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The Effectiveness of Social Science Research in Addressing Societal Problems: Broadening Participation in Computing

Joshua L. Rosenbloom
Iowa State University and NBER, jlrosenb@iastate.edu

Donna K. Ginther
University of Kansas and NBER, dginther@ku.edu

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Keywords

Broadening Participation, Research Evaluation, Information Technology, Gender, Science

Disciplines

Infrastructure | Public Economics | Technology and Innovation

The Effectiveness of Social Science Research
In Addressing Societal Problems:
Broadening Participation in Computing

Joshua L. Rosenbloom
(Corresponding Author)
Iowa State University, Department of Economics,
260 Heady Hall
518 Farmhouse Lane
Ames, IA, United States of America 50011
and NBER.
Email: jlrosenb@iastate.edu

And

Donna K. Ginther
University of Kansas, Department of Economics
415 Snow Hall
1460 Jayawk Blvd.
Lawrence, KS, United States of America 66045
and NBER
Email: dginther@ku.edu

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Abstract

One important rationale for federal funding of social science research is its role in addressing pressing social problems. In this article we examine the impact of the National Science Foundation's (NSF) Information Technology Workforce Program (ITWF) on broadening participation Computing and Information Technology careers. Established in 2000 in response to the declining participation of women and minorities in Computer Science education and Information Technology Careers, the ITWF supported close to $30 million in research before it ended in 2004. We document the quantitative and qualitative effects of this research funding both to illustrate the complex ways in which R&D funding can advance scientific understanding and to identify the challenges that such problem-driven social science research may encounter. The problem of diversity in the IT Workforce has not been solved, but we conclude that the ITWF program nonetheless had important effects on understanding of this problem and efforts to address it.

1. Introduction

The rapid and sustained decline in the costs of computers and computation since the late 1970s has been one of the leading forces for economic change in the United States and the global economy. Successive waves of innovation, from the mini-computer to the personal computer, to cloud computing and smart phones have reshaped large sectors of the economy and contributed to the very rapid growth of the Information Technology (IT) workforce (Rosenbloom et al 2006). Within higher education this transition has been

paralleled by a rapid, though highly uneven, growth in the numbers of undergraduate degrees awarded in computer science (see Figure 1). After rising very rapidly in the late 1970s and early 1980s from a few thousand in 1970 to a peak of close to 40,000 in the early 1980s, computer science majors fell off and plateaued in the 1980s before rising again after 1989; reaching a new peak of more than 50,000 in the early 2000s.

Figure 1
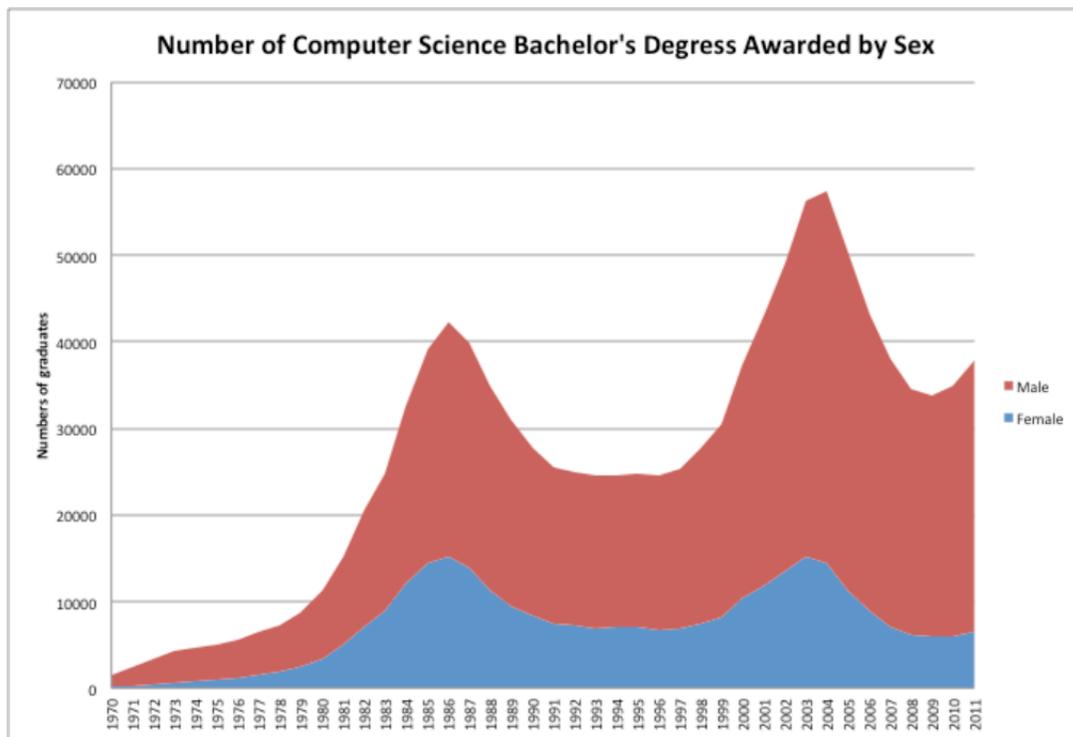
Source: IPEDS Completion Survey available on National Science Foundation's WebCASPAR database (https://ncsesdata.nsf.gov/webcaspar/).

