism for the diffusion of knowledge and strategies.

3.2.2. Enriched project and tool development through collaboration with partners:

One of the strongest components of the EOT-PACI organization was the collaboration between partners over time. This resulted in a variety of outcomes including:

- Project enhancement
- Tool development and refinement
- Development of new projects
- Configuring workshops to better suit the needs of attendees

Different types of projects or partner efforts led to different types of collaborations—some that were short-term and others that were more involved and took a great deal of time. One partner discussed the way collaboration with EOT partners benefited his project creating curricula for teacher workshops. He described the collaboration in the following way:

> “In developing [the curricula] we share the materials [with EOT partners] and make sure that they are on target with respect to what the teachers are being asked to do in terms of curricular reform, and I needed those contacts with the partnership to understand that, because I don’t teach everyday in that regard.”

This type of collaboration also occurred in the process of developing tools, in which the partners from different areas of expertise collaborated. One partner described how working with other partners:

> “…pooled our interests and our abilities. As a result we have developed some really strong modeling materials for one thing, and some strong modeling techniques. I’ve learned from them, they’ve learned from me.”

Anther partner provided the example of how teachers had the opportunity to field-test Biology Workbench, an EOT-PACI educational tool. This allowed partners from different areas of expertise to shape the tools so that they truly met the needs of the teachers who would be using them, thereby enhancing tool’s impact in the K-12 classroom. A partner gave her perspective on these types of collaborations in the following way:

> "It ends up giving the teachers the ability to really have an impact and to change the direction something may be taking, to make it more usable. Being a partner gives us that opportunity for alpha testing that you wouldn't get if you were simply a consumer of something that had already been done….You can have a voice in shaping what should happen, and in doing so, you get a much deeper knowledge of the tools, and that enhances your use of it with your students. Your students get more out of it as a result."

Another type of collaboration occurred when partners participated as presenters or trainers in other partners' workshops. The AN-MSI project is one example of a project that made extensive use of presenters and trainers from other parts of PACI. For the MSI Cluster Computing Workshops that were developed to train representatives of Minority-Serving Institutions in how to set up and use their own computing clusters, AN-MSI recruited presenters from the Shodor Foundation, who provided sessions on modeling and visualization tools for the classroom. They also leveraged assistance from the San Diego Supercomputer Center, who provided a presenter on the future of HPC, and NCSA, who provided technical support and training on PACI cluster software.

Through collaboration, particularly within EOT-PACI teams, partners also were able to identify gaps in existing technology or the need for new programs to better address the goals of EOT-PACI. For example, through team discussions, partners involved in the Undergraduate Education Team identified the need for online repositories of user-friendly computational science tools and lesson plans for undergraduate education. Two repositories highlighting other partners' tools and lesson plans were developed by EOT-PACI partners to address this need. These repositories were not necessarily created collaboratively, but the identification of a critical need and the product to address it grew out of dialogue with EOT-PACI partners.

A similar example of critical issues being identified through collaboration comes from the K-12 Education Team in EOT-PACI. The focus of most of the partners had been predominantly on in-service work with K-12 teachers. Through team discussions, they realized the need to also bring computational science into the pre-service training of teachers. This resulted in a multi-partner collaboration on a successful Department of Education grant proposal for the Ed Grid project. One of the partners described this effort and the role of EOT-PACI in facilitating this major collaboration in the following way:

> "I think that the fact that EOT-PACI existed allowed partnerships to happen, or facilitated partnerships that may not have occurred otherwise. Ed Grid is a really good example. There is just no way that that partnership would have developed without EOT-PACI being there…We would have never thought about partnering on a major proposal. It would have just been too daunting because we wouldn't have had a mechanism to have discussions. Plus, we had basically two years for these partners to get to know each other before the RFP was even out. There's no way we could have responded to that kind of RFP if we hadn't had those kinds of [team] discussions all along."

Another partner summed up the value of collaborating with EOT-PACI partners as follows:

> "Out of that ability to collaborate so easily, our products and our work are so much stronger because we're not operating in a vacuum. We're not just all by ourselves. We're working as a team, and we each have different areas of expertise, so we're not duplicating each other, but we're learning from each other. And then what we're doing gets stronger and spreads out farther as a result. The ideas and the energy and the creativity of the people are extremely satisfying and worthwhile."

Not all partners experienced this degree of collaboration. A few partners who received a very low percentage of their funding from EOT-PACI attended few meetings and had little awareness of the efforts of other partners. Then there were partners who were frustrated when their attempts at collaborating with other partners fell through due to a lack of incentive or a lack of explicit encouragement on the part of PACI leadership. At least two partners felt that there had not been as much collaboration among the partners in their team or between EOT partners and PACI tool developers as they would have liked. One of these partners said, "I'm not convinced that we have the P part in the EOT-PACI partnership."

3.2.3. Enhanced dissemination pathways for existing curricula, tools, and projects through connections with other partners:

Through participation in the EOT-PACI community, many partners experienced new avenues for dissemination of their curricula and tools, and participated in exchanges that assisted them in recruiting individuals for their programs. For example, partners described how they used the partner network to recruit students for their summer undergraduate research programs and teachers for their workshops. Another example came from the Shodor Foundation assisting the AN-MSI program in conducting their HPC Cluster Computing Workshops for MSI representatives. As a result of Shodor's participation in these Cluster Workshops, many of the MSI representatives sought more in-depth training in using PACI's modeling and visualization tools and signed up for summer workshops offered by Shodor's National Computational Science Institute.

Another example of dissemination through the EOT-PACI network was when partners shared their curriculum materials with other programs that were involved in similar types of outreach. This type of dissemination allowed programs to build on each other and not have to reinvent the same types of materials. As one partner stated:

> "There's a lot of preparation time that went into these materials because it is taking very complex things and trying to make them understandable to people who've never really done things like this before….So others can take advantage of our experience—fairly directly, without having to put in so much effort."

According to several partners, EOT-PACI's dissemination channels have also been very effective in promoting and supporting attendance at new events, like the Richard Tapia Celebration of Diversity in Computing Conference, now in its second year.

3.2.4. Increased scaling of projects through connections with other partners' institutions and organizations:

Most projects either grew in size or disseminated their programs to new sites as a result of EOT-PACI funding and their connection to the EOT community. Many partners discussed how EOT-PACI helped their projects to include more participants, provide more workshops, or expand their activities as a result of EOT-PACI support. The following partner statement is representative:

> "I would say that there's been a scale effect as a result. We've doubled in size since our initial partnership with EOT-PACI. Now, some of that would have happened anyway, but certainly EOT-PACI can take credit for a lot of it. They've enabled us to be more successful in both the grants we've pursued, and they've given us a constant resource."

Other EOT-PACI programs were able to scale to other sites. One program did this as a direct result of the network provided by EOT-PACI. Rice University's GirlTECH program had been a very successful teacher technology and equity program. This program became well known to EOT-PACI partners, both as a result of interactions with the program administrator, and because of an external evaluation that was conducted during the first year of the EOT-PACI grant. Through discussions and planning with other EOT-PACI partners, the program was scaled to four other sites in Boston, Chicago, Pittsburgh, and San Diego. The partner described EOT-PACI's influence on this scaling in the following way:

> "EOT-PACI connections gave us a network of individuals who said, 'We would be interested in hosting such a program.' So basically, it gave us a network of concerned individuals who were very supportive of the activity."

What is notable about this example of scaling is that the partners did not have to write another grant proposal to scale GirlTECH to other sites. As the creator of the original program stated, "It was a grassroots-type thing in which partners said, "We want to do this here, so let's go out and find enough money for it to be funded here."

Another major example was the scale-up of the Spend a Summer with a Scientist Program at Rice University. Not only did this underrepresented minority graduate recruitment and retention program scale to 16 departments at Rice University, but it also scaled to an EOT-PACI partner site at the UW-Madison. This program's scale-up was facilitated through an EOT-PACI sponsored external evaluation in the first year of EOT-PACI funding.

3.2.5. Access to computational science researchers at supercomputing centers:

Many partners discussed EOT-PACI's role in providing them with access to PACI computational science researchers who they wouldn't have had access to otherwise. This access to researchers at PACI's supercomputing centers was especially important for EOT-PACI participants from Minority-Serving Institutions and non-Research I institutions. Connections and collaborations with these researchers were critical to the success of some of the projects in EOT-PACI. One partner expressed how being part of EOT-PACI provided this key opportunity:

> "[EOT-PACI] is a source of funds, but it's also a source of opportunities, meaning we have an open door to talk to the different researchers…because we're on the inside. We're part of the club. And so we can get a response to our questions and get a collaboration, or at least some help in understanding where a collaboration could be possible."

Another partner discussed how, through his participation in EOT-PACI, he was able to provide connections for researchers from Minority Serving Institutions with researchers at the supercomputer centers who could assist them in their research. This partner expressed how much he valued,

> "…the fact that I was able to extend the research of quite a few faculty here at this institution and other minority institutions. By being a partner, I was able to connect people. The most important thing was developing a human network. I could point to a whole host of institutions where I have made contacts with minority faculty or minority institutions and put them into contact with NCSA researchers….On the research level, I think that has made a tremendous impact on what these people have done, and also in bringing the idea of connectivity to their institution."

Another partner, whose project's mission is to facilitate the creation of technology that is accessible for individuals with disabilities, used his EOT connections to link with PACI researchers and try to influence the development of emerging technologies within PACI. This partner said, "If our mission is to make sure that people with disabilities don't get excluded, then we have to look at where the technology is going. We need to help create the technology map for the future and so we can't wait until it's done and then get involved." His connections with EOT-PACI aided his project in pursuing that goal.

