

**Report of NSF Midwest Region Workshop on
Integrative Computing Education and Research (ICER):
Preparing IT Graduates for 2010 and Beyond**

February 2006

Editors:

David Lee, Bruce W. Weide, and Stuart H. Zweben
The Ohio State University

Any opinions, findings, conclusions or recommendations expressed in this report are those of the workshop participants and do not necessarily reflect the views of their institutions or the NSF.

The NSF Workshop on Integrative Computing Education and Research (ICER), Midwest Region, was supported by NSF under grant CNS-0548403.

Table of Contents

1	Executive Summary	3
2	Background and Workshop Organization	5
3	Computing Education	6
	3.1 Problems, Challenges and Opportunities	6
	3.2 Recommendations	9
4	Integrative Education	9
	4.1 Problems, Challenges and Opportunities	10
	4.2 Recommendations	11
5	Interdisciplinary Education.....	12
	5.1 Problems, Challenges and Opportunities	12
	5.2 Recommendations	14
6	Education Pipeline	14
	6.1 Problems, Challenges and Opportunities	15
	6.2 Recommendations	15
7	Appendix	17
	7.1 NSF ICER Midwest Workshop Information	17
	7.2 List of Workshop Attendees	17
	7.3 White Papers by Attendees	17
	7.4 Group Discussion Reports	17

1 Executive Summary

Our nation’s critical infrastructure depends on information technologies, which have tremendous impact on many other sectors of our society as well. Integrative Computing Education and Research (ICER) will play a key role in maintaining our nation’s world leadership in information technologies. The NSF ICER Midwest workshop was organized to investigate different aspects of integrative computing education and research: computing education, its increasingly integrative and interdisciplinary nature vis-à-vis computing research, and the education pipeline. In light of current problems, challenges, and opportunities, the workshop participants make the following recommendations:

1. Explore new ways of teaching computing at all levels, evaluate their impact, and disseminate the best practices.

Rally together appropriate members of the computing community to reconcile the issue of research-preparation versus industry-preparation needs of computing education programs. Explore new models to bring people with industry experience into the classroom, or to obtain industry experience for existing faculty members. Identify the most promising fields for interdisciplinary/multidisciplinary¹ programs and work with experts from those fields to create true interdisciplinary educational programs at an appropriate level, and to explore mechanisms to teach these subject matters effectively.

2. Promote integrative computing education in terms of multiple career paths, problem solving skills, and special programs for nurturing future IT world leaders.

Prepare students for multiple possible career paths, particularly for the IT industry, and get started at the introductory level. Emphasize communication skills, social and ethical responsibility, working in teams, and collaborative group projects. Develop integrative computational problem solving expertise. Create a special CS program to nurture future IT and high-tech industry world leaders.

3. Foster interdisciplinary education activities.

Explore ways to introduce interdisciplinary work early in the computing curriculum. Support experimentation with alternative curricular models. Develop a number of clear formulations of interdisciplinary problems to serve as foci for both research and education activities. Create repositories of interdisciplinary educational materials. Facilitate and reward faculty participation in conferences outside their own nominal disciplines. Develop infrastructure to support more effectively collaboration at a distance, especially to support collaborative work at non-research

¹ “Interdisciplinary” involves different sub-disciplines within a department (or college), and “multidisciplinary” involves different disciplines across departments (or colleges). However, that distinction depends on local administrative conditions. This report does not distinguish the two terms. It generally uses the term “interdisciplinary” to describe knowledge, activities, and skills that are not normally understood or practiced entirely within a single academic field — in this case, computer science.

institutions. Support consortia of institutions to foster collaborations on interdisciplinary educational activities.

4. Catalyze a nationwide effort for implementing changes in the education pipeline.

Integrate promotion and understanding of computing into the school curriculum, pedagogy, and professional development for teachers and counselors at all levels of the education pipeline. Launch an education publicity campaign to change attitudes and perceptions of the computing discipline among teachers, students, parents, and other relevant groups. Develop a tradition and national networks for promoting the discipline throughout the education pipeline. Support non-traditional student channels and encourage women, minorities, and graduates from community colleges to enter the integrative computing education pipeline.