By the late 1990s, with the personal computer revolution well underway and the internet-economy beginning to take off, the challenge of meeting the nation's demand for an appropriately trained computing workforce was becoming increasingly apparent in the United States. Measuring the IT workforce is complicated, as the skills required and tasks
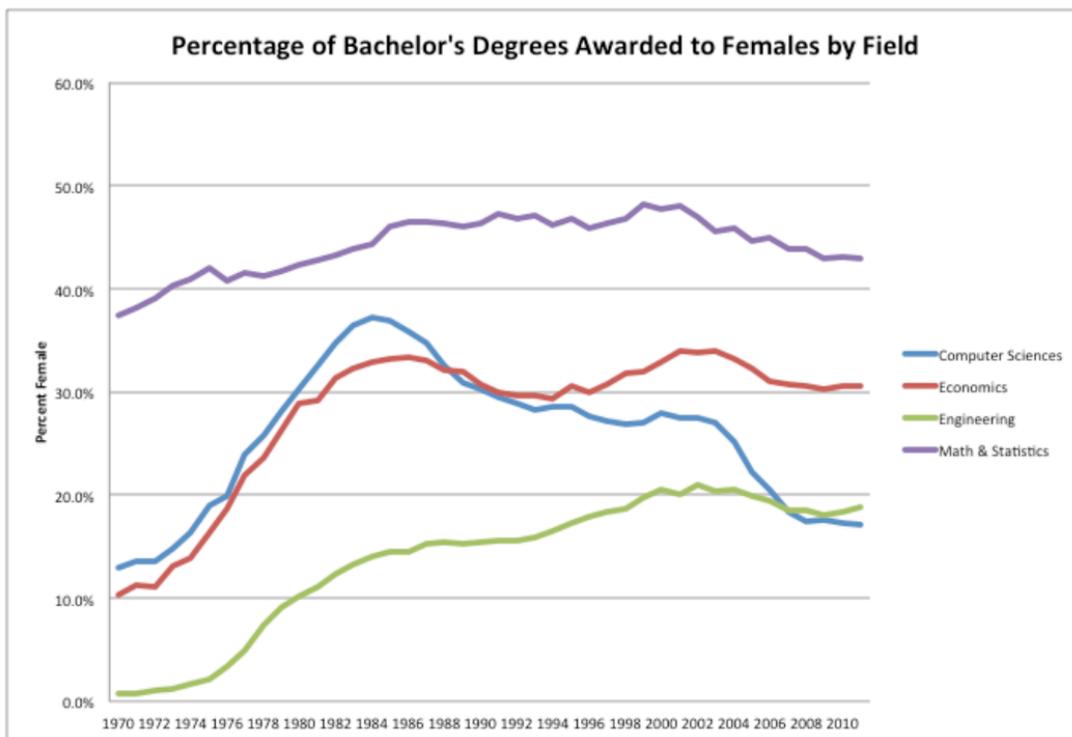
involved have changed dramatically over time. Nonetheless, by one estimate, from 1983 to the peak of the technology boom in 2000, the number of IT professionals more than doubled, rising from 1.47 million to 3.13 million. Over this same period wages earned by IT workers grew substantially faster than for non-IT workers, which suggests the growth of demand for IT workers outpaced the economy's ability to supply them (Rosenbloom et al 2006, p. 851).