3.2.6. Increased likelihood of receiving additional grants through leveraging:

Many EOT-PACI partners discussed how their involvement in the EOT-PACI program over the past six years had facilitated their project's receiving additional grant funding. For many partners, this occurred because their locally successful programs became known by a larger and more national audience through their association with EOT-PACI. In addition, partners felt that an endorsement by EOT-PACI conferred a certain respect that assisted partners in receiving additional grant funding. As one partner stated, "one reason we got the NSF grant to develop the material is because of the EOT-PACI seal-of-approval."

This not only helped partners get additional grants, but also facilitated their ability to participate in the national dialogue about critical issues. One partner discussed the larger scope of impact that was available to his project because of connections to EOT-PACI:

> "All of a sudden, I could do things that would impact a big community. For example, I could have a conference at Rice on leadership of underrepresented minorities. And I could do it, and it would be a national activity. I could invite people from all over the country. But the dollars that we would use would come from different sources: some of the money came from EOT PACI, some of the money maybe from NSF, maybe some of the money from small foundations. And we would now have these big workshops and big conferences where we could really have things discussed at the national level."

Another way in which partners were assisted in getting additional grant funding was through getting initial funding for a project through EOT-PACI, and then seeking other funding sources to build on that project. For example, one partner was involved in a project to develop undergraduate computational science curriculum materials using EOT-PACI funding. His group then turned to NASA for a major grant to help disseminate this curriculum material.

EOT-PACI partners were also able to leverage ties with influential EOT-PACI partners through letters of support, collaboration on their projects, or through having the EOT-PACI partners serve on program advisory boards.

3.2.7. Increased professional development opportunities for EOT-PACI partners:

For most partners, participation in EOT-PACI had an impact on their professional development in some way. As one would expect, there was a range in the degree of this type of impact. On one end of the spectrum were the partners that felt that their participation in EOT-PACI had a tremendous impact on their professional careers. One such partner discussed the impact in the following way:

> "This whole experience has changed my life. I don't want to get sappy or anything--but honestly, it has changed my life. I was a teacher and I was good at what I did. After I started working with EOT-

> PACI and meeting all of these people and learning about all the different ways that things could have been done, it was just incredible. I came back to my classroom saying, 'I want to do this!' And I came back to this job and wanted to share everything with my teachers and do visualizations that I had learned how to do, like Biology Workbench and ChemViz. I just got so excited about implementing these things in the classroom…We've had a lot of workshops where we've taught things that I didn't know about initially and it made me go back to school and start working on a different degree...It opened all these new avenues that I could go down."

Other partners discussed how their participation in EOT-PACI provided them access to a range of professional opportunities that they never would have been exposed to otherwise. For most partners this was the result of the new professional connections that EOT-PACI facilitated. For example, one partner discussed how she had moved out of a local sphere of influence through being a part of this organization:

> "[EOT-PACI] has connected me to people that I wouldn't have been connected to otherwise. So it has increased my network of professional colleagues. It's given me opportunities that you don't normally get at a university to collaborate….Before EOT-PACI, all the things I did were primarily local…I didn't really have many opportunities to work in a more national venue and think about things from a bigger-picture perspective. There was very little growth because we didn't have a critical mass of people that you could feed off of and build things together."

Other partners discussed how being a part of EOT-PACI had facilitated their professional growth in new and different directions as a result of having, "access to a wide range of people with different expertise and experience." Not all partners were asked directly about the impact of EOT-PACI on their professional development, and not all discussed it, but the quotes excerpted here are representative of partners' responses to this question.

4. Feedback from partners on EOT-PACI's programmatic efforts and organizational structure

In this section, we describe the feedback collected from interviewed partners on EOT-PACI's programmatic efforts and organizational structure, with an emphasis on how to improve these aspects of EOT-PACI in the future. The purpose of this feedback is to illuminate both effective and ineffective administrative strategies so that EOT-PACI can expand on its strengths and address its weaknesses in the years to come. The partners' feedback generally focused on three areas: (1) EOT-PACI's efforts to encourage collaboration between partners, (2) channels of communication and feedback between the Leadership Team and partners not represented on that team, and (3) the current funding structure of EOT-PACI, as established by the NSF's PACI grant.

4.1. Partners' feedback on EOT-PACI's efforts to encourage collaboration:

- The feedback from multiple interviewees suggests that, although there was a strong push for partner collaboration in Years 2-4 of the project, **there seems to have been less of an emphasis on collaboration in the last year or two**. Because there are no longer EOT team phone calls, a team intranet site, or regular calls and emails from EOT Program Directors directing partners toward collaborative opportunities, some partners wondered whether collaboration had become less important. Several NCSA partners said that the new Expeditions attempting to link EOT partners with NCSA tool developers are a positive development, but many NPACI partners said there has been much less cohesion and collaborative emphasis in NPACI's EOT efforts over the past year. Some of these partners mentioned feeling “out-of-touch” or “adrift” because of reduced communication opportunities with someone on the Leadership Team.

- **Many partners felt there was less collaboration between partners from NCSA and partners from NPACI than they would have liked**. Although EOT has been described as a single, unified partnership within the two PACI partnerships, separate sources of funding and lingering competition (what one partner termed “turf battles”) between the two sides of PACI have sometimes discouraged cross-partnership collaborations. Outside of those in the Leadership Team, few partners mentioned examples where EOT partners from one side of PACI had collaborated with those on the other side. For the most part, NCSA partners went to NCSA meetings and NPACI partners went to NPACI Meetings, although there were always some partners (usually Leadership team members) who attended both. This tendency to attend only one side’s All Hands Meeting—the side a partner was being funded by—was not helped by the fact that the meetings were often held only a month apart, forcing many to choose.

- **About a third of partners said they would have appreciated more chances to engage in face-to-face discussions with EOT partners during the year**, and not just during major conferences like Supercomputing, where most partners have competing obligations. Many of these partners acknowledged that it was not always easy to schedule or attend such meetings, but they felt that the face-to-face discussions and informal interactions that occurred during partner meetings were more effective at drawing people together into collaborative efforts than activities like conference calls or listserve discussions.

- **Differences in NCSA and NPACI’s partner groups and funding structure led to differences in how easily partners within their group could collaborate**. NCSA’s collaborative efforts like Ed Grid were greatly helped by the fact that someone at the Leading Edge Site was charged with leading a collaborative effort as part of her regular duties. NCSA’s collaborations were also helped by the fact that many partners had worked at NCSA and knew each other prior to the PACI program. NPACI had fewer partners, most of whom had never met prior to the PACI program, and none of whom were funded by EOT to work on collaborative efforts. This made collaborative efforts between NPACI partners somewhat harder to initiate.

- **Structuring EOT-PACI into five “teams” produced collaborations that some partners felt wouldn’t have happened otherwise, yet other partners felt that creating a team around a single aspect of one’s project inhibited collaboration with those from other teams.** Several partners, particularly those in the K-12 and Access and Inclusion teams, described how being placed on a team spurred collaborative efforts that wouldn’t have occurred otherwise. But other partners, especially those involved in the adaptation of HPC tools for the classroom or in encouraging computational science’s integration into the curriculum, said that the best partners for them to collaborate with were not necessarily the partners on their assigned team. For those partners who needed to work with K-12 teachers, undergraduate instructors, HPC tool developers, *and* underrepresented groups, being placed on a single team made it more difficult to initiate collaborative efforts outside of their team.

- **Some partners' projects demanded greater collaboration with HPC tool developers from the other areas of PACI, something which the EOT Leadership had little power to initiate or require.** A few partners said that their projects' long-term success would hinge on getting greater collaboration from the PACI thrust areas responsible for developing PACI's HPC research tools. Since these tool developers are not generally members of EOT-PACI, the EOT partners and EOT leadership have little leverage with which to encourage such collaboration. Some partners suggested that EOT-PACI provide more funding for educational liaisons who could spend a substantial portion of their time working with tool developers to adapt their research applications for educational use.

4.2. Partners' feedback on the degree of communication between partners and the Leadership Team:

- **Many partners felt the Leadership Team was not giving partners enough feedback on their individual performance and efforts**. Many partners said they couldn't tell from year to year if they were meeting the Leadership Team's expectations or not. How much partners were concerned with this lack of guidance depended on how much of their funding came from EOT-PACI. Some NPACI partners—who tended to receive a higher percentage of their project funds from EOT-PACI—expressed concern over a perceived decrease in guidance and contact with Leadership Team members over the past year.

- **Some partners felt there were insufficient mechanisms for feedback from partners**. Until these summative interviews, several partners felt that their opinions on how EOT was being structured and run were not being requested in any formal way. These partners felt that the Leadership Team was open to feedback if one offered it, but that they rarely solicited such feedback, except for discussions and emails regarding metrics. Most partners felt that the Leadership Team did a good job at providing them with information about upcoming program activities or requesting project information from them, but they perceived fewer opportunities to engage with the Leadership Team directly on how EOT was structured and managed.

4.3. Partners' feedback on the limitations of NSF's current funding structure for EOT-PACI:
Interviewees mentioned a number of limitations to EOT-PACI's current funding structure, which has the NSF funds being granted to two separate partnerships: NCSA and NPACI. The amount of funding given to EOT annually is decided by each partnership's PACI leadership, and then the EOT Leadership Team members from each partnership must decide (sometimes in consultation with Leadership Team members from the other partnership) how to fund their current EOT projects. Almost all EOT projects receive funding from just one partnership. The following are the perceived limitations to this funding structure:

- The fact that most partners receive funds from only one side of the partnership provides little incentive for cross-partnership efforts. Because the two larger PACI partnerships were often seen as competing with one another, some EOT partners felt discouraged from working with those from "the other side."
- Because no pool of money was set aside for future projects, bringing in new partners could not be done unless an existing partner's funding was cut. This greatly discouraged the expansion of EOT-PACI beyond the original partners.