2 Background and Workshop Organization

Our nation's critical infrastructure depends on information technologies, which have tremendous impact on many other sectors of our society as well. Integrative Computing Education and Research (ICER) is a key for our nation's world leadership in information technologies:²

NSF's CISE Directorate ... is taking a five to ten-year view of the field of computing education and the impacts of trends such as: decreasing enrollments in academic computing programs, needs of the USA workforce, national demographics, shifts in global competitiveness, movement towards multidisciplinary domains of knowledge in computing applications, and, particularly, the integrative nature of the field of computing, and future grand challenges that may face the field of computing ... The driving forces for ICER planning are domestic and global events and trends that impact on the nation's competitiveness and the maintenance of its intellectual resource base in computing ... For the most part, computing curricula do not address an integrative view of the field nor have curricula kept pace with industry needs and challenges posed by ever expanding and increasingly complex applications. The dwindling pipeline of high school graduates majoring in computing and the under-representation of women and other minorities enrolled in computing programs or working as practitioners persists ... National IT competitiveness is threatened by global economies in a number of ways ... Security has become one of the nation's most pressing immediate needs.

The Midwest Workshop — one of four NSF-funded ICER workshops — was held in Chicago, December 2-3, 2005, to discuss the issues noted above and to make recommendations on how these problems and challenges could be effectively addressed. The specific objectives of the workshop were to:

- Discuss and better understand the current and future grand challenges to the field of computing as a result of the impact of recent trends: decreasing enrollments in academic computing programs, needs of the U.S. workforce, national demographics, shifts in global competitiveness, movement towards interdisciplinary domains of knowledge in computing applications, and the integrative nature of the field of computing.
- Identify long-term strategic recommendations for establishing/supporting integrative computing education and research in the U.S. over the next decade to meet the challenges.

Twenty-five individuals, mainly from the midwestern states, attended the workshop by invitation. Attendees included major stakeholder groups such as: computing faculty, academic administrators, representatives of professional computing societies and trade organizations, government policymakers and funding organizations, recognized national leaders and futurists in

² *Integrative Computing Education & Research (ICER): Preparing IT Graduates for 2010 and Beyond — Executive Summary*. National Science Foundation Computer and Information Science and Engineering Directorate (CISE), CISE/CNS Education and Workforce Cluster.

the field of computing, and representatives of national research and industrial laboratories. Among the attendees, 36% were women, 8% were minorities. Non-Ph.D.-granting institutions were well represented. In addition, three representatives from NSF attended the workshop. The participants listed in the appendix attended the Midwest ICER NSF Workshop on December 2-3, 2005, and contributed to the writing of this report. The workshop was organized by Marjorie Bynum (ITAA), David Lee, Bruce Weide, and Stuart Zweben (The Ohio State University).

In preparation for the workshop, each invitee submitted a short white paper on one or two of the issues related to the workshop theme. The appendix contains a link to the white papers.

The workshop organizers used these white papers to frame the workshop agenda. It included plenary presentations by selected attendees, covering the perspectives from industry, government, and academia. Other attendees made brief statements on their individual views of the workshop theme. The remainder of the program contained four parallel working groups, chosen based on synergies among the white papers. The group themes involved computing education, integrative education, interdisciplinary education, and the education pipeline. It was possible for individuals to switch from one group to another if the discussion in another group appeared to be more suitable to the person's expertise and interests. There were two additional plenary sessions during which the groups came together to share their thoughts. The appendix contains a link to the presentations of the four groups during these plenary sessions.

The following is a summary of the discussions and recommendations associated with the four working group themes: computing education, integrative education, interdisciplinary education, and education pipeline. Because the themes are not disjoint, there is overlap in some of the discussion and recommendations from the different groups. We view this overlap as a sign of common understanding that the issue or recommendation is worth noting.

3 Computing Education

The investigation was focused on what an ideal computing education program might look like over the next decade³, the challenges to achieving such a goal, and the directions in which the computing community might rally support in order to meet these challenges.