Despite the growing opportunities in the IT sector there were also several disturbing trends becoming apparent by the late 1990s. Most striking were the growing gender and racial disparities in entry into and persistence in the IT workforce. Until the mid-1980s, as the number of computer science majors expanded, the field had attracted a growing number of women. Starting at less than 15% in the early 1970s the share of women earning Bachelor's degrees in Computer Science had grown to nearly 40% by the mid-1980s (see Figure 2). But from 1984 onward, the proportion of Computer Science degrees awarded to women had declined, dropping below 30 percent by the early 1990s and continuing to fall. Meanwhile the share of women among IT professions was also declining as the composition of these jobs shifted toward more male-dominated professions. In 1983 nearly 43% of full time IT professionals were women, but this figure had fallen to just 30% by 2002 (Rosenbloom et al 2006).

It was against this background that the National Science Foundation's (NSF) Computer & Information Science & Engineering (CISE) directorate initiated in early 2000 a research program on the Information Technology Workforce (ITWF) (Wardle 2003). Like many other social science research initiatives, the ITWF program was motivated by a perception of a societal problem and the desire to harness research to identify ways of

addressing this problem. Given expectations of strong employment growth and high wages in the IT sector, encouraging women and minorities to enter the field was seen by policy makers as a strategy for addressing issues of pay and employment equity, while reducing potential shortages of skilled workers in this critical field. Moreover, the small numbers of women and minorities in IT careers meant that IT products might fail to adequately reflect the needs of a large segment of society.

Figure 2

Percentage of Bachelor's Degrees Awarded to Females by Field

Source: IPEDS Completion Survey available on National Science Foundation's WebCASPAR database (https://ncsesdata.nsf.gov/webcaspar/).

In this article we look more closely at the products of this funding initiative. In doing so we have two purposes. First, the underrepresentation of women and minorities

remains an issue in Computer Science programs and in Information Technology companies. By taking a comprehensive view of the activities and outputs of the ITWF program we hope to offer insight about how future research on this topic might be more effective in addressing these problems. Second, the ITWF program offers a case study of a more general phenomenon in which research funders seek to harness social science research to generate findings that will offer guidance about how to address pressing social issues.

We believe that a careful examination of the ITWF offers insights both for funding future programs and for the design of appropriate evaluation methods for these efforts. First, as the following discussion makes clear, tracing the impacts of R&D programs requires accounting for the complex and multi-dimensional ways in which knowledge is created, diffused and applied. Evaluation methods must be sufficiently broad-based to capture these effects. Second, we suggest that for some types of research the investigator-driven model of research funding on a specific topic specified by the NSF (as in the case of the ITWF) may be an impediment. In many areas of social science research, on-going data collection efforts may not be sufficiently detailed or collect the information needed to resolve well-posed research questions. Scholars must either draw inferences from imperfect data or develop data collection methods of their own. As we describe many of the researchers funded by the ITWF program pursued this second path. However, small, uncoordinated data collection efforts may be a costly and ultimately ineffective way to shed light on the unresolved issues identified by scholars.

We begin by briefly reviewing the background and goals of the ITWF program and providing an overview of the research that it supported between 2000 and the end of the

program in 2004.[1] We then turn to the task of identifying the impacts of the program. As

this discussion makes clear, gaining a complete picture of the research supported requires

adopting a variety of different methods and grappling with the inherently intangible and

uncertain results of adding to the stock of knowledge and understanding. The final section

seeks to distill lessons from this examination both about the impact of the program and

about the challenges of harnessing social science research to address societal problems.

2. NSF's IT Workforce Program

As is common at NSF, prior to launching a new program the CISE Directorate first

sought the input of the scholarly community about the state of knowledge and open

questions relating to the participation of women and minorities in the IT workforce. In the

Fall of 1999 two virtual conferences were held during which a number of scholars

participated in online forums established for the purpose (Carver 2000; Garcia and Giles

n.d.).[2] Following the recommendations emerging from the reports of these conferences for

additional research CISE solicited proposals through a Dear Colleague Letter (NSF 00-77)

issued in early 2000. This initial solicitation was followed by the establishment of a distinct

program, designated ITWF (NSF 01-33), directed by Caroline Wardle.[3]