- Partners working at a Leading Edge Site (one of the two supercomputer centers) were most likely to be the ones leading collaborative efforts because it got folded into their regular duties. This left some partners wondering what would happen if EOT were no longer connected to a Leading Edge Site. These partners feel it is important that some way of funding individuals to work on EOT collaborative activities and administration be maintained in any future EOT organization.
- Some partners were given too little funding from EOT-PACI for it to have much influence on their activities or their commitment to collaborative efforts. Not surprisingly, a higher percentage of project funding gives administrators more leverage with which to make demands on partners' time.
- Some partners felt there was no clear link between their performance and EOT funding. These partners said they weren't getting enough individual feedback from the Leadership Team to know whether they were doing what was expected of them, and when decisions to cut funds were made, it wasn't always clear why.

5. Evaluations of individual EOT-PACI projects

Since its inception, EOT-PACI has offered support and encouragement to its partners to evaluate the strategies and outcomes of their individual projects. This support and encouragement have come in the form of: (1) selecting one or two projects per year to receive professional evaluations from the LEAD Center, with funding provided by NPACI's EOT grant; (2) periodic workshops and presentations given by the LEAD Center to educate partners about evaluation and direct them towards resources for self-evaluation; and (3) having LEAD create an evaluation toolkit for partners with funding from NCSA's EOT grant. This toolkit, "Guidelines for Self-Evaluation of EOT-PACI Projects," is posted on EOT-PACI's website at http://www.eot.org/evaluations/eval.html.

Since the beginning of the grant in the fall of 1997, EOT-PACI has funded the LEAD Center to perform seven year-long evaluations of particular EOT projects or efforts. LEAD has also evaluated four partners' projects over multiple years using funding provided by the partners' own NSF grants. One of these partners began working with LEAD two years before EOT-PACI's inception. The other three partners received their NSF grants several years into the EOT-PACI program, one with the help of impact data provided by LEAD's evaluation of their project in 1997-98. In 1999-00, LEAD was also given EOT-PACI funding to evaluate a scale-up of that partner's project at the UW-Madison and to assess the effectiveness of NPACI's efforts to connect its partners in education with its high-performance tool developers.

Below is a chronological list of the EOT-PACI-related projects that the LEAD Center has evaluated. Descriptions of all of these projects and the key findings from their evaluations are in the section that follows. Complete evaluation reports can be downloaded from LEAD's publication page at http://www.cae.wisc.edu/~lead/pages/internal.html.

EOT-PACI-related projects that were evaluated by the LEAD Center from 1995-2003:

- ✓ 1995-2001: The Computing Research Association's Distributed Mentor Project (DMP)
- ✓ 1997-98: Rice University's Spend a Summer with a Scientist (SaS) program
- ✓ 1997-98: Rice University's GirlTECH program

- ✓ 1998-99: San Diego State University's Education Center on Computational Science and Engineering
- ✓ 1999-2000: UW-Madison's Graduate Engineering Research Scholars (GERS) program
- ✓ 1999-2000: EOT-NPACI efforts to form direct collaborations between EOT partners and tool developers in NPACI's AT/ET Thrust Areas
- ✓ 1999-2003: Rice University's Alliances for Graduate Education and the Professoriate (AGEP) program
- ✓ 2000-01: The San Diego Supercomputer Center's and San Diego Girl Scouts Imperial Council's Girls Are GREAT program
- ✓ 2000-01: UW-Madison's eTEACH online multi-media application
- ✓ 2001-02: The Computing Research Association's Collaborative Research Experience for Women in Undergraduate Computer Science and Engineering (CREW)
- ✓ 2001-03: Oregon State University's new Bachelor of Science degree program in computational physics
- ✓ 2001-03: EOT-PACI's efforts within the Advanced Networking for Minority Serving Institutions (AN-MSI) project

5.1. Key findings from LEAD Center evaluations of EOT-related projects

The summaries below provide a project description, the goal of the evaluation, the project's main outcomes, and the lessons learned for each of the twelve EOT-related projects or efforts that the LEAD Center has evaluated. They are categorized into seven types of projects: (1) projects designed to recruit and retain underrepresented minorities and women into graduate programs in computer science or the computational sciences; (2) projects designed to increase the participation of Minority-Serving Institutions in computational science education, research, and development; (3) projects designed to facilitate the incorporation of computational science into the undergraduate curriculum; (4) projects designed to train K-12 teachers in using online technology for science and math education; (5) projects designed to encourage K-12 girls' interest in science and technology; (6) online technologies designed to facilitate the delivery of educational materials and improve student learning; and (7) efforts to connect users in education with HPC tool developers. These projects by no means represent the totality of EOT-PACI's efforts.

5.1.1. Projects designed to recruit and retain underrepresented minorities and women into graduate programs in computer science or the computational sciences:

Spend a Summer with a Scientist (SaS): Rice University's well-known graduate recruitment and retention program for minorities and women in the computational sciences was summatively evaluated by LEAD in 1997-98 with an eye toward scaling. Established in 1989, the ultimate goal of the project was to encourage more ethnic minorities and women to enroll in graduate school and complete graduate degrees in computational science or applied math. Graduate participants from Rice and undergraduate participants from around the country were funded to come to Rice for the summer to work with a faculty researcher on a computational science research project and participate in an academic community which provided them with role models, mentoring, opportunities to present their work, and opportunities to discuss issues of race and gender in academia.

LEAD's evaluation established the effectiveness of the SaS program in recruiting its undergraduate participants into graduate school and retaining its graduate participants through advanced degree completion. Long-term tracking of participants and participant surveys demonstrated not only that SaS participants were enrolling in graduate school and obtaining graduate degrees at unusually high rates, but that most participants felt the program had a powerful impact on their decisions and success in pursuing advanced degrees. A number of participants asserted that they would not have completed their degrees—or thought to enroll in graduate school at all—had it not been for the Summer with a Scientist program. For undergraduate participants who had since graduated, 63% went on to enroll in graduate school, while another 33% joined the workforce in mathematics, computational science, or engineering. For graduate student participants, the rate of retention was 97%, with just one student having left graduate school without a degree. At the time of the evaluation, 57% of all graduate participants since 1989 were still in graduate school making steady progress toward their degrees. Of the 40% who had already completed their advanced degrees, two-thirds had received Ph.D.s.

The SaS strategies that were essential to participants' positive outcomes included the following:

- Hands-on experience with computational science research as an undergraduate or early in one's graduate career and opportunities to present that research to others;
- Being part of a sustained, multi-tiered community of undergraduates, graduates, and faculty that provided numerous opportunities for participants to mentor those below them and be mentored by those above them;
- Having sustained interactions and meaningful discussions of graduate school issues with role models and peers who share one's experience as an underrepresented minority or woman in the computational sciences.

For more details on the project's outcomes and essential elements, see Alexander, Foertsch, and Daffinrud (1998) on LEAD's webpage.

LEAD's evaluation was instrumental in Rice's successful application for an NSF Minority Graduate Education grant in 1998. Rice's SaS project has since been expanded to a year-round, 16 department effort called the Alliances for Graduate Education and the Professoriate (AGEP) program, which LEAD has been formatively evaluating with funding from its NSF grant. The same grant was also used to create a similar program for graduate students within the UW-Madison's College of Engineering called the Graduate Engineering Research Scholars (GERS) program, which was formatively evaluated by LEAD in 1999-00.

<u>Alliances for Graduate Education and the Professoriate (AGEP):</u> This scale-up of the Summer with a Scientist program at Rice University was begun in 1998 with a grant from NSF. The goals of the program are to improve the recruitment, admission, and retention of underrepresented minority graduate students in 16 of Rice's science, math, and engineering (SME) departments; create minority leaders within SME careers; and create a university culture that welcomes diversity. The year-round program provides participants with a graduate student community that recruits new students, supports advanced degree completion, and exposes its participants to rigorous academic standards.

LEAD provided the AGEP program with a formative evaluation from 1998-2003, with the goal of helping the program to assess existing challenges in the 16 departments and develop effective strategies for overcoming them. The evaluation also documents the program's progress and impact in three areas of minority graduate education—recruitment, admissions, and retention. To determine faculty beliefs and practices regarding diversity at the graduate level, LEAD surveyed 97 faculty members from 15 departments in the schools of science and engineering in January 2002. This survey resulted in a white paper that is currently being distributed nationwide: "Factors that Influence Science and Engineering Graduate Student Body Diversity: Results of a Faculty Survey."

Preliminary data show that in the first four years of the AGEP program, the average number of minority graduate students enrolled in the 16 AGEP Ph.D. programs was 35, compared to the previous five-year average of 31.8. In that same time frame, 19 minority graduate students in these departments completed their Ph.D.s, for an average of 4.75 completions per year compared to a previous five-year average of 1.2 Ph.D. completions per year.

LEAD's interviews with AGEP program participants found that:

- 92% felt that the AGEP program had a positive or very positive impact on their desire to remain in graduate school and complete their degree.
- 98% said that they were satisfied or very satisfied with the support they received from the AGEP Program.
- 98% of participants said that they were satisfied or very satisfied with the AGEP Program overall.
- AGEP's summer program was particularly effective in helping new minority graduates to adjust to the Rice environment, integrate into the graduate student community, and provide them with knowledge of how to succeed in graduate school before their first year had even started.