3.1 Problems, Challenges and Opportunities

Some have suggested that our national IT competitiveness is threatened by global economies in a number of ways, including off-shoring/outsourcing, emergence of new information-based centers as in the Middle East, and government supported software development industries as in Ireland, Israel, and Poland. At the same time, irreversible global economical and educational changes, such as the rise of computing industry and education in India and China, are widely perceived to be eroding potential career opportunities for U.S.-educated computing professionals. It is often suggested that far fewer jobs will be offered in the U.S. for those with computing degrees, that

³ Rather than focusing on 2010, the workshop attendees tended to look out a decade on the grounds that computing graduates of 2010 will be coming primarily from programs that are already in place.

computing research here will suffer along with the computing industry, and that loss of U.S. leadership in computing and ultimately the entire IT industry is a serious risk.

On the other hand, some argue that the entire off-shoring phenomenon may not be a significant threat. Once computing professionals in developing countries realize they can command higher compensation, it will become far less economical for U.S. companies to offshore IT jobs. Furthermore, off-shoring has serious problems — some are becoming apparent and some are yet to come. They include language and cultural barriers, political instability and complications, possible government regulations, time and geographical differences, intellectual property abuse, and the volatility of employment. Therefore, the U.S. computing education program should not be distracted by a short-term problem that will correct or disappear by itself. Our computing education program should focus on how to teach better the core ideas of computing that are closely coupled with IT industry applications; it should concentrate on promising and well-planned improvements in pedagogy, rather than spending valuable time and resources making untested wholesale changes to computing education programs.

One important problem, then, is which of these views to believe. The jury is still out, though a majority of the workshop attendees seemed to subscribe to the former view rather than the latter.

The incorporation of concepts from other disciplines will become increasingly important to producing graduates with the expertise required by employers in the next decade. Real computing problems motivated by other disciplines will need to be incorporated into the learning of computing concepts and methods. Students should be able to appreciate why these problems are important to other disciplines, understand the nature of the computational issues relevant to these problems, and see examples of how relevant computing concepts and methods can be applied to attack the problems.

Business acumen is another component missing from most computing programs. Yet, it is a component that business leaders regard as very important for success in the workplace, along with strong technical skills and strong communication/collaboration skills. Elements often mentioned in this regard include understanding how organizations and projects work and are managed, and the ability to create a business plan and make a business case for one's technical idea.

The purpose of university education is not merely to prepare graduates for a first job but rather for an entire career. It is therefore particularly important in a rapidly changing field such as computing that educators identify and teach their students the key principles that should be expected to transcend mere technology changes. Despite characterizations of computer science as “problem solving”, graduates of computing programs frequently lack a systematic approach toward problem solving. They often are not adept at dealing with the scale-up challenges associated with complex systems of the type they will encounter as practitioners. There is a big gap between classroom computing and real system design and analysis in the IT industry. Consequently, both the graduates and industry would greatly benefit if what a student learned in class were closer to what is needed in industry, such as teamwork on large and complex projects and heterogeneous system integration and interoperability in addition to the principles of computing.

Whatever computing programs might be in a decade, they must be able to attract and retain good students. They also should support the long-term health of the field by preparing a set of graduates who are well trained to continue in research programs and by providing a larger number of graduates for industry employment. Attracting and retaining good students will be enhanced if the computing education program's inherent content is consistent with the needs of prospective employers so as to be evident to both employers and to students entering and engaged in these programs, and the program is taught in a manner that makes its content interesting and relevant. However, there is concern that today's computing programs do not achieve the above two goals sufficiently well to attract and retain students. Though many traditional computing concepts are still valuable and will remain valuable components of computing programs of the future, they often are taught quite abstractly or using problems that are fabricated just to illustrate a concept. Often, such a concept could be taught in a way that is more obviously connected to students' real-life experiences.

The pedagogy changes that can affect interest and excitement of students include active learning approaches, pervasive group activities, community service projects, and teaching approaches utilizing multiple instructors from different fields. Though web-based activities have their place in a program, relying on the web for distance education is not the best way to achieve the goals of increased interest by new students or retention of students in computing programs. The face-to-face interactions of students with each other and with "customers" of projects are necessary components of the educational process.