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[1] Since 2004 the National Science Foundation has continued to support research on
Broadening Participation across Science, Technology, Engineering and Mathematics
(STEM), and the CISE Directorate has continued to fund research on race and gender as
they relate to computing.
[2] Both studies were published on the NSF website on June 6, 2000. Based on personal
correspondence with Caroline Wardle
[3] This dear colleague letter can be found at
http://www.nsf.gov/pubs/2000/nsf0077/nsf0077.htm [Accessed 6/22/2015]. The
Program announcement is found at
http://www.nsf.gov/pubs/2001/nsf0133/nsf0133.htm#TOC [Accessed 6/22/2015].

The Dear Colleague Letter, issued in early 2000, articulated three basic research themes that the program sought to support. These were:

- **The role of environment and culture**: promoting understanding of the reciprocal relationships between environment, culture and social contexts on the one hand, and interest in IT at different ages on the other.

- **The IT Educational Continuum**: promoting increased understanding of how educational factors affect student progress from grade school through post-graduate education, and what factors impede or encourage students with the potential to succeed in the study of IT disciplines.

- **The IT Workplace**: promoting understanding of the career paths that women and minorities follow in entering and remaining in IT careers and identifying the barriers and obstacles that contribute to their underrepresentation.

The letter went on to encourage multi-disciplinary and collaborative research efforts using a variety of methods.

The program continued to make awards for four years, making its last award in October of 2004. In 2002 the scope of the program was broadened to include studies that address labor market factors affecting the participation of women and minorities in IT careers and the emergence of new forms of education and skill development of IT workers

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NSF programs are assigned unique Program Element Codes [PEC]; the PEC for the IT Workforce program is 1713, and most of the awards made by the program can be located by searching for this code. For the most part these awards include the acronym "ITWF" at the beginning of the title as well. A small number of awards made between 2000 and 2002 are identified by the acronym "ITW." When the ITR program was established at NSF the IT Workforce program acronym was changed to ITWF to avoid potential confusion.

(NSF 02-170).[4] Over this four-year period 59 projects were funded, receiving in aggregate $27.89 million.[5] Including the Principal Investigators on collaborative projects and co-Investigators close to 160 different scholars participated in these projects along with a large number of unidentified graduate students.

Projects supported by the ITWF program covered a diverse array of topics, but the scope of the program can be summarized by focusing on two dimensions of these projects. The first dimension is the point in the education/workforce continuum each project examined. The second dimension differentiates projects by the methodology employed. Based on abstracts on the NSF web site as well as descriptions of research contained in the abstracts from the Principal Investigator Conferences we have summarized the projects according to this scheme in Table 1. A complete listing of project titles, PIs, funding and their classification is provided in Appendix Table 1.

Table 1: Classification of ITWF Projects

Topical Focus	Approach		Row total
	Analysis	Intervention	
Pre-College	8	9	17
College	17	8	25
Workplace	16	0	16
Col. Total	41	17	58

Note: Projects were classified based on descriptions of research in "ITWF & ITR/EWF Principal Investigator Conference" (2006); or from project abstracts on the NSF website.

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[4] http://www.nsf.gov/pubs/2002/nsf02170/nsf02170.htm [Accessed 6/19/2015].
[5] The figure of 59 projects counts separate awards made as part of a collaborative project as a single project. We identified projects primarily by using the advanced award search function on the National Science Foundation website searching for the Program Element Code, and the Acronym ITWF in the project title. Several additional projects were identified by their inclusion in the volume of abstracts from the "ITWF & ITR/EWF Principal Investigator Conference" (2006).

The rows of Table 1 indicate the number of projects focusing on pre-college, college and workplace issues, while columns distinguish between projects that involved "interventions" and those that involved analysis of observed behaviors or the outcomes of these behaviors. Interventions were primarily efforts to modify curriculum or other educational practices to encourage greater participation of women and/or other under-represented minorities. Illustrative of these interventions are projects that introduced pair programming in introductory computer science classes, or explored how manipulating the design and content of computer games might affect interest in IT careers.

At the pre-college and college level, projects were split approximately equally between intervention and analysis. Projects focused on the workplace however were exclusively analytical, presumably reflecting the limited ability of researchers to conduct interventions in this context.