The summative evaluation report for the AGEP program will be released in November 2003.

<u>Graduate Engineering Research Scholars</u> (GERS): A scale-up of the Summer with a Scientist program known as the Graduate Engineering Research Scholars program was established within the College of Engineering at the UW-Madison in 1999-00. EOT-PACI was curious how a program like SaS would be adapted to fit the needs of a partner institution, particularly one with a much lower percentage of ethnic minorities and a cultural climate that was seen as less inviting to minorities than that of Rice University. LEAD conducted a formative evaluation for the GERS program during its first year to help it identify areas of need and develop strategies to improve the College's recruitment and retention of minority graduate students and female graduate students. LEAD interviewed minority graduate students and faculty advisors who had participated in UW's previous fellowship programs and analyzed departmental records to assess how each of the College's eight engineering departments were doing in their recruitment, support, and retention of both minority graduates and female graduates. One internal feedback report written by LEAD described the recruitment and retention situation in each department and identified strengths and areas of concern. Another formative LEAD report, which is available upon request, described the experiences and perspectives of the ethnic minority students enrolled in UW-Madison's graduate programs. These reports provided GERS administrators with a clearer idea of the challenges and obstacles they faced in boosting minority recruitment and retention and helped to get the GERS program off to a good start. The GERS program is now in its fifth year of operation and has served 29 graduate fellows.

<u>Distributed Mentor Project</u> (DMP): The Computing Research Association's Distributed Mentor Project is a summer research and mentoring program for undergraduate women in computer science and computer engineering (CS&CE). Established in 1994, its goal is to encourage participants to enroll in graduate school in CS&CE and give them the research background they need to pursue and complete their graduate degrees. Participants in this program are paired with female CS&CE faculty

mentors at research institutions, spend the summer doing research projects in their mentor's lab, and receive mentoring from the faculty member and her graduate students.

The program was formatively and summatively evaluated by the LEAD Center from 1995-2001, with funding from DMP's NSF grant. Through comprehensive analyses of post-program surveys, annual tracking of former participants, and alumni interviews in '95-'96 and '97-'98, LEAD's evaluation found that the project was highly successful in recruiting its participants into graduate school in CS&CE and giving them the preparation they needed to succeed in pursuing advanced degrees. For the 113 participants tracked by LEAD from 1994-2001 who had already completed baccalaureate degrees, 51% had enrolled in graduate school in CS&CE, and 17% had already completed their Masters. Another 44% were employed in CS&CE fields, and about two-thirds of those were planning to enroll in graduate school at some point. 77% of the participants surveyed rated DMP a "highly influential" factor in encouraging their graduate school enrollment. Before participation in the program, 37% of participants were committed to attending graduate school, but only 6% felt prepared to do so. After the program, 62% of participants were committed to attending graduate school and 67% felt prepared.

Interviews with DMP alumni showed that:

- Immersion in an academic research environment at a doctoral university and interactions with graduate students in their mentors' labs allowed participants to "try graduate school on for size" and gave them insider knowledge about the challenges of graduate school and how to survive them;
- Participating in an academic research group in which they had a clear role boosted participants' confidence in their abilities and increased their personal identification with the field of CS;
- Being mentored by a female faculty member gave participants a role model of a successful woman in academic CS and persuaded them to think they too could succeed.

For more details on the project and its outcomes, see the DMP evaluation reports on LEAD's webpage: Herrera (2002), Daffinrud (2000), Foertsch (1998), Alexander and Penberthy (1997), and Alexander and Daffinrud (1996).

<u>Collaborative Research Experiences for Women</u> (CREW): Based on its success with the DMP, in 1998 the Computing Research Association's Committee on Women created a second undergraduate research and mentoring program that would allow small teams of women to participate in CS&CE research projects at their home institutions during the academic year. This program, called the Collaborative Research Experiences for Women, was designed to encourage female undergraduates to pursue graduate school in CS&CE by increasing their opportunities to do research during the school year and decreasing their isolation from other women in CS&CE. EOT-PACI funded LEAD in 2001-02 to provide CREW with a summative evaluation that would allow program administrators to understand the program's impact and document its outcomes for future grant proposals.

CREW offered its participants many of the same activities and benefits as the DMP, but because it was a year-round program and included women from many smaller, non-doctoral institutions, the demographics of program participants and the impacts on their mentors were somewhat different from DMP. CREW had a significantly higher percentage of non-traditional students (older and with more family responsibilities) and a lower percentage of students who were considering graduate school from the outset. Nonetheless, LEAD's tracking surveys and interviews with program participants showed that CREW was still quite successful in recruiting and preparing participants for graduate school in CS&CE and retaining them in the field. Of the 44 CREW participants who had graduated and been tracked by the summer of 2001, 32% had enrolled in graduate school in CS&CE. Of the 52% of graduates who chose to work in CS&CE right after graduation, almost two-thirds had plans to eventually attend graduate school in CS&CE.

The primary benefits of the CREW program for its participants were:

- The experience helped in choosing or confirming a CS&CE career path and helped introduce the idea of graduate study for some who had never considered it.
- Participating in the program helped participants, especially those from smaller schools, distinguish themselves and get into graduate school or get better jobs in CS&CE.
- The research experience allowed students to feel better prepared for graduate school.
- The fact that the program was year-long allowed participants more time for the false-starts and failures typical of research and enhanced the benefits of mentoring.
- The integration of the program into the academic year increased the transfer of learning and engagement between participants' research projects and their undergraduate courses.
- Through the process of doing research in a safe environment with other women, participants gained self-confidence in their abilities in CS and developed a network of CS women at their home institution, which then served to encourage more women to participate in research.
- Faculty members from smaller institutions benefited from the opportunity to fund and mentor undergraduate researchers, something which many had not had the resources to do in the past.

The outcomes of LEAD's CREW and DMP evaluations were presented at the 2002 Grace Hopper Celebration of Women in Computing Conference. The results of the CREW evaluation were also used to apply for a scaling grant from NSF.

5.1.2. Projects designed to increase the participation of Minority-Serving Institutions in computational science education, research, and development:

Advanced Networking with Minority Serving Institutions (AN-MSI): In September 1999, the National Science Foundation awarded a $6-million grant to EDUCAUSE with a $1-million subcontract to EOT-PACI for a four-year collaborative effort called the Advanced Networking with Minority-Serving Institutions (AN-MSI) Project. EOT-PACI's role in the AN-MSI Project was to assist Minority-Serving Institutions (MSIs) in developing the computational infrastructure and skills needed to utilize high-performance computer applications and resources such as the Access Grid. MSIs include Historically Black Colleges and Universities (HBCUs), Hispanic-Serving Institutions (HSIs), and Tribal Colleges and Universities (TCUs). The overarching goal of EOT-PACI's AN-MSI effort was to increase the participation of MSI researchers and faculty in computational science education, research, and development and to increase their representation within PACI's high-performance computing projects, collaborations, and workshops.

With funding initially from EDUCAUSE's portion of the grant and later from EOT-PACI, the LEAD Center began a formative and summative evaluation of EOT's efforts in June of 2001. The purpose of the evaluation was to help EOT's AN-MSI coordinators assess their progress toward their goals and collect formative feedback that could be used to refine their strategies. EOT-PACI's efforts within AN-MSI were concentrated on the following workshops and activities:

- The MSI High-Performance Computing Workshop Series: 5 workshops from 2000-02
- The SC Minority-Serving Institutions Participation Project: 3 cohorts attending events at SC'00, SC'01, and SC'02
- An MSI HPC Working Group: established in 2002 with 10 members
- HPC-related demonstrations and discussions for MSI representatives: 3 events from 2000-01
- Seven permanent Access Grid nodes to connect MSIs to national HPC networks
- An NSF Proposal Writing Workshop in 2003

A total of 153 individuals representing 23 HBCUs, 18 HSIs, 13 TCUs, and 3 minority-serving technology organizations participated in EOT's AN-MSI events, and 30% of these participants attended more than one event. LEAD's evaluation found that through the SC MSI Participation Program, EOT-PACI has substantially increased the number of minorities and MSI representatives attending the nation's premier supercomputing conference and has created an ongoing community of MSI faculty and staff invested in HPC education and research. Through its MSI Cluster Computing Workshops, EOT-PACI has given 55 MSI representatives high-quality, hands-on training in setting up and using PC clusters to run HPC applications. The participants have used this information and donations of PC clusters from EOT-PACI to set up clusters at their own institutions, several of which are being utilized for both education and research. EOT-PACI has funneled numerous MSI faculty members into the NCSI modeling and visualization workshops run by the Shodor Foundation, where they receive a week's worth of training in how to integrate HPC applications in science and math into their teaching. In addition, EOT-PACI has provided seven MSIs with their own Access Grid nodes and the training in how to use them, connecting these schools via a high-capacity grid to supercomputer centers and majority institutions nationwide.

LEAD's evaluation showed all of EOT's AN-MSI workshops to be of high quality and relevance to MSIs. The long-term impact of these various workshops and activities on the 54 institutions that have participated in them varied: In general, MSIs that were already in a comparatively high state of technical development and small MSIs with very small IT budgets showed fewer long-term impacts from EOT's activities than MSIs that were at a mid-level of technical development but still interested in exploring HPC. MSIs like Bethune-Cookman College and Winston-Salem State University have seen tremendous gains in their technological capacity and their faculty and staff preparedness through both the EDUCAUSE and the EOT-PACI portions of the AN-MSI project. See Foertsch (2003d) on LEAD's website for more details.