It is not clear how to structure computing curricula both to prepare certain graduates for research-oriented career opportunities and prepare the larger number of graduates for industry employment. For example, if a two-track program is required, should these be only at the graduate level, where masters programs might have either a professional objective or a Ph.D.-preparation objective; or should there be distinct tracks in undergraduate programs for these different objectives? If at the undergraduate level, where within the program should branch points occur (e.g., very early in the program or more toward the end) and how should common courses be structured to prepare students for either track?

Within a typical program designed to prepare graduates for entry into industry, insufficient attention is being paid to instilling good experiences with design and early lifecycle activities. Furthermore, students often do not get appropriate understanding of their own productivity and limitations (e.g., in writing software), and do not know how to assess such things. Industry-preparatory programs also need to ensure that students have the most significant practical experiences possible. These can be obtained via co-op or internship programs (which require closer cooperation between industry and university faculty than often is the case, and may need to incorporate international aspects more than they do now). They also can be achieved with more cleverly designed project experiences within the classroom environment.

It is a challenge to obtain faculty with the ability to teach the skills needed by the computing students of tomorrow. Interdisciplinary expertise, business understanding and acumen, and experience in large-scale projects with real-world constraints are some characteristics that the faculty will need.

The “ten pounds in a five pound bag” syndrome is a concern. If we need to add materials not now in undergraduate programs in order to meet the needs of tomorrow’s graduates , what do we remove from today’s programs in order to make room? Do we need a fifth year of university education to prepare students adequately? Can we do a better job in the pre-university environment so students are better prepared when they begin a university computing program? Alternatively, is it more a shift of emphasis of how we teach certain content rather than adding new content? If students need to have practical experiences, how can we encourage industry to provide enough opportunities for students to get these experiences? How can we incorporate international cultural aspects into these experiences?

Another set of challenges concerns the dissemination and sharing of good experiences and practices, so that they can be broadly used and not need be re-invented by every program. Repositories of best practices, great projects and exercises to utilize at key points in the curriculum are not now very well developed, nor are such materials widely shared. It also is hard to identify the teaching paradigms that have proven successful in reaching and motivating students so that they sustain interest and learn well. Thus, evaluation of the effectiveness of a change to the educational process is essential.

3.2 Recommendations

The following are the recommendations of this group for addressing the problems and overcoming the challenges for computing education.

1. Explore new ways of teaching computing at all levels, evaluate their impact, and disseminate best practices.
2. Explore new introductory-level courses, evaluate their impact, and disseminate best practices.
3. Bring together appropriate members of the computing community to reconcile the issue of research-preparation versus industry-preparation needs of educational programs (e.g., multiple undergraduate tracks, a broad-based undergraduate program supplemented by either a professional or graduate degree).
4. Explore new models to bring people with industry experience into the classroom, or to get industry experience for existing faculty members.
5. Identify the most promising fields for interdisciplinary programs and work with members of those fields to create true interdisciplinary educational programs at an appropriate level. Also, explore mechanisms to teach this subject matter effectively (e.g., through team teaching involving faculty from computing and faculty from other disciplines).

4 Integrative Education

The investigation of this group focused on integrative education to prepare students for various possible career paths, particularly for the IT industry. Obviously, our education system should support a variety of different education tracks in an integrative way to provide the world leaders, scientists, and engineers for the IT industry.

4.1 Problems, Challenges and Opportunities

The intellectual content of the field of computing has changed radically over recent years. It affects other fields, is affected by other fields, and involves understanding more complex interactions and integration than in the past. However, a typical computing education program for the most part does not address an integrative view of the field nor has the traditional curriculum kept pace with industry needs and challenges posed by ever expanding and increasingly complex applications; it can't adequately prepare graduates for the demands of the nation for the next decade and beyond. It has to become more outward looking than in the past, i.e., to integrate education and research activities more closely with those of other intellectual areas.