Another important feature of many of the projects supported by the ITWF program was the collection of data. A small number of projects made use of existing data sources such as the NSF's SESTAT data to characterize the IT Workforce. But the majority of projects relied heavily on collecting original quantitative or qualitative data through interviews, focus groups, ethnographic observation or other techniques. Appendix Table 1 includes information about the data sources used for each project.

3. Impact Assessment Methods

There are by now several significant strands of literature around the assessment of the impacts of R&D programs. Much recent discussion in Europe has focused on the concept of "additionality" (see David, Hall and Toole 2000; Gok and Edler 2012). As this literature emphasizes, the effect of public R&D programs should be assessed relative to an appropriately framed counterfactual scenario in which the program is not undertaken. Additionality thus reminds us that public R&D funding might simply substitute for private investments, or that investments made at one level of government (such as the European Union) might substitute for those made at other levels (e.g., national research funding programs). The effects of an R&D program are, in this sense, the projects, behaviors, organizations or other outcomes that would not have arisen in the absence of the R&D program being considered.

Because it compares what actually happened to what would have happened under a counterfactual of no programmatic intervention, additionality poses a tougher standard than has commonly been employed in the literature on program evaluation, which is the more common framework for discussions in the U.S. Most program evaluation efforts have largely ignored the need for counterfactual comparisons and focused on measuring the more or less tangible outputs produced by particular R&D programs. Ruegg and Jordan (2007), for example, identify 14 different methods of assessing these outputs. These methods are quite varied. Some focus on quantitative measurements based on indicators of scientific outputs such as publications, citations to those publications, or patents. Others are more qualitative, relying on peer review of program outputs, case-studies of specific projects in a program's portfolio or analysis of networks of connections revealed through

citations, or other interactions between scholars. Olson and Merrill (2011) offers another overview of approaches to evaluating the impacts of basic science funding that stresses the complex ways in which funding may affect the stock of knowledge and its application.

As this brief discussion suggests, gauging the effects of R&D funding programs is neither simple nor straightforward. Most importantly it is essential to understand the goals of the program and to choose methods of measurement that are most likely to capture the intended effects. In this way we can think of a program as developed to respond to a problem, and measurement of goal achievement as measurement of solving the problem. All of the evidence must be interpreted in context.

In the case of the ITWF program it seems highly unlikely that any other agency would have supported the types of social science research carried out by investigators supported by the program, so we can set aside concerns about displacement of funding by other entities. NSF funds devoted to ITWF would, presumably, have supported other NSF-supported research activities if the program had not existed, but it does not seem practical here to attempt to assess the value of these foregone alternative research activities (although this opportunity cost should be borne in mind). Instead, we choose to focus primarily on accounting for the ways in which ITWF funding advanced scholarship and promoted development of a research community.

The NSF's proposal review criteria specifically ask reviewers to consider both the "intellectual merits" and the "broader impacts" of a project. Intellectual merit relates to the knowledge created and disseminated to the scholarly community. Most immediately, the goal of research is to increase the stock of useful knowledge through the collection of new data, development or refinement of theoretical perspectives and models used to interpret

these data, and the education of new scholars familiar with this data. NSF's broader

impacts criterion encompasses the potential benefit to society and contributions to specific,

desired societal outcomes. In what follows we organize our discussion of the ITWF

program impacts around these two criteria.

To assess the ITWF program's intellectual merit, we begin by considering

publications that resulted from the funded research, and the impact of these publications

on subsequent scholarship measured by citations. Measuring broader impacts is

necessarily more difficult and criteria must be tailored to particular programs and projects.

4. Impacts of the ITWF Program

In choosing to foreground issues of gender and race in the IT workforce, the

National Science Foundation was clearly hoping for the broader impact of encouraging

greater recruitment and retention of women and underrepresented minorities in Computer

Science degree programs and IT careers. In the 15 years since the program was initiated

however, the proportion of women earning Bachelor's degrees in Computer Science has

fallen, while the share of women in IT-related occupations has remained persistently low. It

is, however, unreasonable to judge the efficacy of a research program such as the ITWF

program by its ability to affect these aggregate statistics, especially given the relatively

modest financial investment in the program. As we elaborate below, there are other

criteria for assessing broader impact that are more appropriate.