5.1.3. Projects designed to facilitate the incorporation of computational science into the undergraduate curriculum:

Education Center on Computational Science and Engineering: The Education Center on Computational Science and Engineering opened within the main library of San Diego State University in October 1997, with joint funding from EOT-PACI, SDSU, and the California State University system. The Education Center employed a director, a staff scientist, an administrative assistant, and four student workers whose goal was to assist the faculty at SDSU and elsewhere in integrating high-performance computing (HPC) into their undergraduate teaching and research. Because few professors had even considered using HPC in their teaching, one of the Education Center's early challenges was to devise effective strategies for faculty education, outreach, and support. LEAD formatively evaluated the Education Center in 1998-99 to assist them in assessing their target audience's perceptions and needs with regards to HPC and to provide feedback on the effectiveness of the center's early outreach efforts.

LEAD's survey of 461 faculty members from the three colleges working with the Education Center illuminated the perceived challenges and benefits to using HPC in undergraduate education. At that time, over three-quarters of respondents (90% of Arts & Letters faculty, 70% of Science faculty, and 56% of Engineering faculty) said that they did not have "any knowledge of high performance computing or 'supercomputing' applications and how they may be used in the classroom." When asked whether they saw themselves as having any use for high performance computing applications in their own courses, 50% said they did not and 38% said they were unsure, with the primary reasons being lack of familiarity with HPC applications, lack of accessibility to these tools in their classrooms, lack of comfort with computers in general or with the applications' non-intuitive user interfaces, and a lack of time to redesign their undergraduate curriculum to utilize HPC tools. LEAD's interviews with college deans, department chairs, and faculty who were trying to integrate HPC resources into their curricula further supported the notion that most SDSU faculty had a very limited conception of HPC technology and limited time or motivation for designing curricula that included it.

LEAD worked with the Education Center over the course of the year to collect feedback on their outreach efforts and uncover strategies that held the most promise in persuading some faculty at SDSU to incorporate HPC applications into their teaching. The most effective of these early strategies was the center's Faculty Fellows program, which provided a handful of interested faculty with buyout time, HPC resources, technical and logistical support, and a community of fellow faculty who were also attempting to integrate HPC instructional modules into their curricula. LEAD's evaluation further showed that many of the challenges that the Education Center faced in promoting HPC use could be addressed only with the help of PACI's HPC tool developers, who needed to design more intuitive user interfaces that took the needs of educators and non-expert users into account. Because of the degree of complexity in existing HPC user interfaces, Education Center staff wound up spending a significant portion of their time trying to create more user-friendly applications for faculty clients. One of their early creations, the Sociology Workbench, has since been widely distributed.

For more details on the Education Center's early development, see Foertsch and Alexander (1999) on LEAD's publication page, and Foertsch (2000) in an American Association of Higher Education special publication at http://www.cae.wisc.edu/~lead/pages/external.html. For an update on the Education Center's efforts in the years since the LEAD evaluation, see their website at http://www.edcenter.sdsu.edu.

Bachelor of Science Degree Program in Computational Physics: In the Fall of 2000, Oregon State University received an NSF grant to aid in the development of a Computational Physics degree program that built upon the university's existing computational physics courses. LEAD was selected as the project evaluator and began its evaluation in the same year that the degree program was officially established. From 2001-03, LEAD conducted quarterly formative evaluations of the four computational physics courses that make up the bulk of the degree program. The feedback from these evaluations was used to improve the courses and document their outcomes over time. At the end of the 2003 school year, OSU's current computational science majors were interviewed about their experiences and plans.

A total of 74 students enrolled in one or more of OSU's Computational Physics (CP) courses from the Fall of 2001 to the Spring of 2003. In the two years since the degree program was established, a total of six students have declared themselves computational physics majors or minors. Another 13 undergraduates have indicated in post-course surveys or interviews that they have a high interest ("4" or "5" on a 5 point-scale) in pursuing a CP major or minor. This pool of potential Computational Physics degree candidates is fairly large considering the age of the program and the time constraints on declaring a new major for the more advanced students taking these courses.

When OSU students were interviewed about what motivated them to sign up for the CP major or minor, they emphasized the following three benefits of having a Computational Physics degree:

- All of the interviewees thought that having a strong computational background would make them more marketable and more competitive for jobs.
- All of the interviewees had a primary interest in physics but enjoyed computers and programming, too, and this degree gave them a chance to combine two of their interests.
- Half of the interviewees talked about the growing importance of computer simulations in allowing physicists to test theories that would be difficult or impossible to test otherwise.

See Foertsch (2003a,b) on LEAD's website for summative evaluation reports for the two largest courses and Foertsch (2003c) for a profile of OSU students who have taken CP courses or declared CP majors.

5.1.4. Projects designed to train K-12 teachers in using online technology for science and math education:

GirlTECH: Rice University's GirlTECH K-12 teacher training workshop on Internet technology and equity issues was evaluated by LEAD in 1997-98. The goal of the Houston-based program, established in 1995, is to seed the nation with more technically-capable K-12 science, mathematics, and technology teachers and prepare them to teach and counsel their students with greater effectiveness and sensitivity to issues of equity. Over a two-week period each summer, the twenty or so K-12 teachers selected to participate receive intensive computer technology training from master teachers, resulting in the design of their own online math and science lessons and the creation of their own websites linked to the GirlTECH site. Participants in the workshop are expected to become members of an ongoing teachers' technology support group that communicates via listserve throughout the year. Participants must also make a one-year commitment to advanced technology training and the integration of technology into their teaching.

LEAD's evaluation of the GirlTECH workshop established its effectiveness in helping K-12 teachers to incorporate online educational resources into their curricula. During the two-week workshop, participants significantly increased their Internet searching and programming skills, their awareness of the field of computational science, and their understanding of how issues of gender and ethnicity affect computer use. In the school year that followed, substantial increases were seen in the number of participants using computers in their teaching and curricular research and in the diversity and sophistication of the teachers' computer use. All participants also became members of a sustained, supportive community of fellow teachers and computational scientists at Rice who were dedicated to incorporating technology into the K-12 curriculum, and about one-fourth of participants became technology trainers within their schools.

LEAD's analysis of participant interviews, focus groups, surveys, and listserve discussions produced the following guidelines for successful technology training programs for K-12 teachers:

- Technological skills are best learned through "hands-on" collaborative activities.
- Immersion in the subject matter over several weeks is needed in order to make significant advances in one's technological skills.
- Attention must be given to how the technological skills and resources will be integrated into each teacher's curriculum.
- Follow-up technical support must be readily accessible, timely, and proficient.
- Teachers must be given opportunities during the school year to refresh their training and enhance their skills.
- Providing a forum for ongoing discussions allows teachers to rely on the support and knowledge of their peers.
- For teachers working with underrepresented populations, hearing the success stories of individuals from similar backgrounds provides inspiration and deeper understanding.

See Foertsch, Daffinrud, and Alexander (1998) on LEAD's publication page for more details.

In the years since LEAD's evaluation, GirlTECH has been renamed TeacherTECH and has scaled to other sites including Boston, Chicago, Pittsburgh, and San Diego.

5.1.5. Projects designed to encourage K-12 girls' interest in science and technology:

Girls Are GREAT: The Girls Are GREAT program, sponsored by the San Diego Girl Scouts Imperial Council with support from EOT-PACI, is an in-school science enrichment program focused on minority and low-income 1st-8th grade girls. The program's science enrichment component began in 1997 as part of its partnership with EOT-PACI through the San Diego Supercomputer Center. Since then, the goal of the program has been to advance and sustain girls' interest in science, with a special emphasis on the minority girls who are involved in many of the Girl Scouts' urban-area troops. The program was evaluated by LEAD in 2000-01 with the goal of national scale-up within the Girl Scouts of America. At that point, 5,600 girls in over 50 elementary and middle schools throughout San Diego and Imperial counties were participating in the program.

Because of the difficulties in collecting data from young students, most of LEAD's evaluation relied on interviews with the teachers, program leaders, parents, and principals involved in the Girls Are GREAT program. A total of 48 such interviews and were conducted. In addition, surveys were distributed to 81 teachers participating in the program, with 32% returning responses, and focus group interviews were conducted with 26 student participants.

From the teachers' perspective, the most frequently cited impacts of the Girls Are GREAT program on its student participants were:

- Increased collaborative learning skills.
- More positive attitudes towards science and increased confidence in doing science activities.
- The development of better English language skills.
- Increased motivation to learn and greater engagement in school activities.
- A reinforcement of the science lessons already being taught in the classroom.

These benefits were seen as being tied to the following program strategies:

- Using hands-on science activities to engage the girls' interest and allow them to explore scientific concepts through experience and experimentation.
- Providing science equipment to classrooms that would be unable to afford such resources on their own.
- Presenting academic material in a relatively informal context, which makes science more approachable and less intimidating for students who lack confidence in their science and math abilities.

See Alexander and Herrera (2002) on LEAD's webpage for more details. The Girls Are GREAT program has since been scaled to Houston and Atlanta through those regions' Girl Scout Councils.

5.1.6. Online technologies designed to facilitate the delivery of educational material and improve student learning:

eTEACH: With funding from EOT-PACI, programmers at UW-Madison designed an online, streaming-video and multi-media education application called eTEACH. In 2000-01, eTEACH was used to reform one of UW-Madison's large, lecture-based computer science courses for engineering majors. The course's in-class lectures were replaced with videotaped lectures and supporting materials that students could view on the Internet on their own schedule, making it possible to use the live class periods for small-team problem-solving sessions facilitated by the professors and a teaching assistant. By using the eTEACH application to transform course lectures into "homework" and free up the face-to-face class time for working on problems similar to homework assignments, the professors made better use of their in-class time, providing their students with helpful hints and guidance when they needed it most.