In fact, some problems that are inadequately addressed actually have been brought on by the success of computing. An example is the need for more attention to information security concerns in the presence of the ubiquitous Internet. Security has become one of the nation's most pressing immediate needs. However, a traditional computing program typically does not include it or only addresses its principles in a narrow way. On the other hand, security is an interdisciplinary area that involves other fields such as business, law, and management. An integrative computing program would prepare graduates for security needs in real practical systems for the whole society in the U.S., in addition to covering the basic principles.

The computing field has much to offer toward coping with such problems and toward educating students for the next decade and beyond — but it cannot act alone.

In the near future, we will have many flavors of CS, and some of the problems now will be incorporated into those flavors. A curriculum might be problem-based and project-oriented. Yet integration is not adequately built into the typical curriculum today, making it inadequate for the IT industry for the next decade and beyond. It is as though we give students the nails and a hammer, and tell them to go out and build a house.

“What is it that you look for in potential employees in industry?” Two answers are common: communication skills and ability to work in groups. Technical skills often do not make it to the top of such lists. However, job ads do not reflect that. Part of the problem is that industry is not good at articulating its needs. This also affects student perceptions of what a job in CS entails (hence whether they want to go into the field).

What are we looking for in our graduates? One might argue for someone ready for graduate study or someone who can walk out the door, get a job, and immediately advance industry. As evidence, they note that the engineering profession as a whole calls a well-prepared B.S. graduate an “engineer-in-training”, reserving the title “professional engineer” for those who do well academically *and* who have at least four years of on-the-job experience. The IT industry often seems to demand that “computing professionals” come right out of school with such experience.

Apparently, there is no uniform agreement on what constitutes the core of the computing field or how to produce graduates who are intellectually agile in a dynamically changing discipline.

Typically, multiple IT programs exist on a single campus, often housed in different administrative units. Cross-campus coordination and integration of these programs will improve the efficiency and effectiveness of education and research.

It is not clear how can a new college graduate get a good computing job. There is a variety of perceptions and proposals. For instance, one might argue that the graduate needs to understand more about business: marketing, finance and management. Therefore, perhaps some of the technical courses for undergraduate computing majors should be replaced by (or closely integrated with) business courses in order to satisfy industry's requirements for more business savvy among potential employees. Major curricular changes in this direction should be simultaneously addressed in the accrediting guidelines of the Computing Accreditation Commission and the Engineering Accreditation Commission.

The typical current computing education program lacks multiple paths/tracks; not everyone needs to take business courses and know about ROI. However, paths through a department's programs that remain about a single subject probably will die. The only ones that will survive the test of the market are those that are interdisciplinary and of an integrative nature. The definition of what we call CS now is too narrow and has to expand.

As the same time, it is not advisable to change drastically or to remove much technical content from an undergraduate computing major's course of study. The knowledge and skills a U.S. graduate will need in the future in order to secure a good job in the computing field are not diminishing but expanding. Therefore, it is possible that many U.S. jobs in computing will soon require an undergraduate computing degree, plus an advanced degree in computing or in a related field, in some cases (but not all) with a business focus. Should some new efforts in computing education should be on professional M.S. degrees, for instance, and on integrated graduate degrees in which computing plays a major role?

Many other questions about current education programs remain unanswered. How do we get more efficient at delivering education? How can we develop shared and proven effective learning materials and lab exercises? How can we minimize duplication? Why aren't existing learning repositories being utilized? Will, or should, education delivery methods be changed? For instance, anything that is distance insensitive can be shared and done remotely. Will the role of the instructor be changed to more of a consultant or coach?

4.2 Recommendations

The following are the recommendations of this group for addressing the problems and overcoming the challenges for integrative education.

1. Prepare students for multiple possible career paths, particularly for the IT industry, and get started at the introductory level. The railroad switchyard model for intertwining paths in the curriculum is advisable.
2. For all tracks of integrative education for multiple career path development, emphasize communication skills, social and ethical responsibility, working in teams, and

collaborative group projects. For some tracks, require business perspectives and professional focus.