LEAD's evaluation of the computer science course over two semesters showed that students who took the eTEACH version of the course gave significantly higher ratings to all aspects of the course, including lecture usefulness, professor responsiveness, the instructor, and the course overall. Although a few students missed the opportunity to ask questions during lectures, about two-thirds of the 531 students surveyed felt it was easier to take notes and understand the lectures presented via eTEACH than it would have been while attending the same lecture live, and three-fourths of students appreciated the ability to view and review course lectures on their own schedule. Overall, 59% of students felt that placing the lectures online through eTEACH had a positive effect on their learning (42% "somewhat positive"; 17% "very positive"), 25% felt it didn't make a difference, and only 16% felt it had a negative effect (13% "somewhat negative"; 3% "very negative").

The benefits of eTEACH lectures that students mentioned the most frequently were:

- The ability to learn from lectures at one's own pace, with review available on demand
- The convenience of watching lectures on one's own schedule
- Watching lectures at the times that were the most conducive to learning

Alternatively, the 36% of students who thought it would have been easier to understand the material if it had been presented in a live lecture mentioned the following drawbacks to online lectures:

- No opportunity to ask questions in the middle of a lecture.
- Having printed course notes and the ability to replay lectures discourages some students from taking notes, and note-taking can help one learn.

The results of the LEAD evaluation were published in the *Journal of Engineering Education*. See Foertsch, J., Moses, G., Strikwerda, J., & Litzkow, M. (2002). Reversing the lecture/homework paradigm using eTEACH web-based streaming video software. *JEE*, 91 (3), 267-274.

5.1.7. Efforts to connect users in education with HPC tool developers:

Collaborations between NPACI's EOT partners and HPC tool developers: In 1999-00, NPACI's EOT Director asked LEAD to assess the collaborative efforts between EOT-PACI partners and the HPC tool developers in NPACI's Applications Technology and Enabling Technology Thrust Areas. Her goal was to collect information on any existing collaborations and to develop strategies for how to make such collaborations more frequent and more effective. LEAD performed case studies of eleven NPACI projects in which collaboration between educators and HPC tools developers had occurred, including the BioQUEST project, the eTEACH project, the Envision, Explore, Engage project, and projects coordinated by the Education Center for Computational Science and Engineering. Through the interviews and document analyses conducted for this evaluation, the following lessons were learned:

- NPACI personnel like the EOT Director and conferences like the All Hands Meeting have been essential in initiating collaborations between technology developers and users in education.
- A lack of time is the greatest obstacle to tool developers' participation in educational collaborations, but there are several effective strategies for overcoming time constraints.
- The most effective collaborations are those in which each partner respects and sees value in what the other collaborators can provide.
- EOT-NPACI should focus its support efforts on tool developers who are already invested in education, not on reluctant participants.

See Foertsch (2000) on LEAD's webpage for the complete evaluation report.

5.2. Lessons learned from evaluating a broad array of EOT-PACI projects and efforts

One benefit of having a common evaluator for so many of EOT-PACI's projects is that the lessons learned from evaluating one project can readily be used in subsequent evaluations to guide both project refinement and evaluation design. A second benefit is that evaluating numerous projects with similar or complimentary goals allows the evaluator to uncover best practices and effective program strategies that are generalizable across a wide variety of projects. In this section, LEAD's evaluators share five general lessons that they have learned through evaluating a broad array of education, outreach, and training projects within EOT-PACI.

5.2.1. The key to sustaining and broadening a project's impact over time is creating an ongoing community of participants.

One lesson that many partners within EOT-PACI have learned over the last six years is the power of community in sustaining and increasing a project or program's outcomes. Many education, outreach, and training projects are centered around workshops that last only a few days to one week, curriculum development exercises that last a semester, or summer undergraduate research programs that last two or three months. LEAD's evaluations have found that the long term-impacts of these experiences will be much greater if project administrators create an ongoing community of participants that continues to interact and support each other's efforts long after the workshop, course, or summer program has ended. The EOT-PACI programs that have been the most successful at reaching their ultimate goals and scaling are those that have created ongoing participant communities through listserves, follow-up meetings, and the use of participants to recruit and train new participants. Examples of projects whose successes have been multiplied through the interactions of an ongoing participant community are: The SaS/AGEP/GERS graduate recruitment and retention programs, the GirlTECH/TeacherTECH K-12 teacher training programs, the Faculty Fellows program coordinated by the Education Center for Computational Science and Engineering, and the MSI HPC Working Group coordinated by the AN-MSI program. Participants in all of these programs spoke of the importance of being part of a sustained community of people who had similar goals and faced similar struggles, and many interviewees said they would not have persisted in their efforts at curricular reform, professional development, or pursuit of advanced degrees if it had not been for the support of these EOT-PACI project communities. Ongoing project communities provided their members with advice, technical support, creative solutions to common problems, encouragement, perspective, and a sense of belonging at the times that they needed it most. This was true on the level of individual projects, and at the level of the EOT-PACI program overall. The impact of the partnership-wide community created by EOT-PACI was discussed in Section 3.

5.2.2. Successful project communities often include participants with diverse backgrounds.

LEAD's evaluations of numerous EOT-PACI project communities suggest that many successful communities include members from diverse backgrounds who pursue common goals. The goals of the project or program are shared by all participants and provide them with a sense of belonging and common purpose, yet the participants themselves often come from different backgrounds, disciplines, races and ethnicities, or educational settings. Indeed, these communities are often more effective at offering their members advice, broadening their perspective, and coming up with creative solutions to their problems precisely *because* they include people from a broad range of backgrounds. Both at the individual project level and at the program level, participants have frequently mentioned how interacting with community members who work in a different discipline or level of the educational system or who come from a different ethnic culture has given them valuable perspective, opened their eyes to new approaches, and made them more effective at developing relevant tools, curricula, and resources. In such communities, common goals hold the community together while diverse backgrounds help to make the community more successful at reaching its goals and broadening its participant base. The importance of common goals and diverse backgrounds to the EOT-PACI program as a whole was discussed in Section 3.

5.2.3. Undergraduate research and mentoring programs that are highly successful in recruiting and preparing their participants for graduate school have several best practices in common.

LEAD evaluated three EOT-PACI undergraduate research and mentoring programs that were designed to recruit women or underrepresented minorities into graduate school in computational or computer science: the Collaborative Research Experience for Women, the Distributed Mentor Project, and the Summer with a Scientist project. Like other undergraduate research programs that LEAD has evaluated at UW-Madison and elsewhere, these programs have several strategies in common that were found to be critical to their positive outcomes. These strategies are:

- *Giving undergraduates the chance to engage in hands-on, open-ended research that, unlike many classroom lab exercises, has no predetermined answers and no defined path to success.* Until they are given the chance to experience genuine research in their discipline, many undergraduates do not know whether research really interests them and lack confidence in their ability to perform it. This confidence-building is particularly important for members of underrepresented groups, who, due to a surfeit of role models, are less likely to feel that they "belong" in a discipline.

- *Immersing undergraduates in an academic research environment at a doctoral university and providing numerous opportunities to work and interact with graduate students in their mentors' labs*. This gives participants first-hand experience in the type of labs that are the centerpiece of a graduate career and allows them to get insider knowledge from current graduate students about the challenges they face and how to survive them;
- *Providing program participants with opportunities to present their research to peers and to advanced members of their discipline.* Numerous LEAD evaluations have found that having undergraduate program participants present on their research encourages research rigor, enhances their resumes, and provides important professional development in a skill that is critical to an academic research career.
- *Being mentored by a faculty member and/or graduate students who share key background characteristics with the undergraduate participant*. Seeing someone "like them" succeeding in a scientific discipline provides program participants—especially those from underrepresented groups—with a role model, increasing their identification with the discipline and encouraging them to think that they too can succeed. The importance of role models to the persistence of women and ethnic minorities in science, engineering, math, and technology cannot be overemphasized.

5.2.4. HPC tools used in education must be well-adapted to the needs and skill-levels of non-expert users.

To be effective and worthwhile, modeling and visualization applications used in education need to do one or more of the following:

- Replace a necessary and fairly frequent educational task with something quicker and more convenient.
- Illuminate something about an object or topic in a way that is easier to grasp, more engaging, or goes into greater depth than other methods of exploring the same topic.
- Enhance or enrich person-to-person communication rather than replace it.
- Have intuitive user interfaces that are fairly easy to learn and that take the perspectives and needs of students and teachers at that level into account.

Many of the HPC applications currently available do at least one of the first three things well, at least for disciplinary experts who are well-versed in the content area and well-practiced in the use and programming of high-end technology. (And, one could argue, those are precisely who most HPC tools are currently designed for: a small and elite group of researchers or educators who are already comfortable using HPC technology). But many HPC applications, including some developed by PACI, do poorly in the fourth area: having intuitive user interfaces that take the needs of non-experts into account. And because of the difficulties that non-experts encounter in deciphering and using the applications, the user base of HPC technology has been slow to expand, even at the level of graduate students and beyond. Furthermore, the lack of "user-friendliness" means the applications often perform below their potential in the first three areas as well. If a tool is too hard to learn to use or its output too hard to decipher, it will fail to improve over existing methods of education, communication, and illumination within a reasonable expenditure of user effort. Most professors, and certainly most K-12 teachers, simply don't have the time and technical support to tackle a tough learning curve for a computer tool, even if they know for certain that the tool could improve their teaching or research in some way. Potential solutions to this problem are: (1) to have existing HPC tools extensively modified by technically-skilled educators in collaboration with the tools' original developers, or (2) to involve educators or other non-expert users in the user interface design from the very start. This does not mean that all HPC applications should be made useable by everybody, but it does mean that HPC technology will have a much greater impact on research, education, and society at large if its developers are willing to more broadly define their potential user groups.

5.2.5. Intensive evaluation is often needed to refine the strategies of education and outreach programs, document their outcomes, and increase the programs' likelihood of successful dissemination and scaling.

As awkward as it is for a professional evaluator to name evaluation as a best practice for successful education and outreach programs, the experiences of numerous EOT-PACI partners have demonstrated that evaluation is indeed important. EOT-PACI partners who have received professional evaluations of their projects have repeatedly said in interviews and presentations that these evaluations were critical to improving their programs, getting additional funding, or encouraging others to replicate their programs at other sites. Administrators involved with the Computing Research Association's two EOT projects (DMP and CREW), Rice's two EOT projects and scale-ups (SaS/AGEP and GirlTECH/TeacherTECH), San Diego State University's Educational Center on Computational Science and Engineering, Oregon State University's Computational Physics degree program, and UW-Madison's eTEACH course reform have all said that third-party evaluation (in this case provided by LEAD) aided in the successful development, dissemination, or scaling of their programs. On the programmatic level, members of EOT-PACI Leadership Team have asserted that evaluation has been a key factor in the program's well-documented success, naming it as one of EOT-PACI's "best practices." Evaluation can be performed by program administrators themselves using self-evaluation toolkits and guidelines like those developed by the LEAD Center or the NSF, but high-quality evaluation is a labor-intensive enterprise that is best incorporated into a project from its inception and that continues for as long as feasible. This sort of evaluation must be worked into a project's budget from the outset, both in terms of funding and in terms of staff time. For summative evaluations in particular, evaluating the long-term outcomes of a program is time-consuming and requires up-to-date record-keeping to enable tracking of participants over time. Project administrators who know they will eventually want to assess their project's progress in reaching its ultimate goals are well-advised to collect contact information and set-up communication channels that allow them to get feedback and updates from project participants one or more years after their involvement in the project.

5.3. Survey of the evaluation data collected by EOT-PACI partners

LEAD's evaluations of EOT-PACI-related projects represent only some of the assessments that have been performed to document the outcomes of EOT-PACI projects. In addition to the evaluations performed by the LEAD Center, two partners (Biology Workbench and Maryland Virtual High School) have received comprehensive professional evaluations of at least one of their projects from an evaluator other than LEAD, and a majority of partners have collected evaluation data on one or more projects using their own evaluation instruments. LEAD's survey of 27 EOT-PACI partners in February of 2003 discovered the following about the extent to which individual projects have been evaluated:

- 66% of partners had one or more of their project activities evaluated in a systematic way, usually with post-activity surveys (56%) or focus groups/interviews (55%).
- 44% of partners received professional evaluations of their projects at some point during the EOT-PACI program (37% received evaluations of one year or longer from LEAD).
- 26% of partners used follow-up surveys to assess the longer-term impacts of their projects (19% had LEAD conduct this assessment for them).

When partners were asked, “Can you tell from the type of data you have collected what percentage of participants/respondents have achieved the ultimate goal of your program or product,” the responses were the following:

19% marked, “Yes, and I know the percentages.”
22% marked, “Probably, but the data has never been analyzed that way.”
26% marked, “Not yet, because there hasn't been time for many to reach the ultimate goal.”
33% marked, “No data of this type has been collected.”

EOT-PACI partners were also asked to describe the obstacles to evaluating their projects. An analysis of their responses indicated the following:

- About half of the partners felt it was challenging to adequately evaluate some or all of their project activities because of the age or high mobility of their project’s participants or the limited amount of contact they had with these participants. For example, some projects involved the creation and maintenance of online websites and tools, and it was not possible in many cases for project administrators to know exactly who was using these tools or how. Some of these partners had incorporated online evaluation forms into their websites, but responses rates for users completing a tutorial, searching a database, or downloading a tool were often low. Furthermore, online surveys connected to a tool are generally filled out too early to be able to assess how the tool affects the classroom or work environments in which it is ultimately used. Other partners whose projects involved workshops or summer programs had contact with participants during the activity, but relocating those participants and collecting data from them months or years afterwards was generally too expensive and time-consuming. In other cases, even when administrators could collect data from the workshop participants (e.g., K-12 teachers), they felt it would be too complicated to collect impact data on the target population in which NSF is most interested (e.g., the teachers’ students).
- About one-fourth of the partners said that many of the participants in their programs had not yet had time to reach the long-term goals of the program: for example, middle school students who were many years from going to college and declaring majors in science, or undergraduates who were many years from entering graduate school in computational science, much less completing their Ph.D.s.
- At least one-fifth of partners feel that a lack of time and money is a significant obstacle to evaluating their EOT-PACI projects. Many partners have commented on this issue in the past; however, survey respondents who mentioned methodological obstacles to performing evaluations did not bother to mention time and money as well, even if they had raised this problem in other contexts.
- One-fifth of the partners felt there were no major obstacles in evaluating their projects. About half of these partners had already had their projects evaluated and didn’t face any significant challenges in collecting the data they needed. The other half hadn’t evaluated their projects but didn’t feel that they would encounter major problems in doing so.

- A few partners said the major obstacle to their evaluating their EOT-PACI project was that the project was still in its development phases and hadn't had time to produce a measurable impact.

6. Conclusion: EOT-PACI looks to the future

The evaluation data in this summative report demonstrate the successes of the EOT-PACI program in improving and diversifying science, math, engineering, and technology education at every level from K-12 to graduate school; increasing the opportunities available to underrepresented groups in these disciplines; and integrating computational science into classrooms, labs, and new communities nationwide. Through meetings, conference calls, listserves, and community websites, partners administering EOT-PACI projects have been able to network with one another and form an ongoing community of computational science educators and tool developers with common goals like diversifying and expanding their participant base, integrating computational science into the curriculum, and scaling their projects nationwide. This community has shared resources, ideas, and strategies; learned about funding opportunities and best practices from one another; participated in collaborative proposals and projects; and disseminated their successful projects to other partners' sites. From interviews that the Evaluation Team conducted with EOT-PACI partners in 2003, there is no question that without the funds, technical support, and logistical support provided by EOT-PACI, most partners' projects would have been less capable of producing their favorable outcomes and scaling to include so many participants nationwide. Indeed, some of these projects would not have existed or continued at all without EOT-PACI support.

This summative evaluation report also reveals aspects of EOT-PACI that can be improved if some form of the collaborative program continues under the NSF's proposed Cyberinfrastructure grants. Partners' suggestions for improvement and their recommendations to NSF for how the program can be better funded, structured, and administered are summarized in Section 4. This feedback should be useful to both EOT-PACI and the NSF in considering how to best meet the education, outreach, and training needs of diverse user groups and future computational scientists at every level of the educational system, in every discipline within the academy, and for every arena in which sophisticated computer tools are used for learning, exploration, and problem-solving.

Appendix: Projects associated with or supported by EOT-PACI

Access Grid Documentation and Training Projects
Institutions: Boston University, Argonne National Laboratory, NCSA, Ohio Supercomputer Center, North Dakota State University, University of Maine, University of Manchester (UK), University of Montana, Worcester Polytechnic Institute
Contacts: Jennifer Teig von Hoffman
URLs: http://www.accessgrid.org/agdp/ http://webct.ncsa.uiuc.edu:8900/public/AGIB

Applying Computational Science Tools and Techniques in K-12
Institution: University of Alabama at Huntsville
Contacts: Edna Gentry, Carl Davis
URL: http://www.aspire.cs.uah.edu

Balboa Elementary Math Technology Pilot Project
Institutions: San Diego Supercomputer Center, Balboa Elementary School
Contacts: Rozeanne Steckler, Lyn Mora
URL: http://education.sdsc.edu/enrich

BEDROCK
Institution: Beloit College
Contacts: Sam Donovan, John Jungck
URL: http://bioquest.org/bioinformatics

Biocomplexity Project
Institution: Beloit College
Contacts: John Greenler, Robin Greenler
URL: http://bioquest.org/biocomplexity/

Biology Student Workbench
Institution: NCSA, University of Illinois at Urbana-Champaign
Contacts: Deanna Raineri, Umesh Thakkar
URL: http://peptide.ncsa.uiuc.edu

Bridging Research and Practice for Technology in Government
Institutions: Center for Technology in Government, University at Albany, SUNY
Contacts: Sharon Dawes, Derek Werthmuller
URL: http://www.ctg.albany.edu

Center for Theoretical Biological Physics
Institutions: San Diego Supercomputer Center; University of California, San Diego
Contacts: Kim Baldridge, Jason Wiskerchen
URL: http://ctbp.ucsd.edu/index.html

ChemSense
Institution: SRI International
Contacts: Patricia Schank, Vera Michalchik, Anders Rosenquist, Brian Coppola
URL: http://chemsense.org

ChemViz
Institution: NCSA

Contacts: Richard Braatz, Lisa Bievenue, Sudhakar Pamidighantam
URL: http://chemviz.ncsa.uiuc.edu/

Coalition to Diversify Computing
Institutions: Clark Atlanta University, Texas A & M University
Contacts: John Hurley, Valerie Taylor
URL: http://www.cdc-computing.org