3. Develop integrative computational problem-solving expertise, starting from initial fuzzy requirements through to results, using computing techniques and tools, that is, “computing maturity”.
4. For use-inspired learning in an integrative and active way for students’ problem-focused curriculum development, use on-going problems as a mechanism to integrate concepts and techniques from various areas of computer sciences, mathematics, physics, and engineering.
5. Develop special CS programs/tracks for future IT and high-tech industry world leaders that recognize that the special needs of high-ability students do not all involve preparation for graduate school. For example, consider one possible program of this type that could be funded by government and the university: select highly motivated and well-prepared high school graduates from programs where mathematics and science are a focus of attention⁴; complete the basic college education in two years, skipping or simplifying courses unrelated to the computing core and emphasizing IT-related topics; focus on business and entrepreneurship for a year; and have the students run real start-up companies with their own ideas in the final year.

5 Interdisciplinary Education

The focus of the investigation by this group was on the interdisciplinary nature of computing education and the computing field in the next decade and beyond. Various issues were addressed from the points of view of both industry and academia with an emphasis on undergraduate computing major programs.

5.1 Problems, Challenges and Opportunities

Computing has become a key enabler of advances that have occurred — and that will continue for the foreseeable future — across all disciplines of the academy and throughout all segments of industry and society. However, much the same can be said, historically speaking, about mathematics and statistics. For example, engineering students a century ago did not learn to use calculus to build mathematical models of their systems; that is a relatively recent development (about 75 years old) that also has accelerated progress across these disciplines. Why should we expect that computing will be any different in the long run? A focus question considered by the group was whether computing as an academic discipline is inevitably headed in the same direction as mathematics and statistics. Specifically, will computing become an academic discipline where faculties are generally theoretically oriented, teaching primarily service courses to other majors and graduating few of their own majors? Even if this is not inevitable, then do we want that outcome anyway, or do we wish to point computing education in a different direction?

⁴ Such high schools are already in place in some areas, and others are being established (see, for example, “New Metro High School Seeks Applications”, *Upper Arlington (Ohio) News*, Jan. 25, 2006).

We do not want or expect future computing departments to resemble current mathematics or statistics departments in these respects — not that there is anything inherently wrong with those models, but simply that it is not a hoped-for future of computing. Moreover, there are differences among the roles of computing, mathematics, and statistics that suggest it is not inevitable that computing departments will wind up being similar to mathematics and statistics departments. The primary reason is that the main value of computing across the economy will not arise from students majoring in other disciplines who have had a somewhat shallow introduction to the concepts of computing, but rather from students who have a deeper understanding of computing concepts and the ability to apply them both in traditional computing contexts and with a broader perspective. Computing graduates in the next decade will be highly valued employees in a wide variety of industry positions if they:

- Excel as tool builders because they understand (much more deeply than majors in other disciplines), and can apply, the principles behind “intellectual amplification” that make computers so valuable across all disciplines and throughout the economy.
- Know how to deal (much better than majors in other disciplines) with the “complexities of scale” associated with increasingly large systems and models of all kinds by applying principles of abstraction, modularity, etc.
- Facilitate (much better than majors in other disciplines) communicating and “translating” ideas between people in disparate technical disciplines by applying principles of ontology and language design.

Computing should be more outward looking than it has been in the past, and some new sorts of interdisciplinary education programs will be needed to give computing graduates of the next decade knowledge and skills such as those listed above. On the other hand, there will still be “disciplines” in the academy, computing will be one of them, and it will be central as illustrated here. In other words, while there will be interdisciplinary connections of various strengths and importance between many different pairs of academic fields, computing will continue growing stronger interdisciplinary ties with many other disciplines.

The problems associated with achieving this vision of computing are many. What kinds of interdisciplinary degree programs are appropriate, if any? What interdisciplinary curriculum models will work best, e.g., minors, tracks, a “consulting” model similar to statistics, or something else? What interdisciplinary problems will work best to illustrate and teach the relationships between computing fundamentals and the problems of neighboring disciplines? The list goes on and on.

If these are some of the problems that need to be addressed by interdisciplinary computing education in the next decade, what are the challenges currently constraining our ability to solve them?

Some serious challenges involve the inertia of academic and industrial institutions, most of which are comfortably ensconced in organizational models built around disciplinary “silos”. For example, universities have colleges and departments — and for many good reasons. Promotion and tenure decisions are made by peers in nominally the same discipline as the candidates for advancement. What happens when faculty engaged in interdisciplinary research, not to mention

interdisciplinary course development, come up for promotion and tenure? Several organizational models have been tried by the participants' institutions to buffer the impacts of such organizational boundaries as impediments to developing interdisciplinary research and educational activities. While most of them seemed promising, it will be challenging to provide convincing evidence that any is "effective" in overcoming institutional and organizational barriers to interdisciplinary activities.

Another challenge is achieving faculty buy-in to interdisciplinary education sufficient to cause them to develop the new courseware, etc., required to update the computing curriculum in this direction. It is likely to be a slow process even with adequate funding and similar incentives for change — and a much slower one without them.

Then there are the perennial challenges of how best to teach computing majors the required principles and skills, and how to get human resource departments in industry to realize that they should value them despite their seemingly indirect contributions to the bottom line.

5.2 Recommendations

The following are this group's recommendations to address the problems and overcome the challenges for interdisciplinary education.

1. Explore ways to introduce interdisciplinary work early in the computing curriculum — in introductory courses if possible.
2. Support experimentation with (and associated evaluation of) alternative curricular models that emphasize interdisciplinary work, both at the course level and at the program level.
3. Support the development of a number of clear formulations of interdisciplinary problems — essentially, well developed problem statements — to serve as foci for both research and education activities.
4. Create repositories of educational materials to assist faculty in learning about interdisciplinary problems and in developing new course variants.
5. Facilitate and reward faculty participation in conferences outside their own nominal disciplines.
6. Find ways to help teach both university and K-12 teachers how best to teach interdisciplinary concepts, including advice on structuring course materials and assignments, and evaluating students.
7. Develop infrastructure to support more effectively collaboration at a distance, especially to facilitate collaborations involving faculty at institutions without the comprehensive research and educational programs of very large universities.
8. Support consortia of research/graduate institutions, four-year undergraduate institutions, and community colleges to foster collaborations on interdisciplinary educational activities.

6 Education Pipeline

The investigation of this group was focused on the pipeline for integrative computing education. Enlarging and strengthening the education pipeline has become a national security issue that requires a Manhattan Project style and scale of solution.

6.1 Problems, Challenges and Opportunities

There is a dwindling pipeline of high school graduates majoring in computing, and the under-representation of women and other minorities enrolled in computing programs or working as practitioners persists. In the past, international students compensated for the dwindling pipeline, studying both at the undergraduate and graduate levels and most often remaining in the U.S. workforce after graduation. However, with restrictions on visas, the U.S. has been losing this important source of students and practitioners. On the other hand, the number of domestic students wishing to major in computing in college has been rapidly declining in the past few years. This by itself may be just a natural cyclical phenomenon faced many times by other fields, such as engineering. There is evidence that job prospects might be on the upswing soon. However, because of the four-year phase lag between the choice of major and graduation, there is the prospect of a serious shortage of U.S. computing graduates by 2010. This will be a true disaster because it will lead to accelerated off-shoring of computing positions at that point; U.S. employees will be scarce or at least very expensive. This will further hasten the possible loss of U.S. world leadership in the computing field and even in the IT industry as a whole.

Notably, interest among women and minority students has dwindled most rapidly, among all groups, during the past few years. Two-thirds of university students are in one or both of these groups. Therefore, steps must be taken immediately to encourage (or entice) all students — not just white males — to consider computing careers. However, mere verbal encouragement is far from being enough.

One of the challenges in overcoming this problem is the lack of sufficient role models, both as teachers in our primary and secondary school systems, and in the workforce itself. It is hard to continue going to the same few individuals to mentor others and to encourage others to take up this cause.

A second challenge concerns the branding of computing. Parents need to understand more about the value of computing if they are to be advocates of their children's entry into our field. It is easy to blame the media for the image of computing professionals as Dilbert-like geeks, but what can we do to counter it?

The pipeline problem involves all levels of the educational system in the U.S. Creating partnerships between different segments of the educational system is a challenge. For example, articulation agreements between two-year and four-year institutions often are difficult to consummate.