Computational Science Education Reference Desk
Insitutions: Shodor Education Foundation, National Computational Science Institute, Clemson University
Contacts: David Joiner, Steve Stevenson
URL: http://www.shodor.org/cserd

Computational Tools and Resources for Biology Educators
Institution: Beloit College
Contacts: Ethel Stanley, John Greenler, Robin Greenler
URL: http://bioquest.org

Computer Science Computing and Mentoring Partnership (CS-CAMP)
Institution: Rice University
Contacts: Richard Tapia, Michael Sirois
URL: http://ceee.rice.edu/cs-camp/

CoreModels
Institutions: Maryland Virtual High School, NCSA
Contact: Susan Ragan
URL: http://mvhs.mbhs.edu

CRA Committee on the Status of Women in Computing Research (CRA-W)
Institutions: Duke University, Georgia Tech
Contacts: Carla Ellis, Mary Jean Harrold
URL: http://www.cra.org/craw

CSynergy
Institutions: NCSA, Shodor Education Foundation, National Computational Science Institute
Contact: Edee Norman Wiziecki
URL: http://csynergy.ncsa.uiuc.edu

Data Intensive Computing Environments (DICE)
Institution: San Diego Supercomputer Center
Contact: Reagan Moore
URL: http://www.npaci.edu/DICE

Deploying and Integrating Collaboration Technologies
Institution: Indiana University
Contact: Geoff Fox
URLs: http://grids.ucs.indiana.edu/ptliupages/ http://www.naradabrokering.org

Digital Video/eTEACH
Institution: University of Wisconsin-Madison
Contact: Greg Moses
URL: http://eteach.engr.wisc.edu

EdGrid
Institution: Shodor Education Foundation
Contact: Lisa Bievenue
URL: http://www.edgrid.org

Enabling and Integrating Problem-Based Computational Science Research in K-12 Classrooms
Institution: Ohio Supercomputer Center
Contact: Steve Gordon
URL: http://www.osc.edu/education/webed/Test_Course/announce.htm

Envision, Explore, Engage (E3): K-12 Curriculum
Institution: San Diego Supercomputer Center
Contacts: Anne Bowen, Zack Schumann, Apryl Bailey, Rozeanne Steckler
URL: http://education.sdsc.edu/e3

EOT-PACI Website
Institutions: Boston University, NCSA
Contacts: Ed Boyce, Maria Fish
URL: http://www.eot.org

Evaluation of EOT-PACI Projects
Institution: LEAD Center at University of Wisconsin-Madison
Contacts: Baine Alexander, Julie Foertsch
URL: http://cae.wisc.edu/~lead/

Fun Math Lessons
Institutions: Rice University, Sinton Independent School District
Contact: Cynthia Lanius
URL: http://math.rice.edu/~lanius/Lessons/index.html

Girls Engaged in Mathematics and Science (GEMS)
Institution: NCSA
Contact: Edee Norman Wiziecki
URL: http://gems.ncsa.uiuc.edu/

Girl Scout Partnerships-San Diego, Houston, and Atlanta
Institutions: San Diego Supercomputer Center
Contact: Rozeanne Steckler
URL: http://education.sdsc.edu/enrich/girl.html

GirlTECH
Institution: Rice University
Contacts: Richard Tapia, Michael Sirois
URL: http://teachertech.rice.edu/

Graduate Teaching Fellows in K-12 Education (GK-12)
Institutions: NCSA, University of Alabama Birmingham and Huntsville
Contacts: Richard Braatz, Umesh Thakkar, Sharon L. Comstock
URL: http://gk12.ncsa.uiuc.edu

Humanities Research: Technologies Enabling Large-scale Thematic Repositories
Institution: University of Virginia
Contact: Worthy Martin
URL: http://www.iath.virginia.edu/

Improving Undergraduate Education through the EdCenter (EC/CSE)
Institution: San Diego State University
Contact: Kris Stewart
URL: http://www.edcenter.sdsu.edu

Integrating Computational Biology in Undergraduate Education
Institution: Boston University
Contact: Raquell Holmes
URL: http://eot.bu.edu/ccb

Inquiry Page
Institution: Graduate School of Library and Information Science, University of Illinois at Urbana-Champaign
Contacts: Chip Bruce, Ann Bishop
URL: http://inquiry.uiuc.edu

LifeLines OnLine
Institutions: Southeast Missouri State University, Beloit College
Contacts: Margaret Waterman, Ethel Stanley
URL: http://bioquest.org/lifelines

Mathematics, Science and Technology Education (MSTE)
Institution: College of Education, University of Illinois at Urbana-Champaign
Contact: George Reese
URL: http://www.mste.uiuc.edu/

Mentor Center
Institution: Shodor Education Foundation
Contacts: Robert M. Panoff, Cornelia V.M. Simons
URL: http://www.shodor.org/mentorcenter

Mentoring Minority Students and Computational Science Academy
Institution: University of Houston/Downtown
Contacts: Richard Alo, Sangeeta Gad, Aon Tejani
URL: http://www.uhd.edu/ccsds

Metrics Gathering and Compilation
Institution: Boston University
Contacts: Raquell Holmes, Raymond Giles
URL: http://family.bu.edu/metrics

Minority Serving Institution Cyberinfrastructure Project (MSI-CI Project)
Institutions: NCSA, Boston University
Contacts: Stephenie McLean, Roscoe Giles
URLs: http://www.eot.org/projects.msi.html http://www.ncsa.uiuc.edu/Divisions/AccessInclusion/

Modeling Environment for Atmospheric Discovery (MEAD)
Institutions: NCSA, BioQuest, Maryland Virtual High School, Ohio Supercomputer Center, Shodor Education Foundation, University of Illinois at Urbana-Champaign

Contacts: Scott Lathrop, Dan Bramer
URL: http://www.ncsa.uiuc.edu/expeditions/MEAD/

Modeling Interorganizational Information Integration
Institution: Center for Technology in Government, University at Albany, SUNY
Contacts: Sharon Dawes, Derek Werthmuller
URL: http://www.ctg.albany.edu

National Computational Science Institute
Institutions: Shodor Education Foundation, NCSA, Sigma Xi, AN-MSI
Contacts: Bob Panoff, Kirsten Riesbeck
URL: http://www.computationalscience.org

Opening Gateways: Online Tools for Designing Electronic Access Programs
Institution: Center for Technology in Government, University at Albany, SUNY
Contacts: Sharon Dawes, Derek Werthmuller
URL: http://www.ctg.albany.edu

OptiPuter Education Project
Institutions: San Diego Supercomputer Center, Preuss School UCSD; University of California, San Diego
URL: http://education.sdsc.edu/optiputer

OSC K-12 Educational Outreach Programs
Institution: Ohio Supercomputer Center
Contact: Steve Gordon
URL: http://www.osc.edu

Partnering with Local Elected Officials through Web-Based Technology and the Academy for Municipal Excellence
Institution: Institute of Government and Public Affairs at University of Illinois Urbana-Champaign
Contacts: Robert Rich, Daniel Alpert
URL: http://www.igpa.uiuc.edu

Portal and Grid Technologies for Education
Institution: Indiana University
Contact: Geoff Fox
URL: http://www.grid2002.org/education

Preuss School UCSD Robotics Team
Institution: Preuss School UCSD, San Diego Supercomputer Center
Contacts: Rob Mainieri, Rozeanne Steckler
URL: http://education.sdsc.edu/preussrobotics

Project Interactivate
Institution: Shodor Education Foundation
Contact: Bethany Hudnutt
URL: http://www.shodor.org/interactivate

Project SUCCEED
Institution: Shodor Education Foundation
Contacts: Matt Lathrop, Garrett Love
URL: http://www.shodor.org/succeed

REVITALISE
Institution: NCSA
Contacts: Scott Lathrop, Edee Wiziecki
URL: http://www.eot.org/revitalise

TeacherTECH—Boston, Chicago, Houston, Pittsburgh, San Diego
Institutions: Boston University, NCSA, Rice University, Pittsburg Supercomputer Center, San Diego Supercomputer Center, Sinton Independent School District
Contacts: Cynthia Lanius, Raquell Holmes, Maryanne Jule, Scott Lathrop, Edee Wiziecki, Richard Tapia, Michael Sirois, Cheryl Begandy, Ange Mason, Jason Wiskerchen, Anne Bowen, Rozeanne Steckler
URLs: http://teachertech.bu.edu http://www.ncsa.uiuc.edu/Divisions/eot/programs/TeacherTECH http://teachertech.rice.edu http://www.psc.edu/training/teachertech http://www.education.sdsc.edu/teachertech

Undergraduate Curriculum Development in Computational Physics
Institution: Oregon State University
Contact: Rubin H. Landau
URLs: http://www.physics.orst.edu/CPUG/ http://www.physics.orst.edu/~rubin/

Understanding Risk and Probability through the Study of Hurricanes and Flooding
Institution: Ohio Supercomputer Center
Contact: Steve Gordon
URLs: http://www.osc.edu/education/webed/Projects/floyd/ http://www.ncsa.uiuc.edu/expeditions/MEAD/

Universal Design/Disability Access Program (UD/DA) for Advanced Computational Infrastructure
Institution: Trace Research and Development Center at University of Wisconsin-Madison
Contacts: Gregg Vanderheiden, Al Gilman, Tom Yen, Gottfried Zimmermann
URL: http://trace.wisc.edu/world/udda

WebSims Project
Institutions: Maryland Virtual High School, NCSA
Contact: Susan Ragan
URLs: http://mvhs.mbhs.edu http://www.ncsa.uiuc.edu/expeditions/MEAD/