6.2 Recommendations

The following are the recommendations of this group for addressing the problems and overcoming the challenges for education pipeline.

1. A nationwide effort is needed for effecting changes in education pipeline, such as creating congressional joint task forces that include representatives from business, education, and professional organizations — “best minds” — to develop policy recommendations. This effort should be tied into existing national and regional professional organizations for academic groups. Taking advantage of existing research and education knowledge, the needs of the education pipeline should be integrated into school curriculum, pedagogy, and professional development for teachers and counselors with best practices that can be scaled and successfully implemented. Appropriate attention is required for the recruitment and retention of students into computing education.
2. Launch an education publicity campaign to change attitudes and perceptions of computing among students, parents, and other relevant groups. Develop and elevate the key messages of the roles of pipeline education in supporting our nation’s economy and national security with an emphasis on the benefit of math, science, and technology and their integrative education with different disciplines, using the media to help make the case. Highlight career plans and development for students, involving IT industry and identifying champions and role models.
3. Develop a tradition and national networks for promoting computing throughout the education pipeline. Identify advocates (industry, student alumni, etc.) from every state to reach back to schools and show connections between the education pipeline and career development. Offer specific scholarships that require program completion and promote continued benefit corporations, job shadowing, and apprenticeships for the education pipeline.
4. Support non-traditional student channels. Identify and take advantage of existing programs to encourage non-traditional students, particularly women, minorities, and graduates from community colleges, alternative high schools, and workforce development programs.

7 Appendix

7.1 NSF ICER Midwest Workshop Information

<http://www.cse.ohio-state.edu/~lee/NSF/home.htm>

7.2 List of Workshop Attendees

Marcella Black	LLC	mblack100@yahoo.com
Marjorie Bynum	ITAA	http://www.ita.org
Jim Cremer	University of Iowa	http://www.cs.uiowa.edu/~cremer
Laurie Dillon	Michigan State University	http://www.cse.msu.edu/~ldillon
David Du	University of Minnesota	http://www-users.cs.umn.edu/~du
Shashi K. Gadia	Iowa State University	http://www.cs.iastate.edu/people
Forouzan Golshani	Wright State University	http://www.cs.wright.edu/~golshani
Curt Hill	Valley City State University	http://community.vcsu.edu/facultypages
Susan B. Horwitz	University of Wisconsin-Madison	http://www.cs.wisc.edu
Chuck Huff	St. Olaf College	http://www.stolaf.edu/people/huff
Raj Jain	Washington University in St. Louis	http://www.cse.wustl.edu/~jain
Ming-Yang Kao	Northwestern University	http://www.cs.northwestern.edu/~kao
David Lee	The Ohio State University	http://www.cse.ohio-state.edu/~lee
Wen Liu	ITT	wliu@itt-tech.edu
Nan Poullos	Walsh College	npoullos@walshcollege.edu
Brian Shea	KPMG Peat Marwick	bshea@kpmg.com
David Su	NIST	david.su@nist.gov
Harriet Taylor	NSF	http://www.nsf.gov/staff
Gloria Townsend	DePauw University	http://www.depauw.edu/acad/computer
Beth Unger	Kansas State University	https://www.ksu.edu/provost/about/staff.htm
Ignatios Vakalis	Capital University	http://capital2.capital.edu/faculty/ivakalis
Grace Wahba	University of Wisconsin-Madison	http://www.stat.wisc.edu/~wahba
Henry M. Walker	Grinnell College	http://www.cs.grinnell.edu/~walker
Garrison Walters	Ohio Board of Regents	http://www.regents.state.oh.us
Caroline Wardle	NSF	http://www.nsf.gov/staff
Bruce W. Weide	The Ohio State University	http://www.cse.ohio-state.edu/~weide
Wei Zhao	NSF	http://www.nsf.gov/staff
Stuart H. Zweben	The Ohio State University	http://www.cse.ohio-state.edu/~zweben

7.3 White Papers by Attendees

<http://www.cse.ohio-state.edu/~lee/NSF/whitepapers/>

7.4 Group Discussion Reports

<http://www.cse.ohio-state.edu/~lee/NSF/Group%20Presentations/>