4.1 Intellectual Merit: Publication Impacts of the ITWF Program

While the ITWF program was ongoing there were annual meetings of Principal Investigators that served as a forum for disseminating research results, and facilitated both formal and informal communication between researchers involved with different projects. Each meeting resulted in a collection of abstracts describing the progress of individual projects. These volumes of progress abstracts offer a valuable collection of research results, but they were not distributed widely beyond the group of conference attendees.

Several other publications did seek to aggregate the results of ITWF research in more widely accessible formats.[6] Two publications in particular should be noted. The first is Aspray and Cohoon (2006). This edited volume included three survey chapters summing up the state of research on underrepresentation in pre-college, college, and workplace environments as well as original research articles by leading scholars addressing each of these topics. Not all of the chapters derived from ITWF-supported projects, and the volume could accommodate only a small selection of the topics covered by ITWF-funded researchers. According to WorldCat, in mid-2015 this volume was in the collections of 1,280 libraries worldwide, making it a relatively widely accessible source for those seeking to assess the state of research on underrepresentation in IT.[7]

The three survey chapters in the Aspray and Cohoon volume (2006) were intended to be as comprehensive as possible in collecting relevant literature and reflected

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[6] In addition to the publications discussed below, the Fall 2003 issue of *IEEE Science and Society* was a special issue on Women and Minorities in Information Technology, guest edited by Roli Varma. Several of the articles in this issue were authored by investigators funded by the ITWF program, but for the most part the research they wrote about arose prior to their ITWF funding.
[7] WorldCat Searched on 18 June 2015.

considerable effort on the part of their authors to comb through available sources. Perhaps

reflecting the time lags inherent in conducting and interpreting research, very few of the

ITWF-funded projects were cited or discussed in these survey chapters. Only three of the

projects focused on pre-college issues and another three focused on college-level issues

were cited in the reviews. A somewhat greater number of those addressing workplace

issues were mentioned, but almost all of the references pointed to abstracts from the 2004

Principal Investigator Conference, rather than to more readily accessible publications.

The second published effort to summarize the research on underrepresentation and

including mention of the ITWF projects is the *Encyclopedia of Gender and Information

Technology* edited by Eileen Trauth (2006). Encompassing 213 entries in 1300 pages, this

volume offers a more encompassing view of the field, and included one or more entries

authored by 20 Principal Investigators supported by the ITWF program. It is, however, far

less widely available than Aspray and Cohoon (2006) being found in the collections of 239

libraries worldwide.

Since both the Aspray and Cohoon and Trauth volumes were published in 2006

when much of the research conducted with ITWF program funding was still ongoing, it is

quite possible that additional important research results subsequently emerged. In an

effort to identify these contributions we searched the Web of Science database during the

Spring of 2015 for publications by ITWF Principal Investigators and co-Investigators

related to topics supported by the ITWF program.[8] Web of Science is a selective index of

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[8] On the one hand this approach is restrictive since we are only considering publications indexed in Web of Science. On the other hand, we have adopted a broad definition of the program's influence on the investigators it funded by including in our count all publications related to ITWF themes by investigators regardless of whether they appear to be directly related to the specific projects funded by the program.

scientific literature that indexes publications and citations in approximately 12,000 "top

tier international and regional journals in every area of the natural sciences, social sciences

and humanities."[9] We also searched online for CVs of ITWF Principal Investigators and

contacted these Principal Investigators requesting a listing of relevant publications. Our

analysis, however, is confined to those articles that were indexed in Web of Science and

may omit publications in journals not included in that index.

To be included in our count, articles had to have been published any time after the

award date of their ITWF-grant, and the title had to indicate it addressed gender and/or

race-related issues in IT. Once we had located what we deemed to be the relevant articles

for each Principal Investigator we also counted forward-citations to those articles as a

measure of their influence in subsequent scholarly discussion.

The results of our investigation are summarized in Table 2, which lists the projects

for which we found at least one publication in Web of Science. Projects are identified by

the Principal Investigator and title, even when publications are authored by co-

Investigators and do not include the Principal Investigator as an author. Of the 59 projects

funded by the ITWF program, 18, or slightly less than one third, resulted in at least one

publication in journals covered by the Web of Science database. The median number of

publications among these 18 projects was 2. The most prolific author, Eileen Trauth,

published a total of 17 articles, many of them addressing the development and refinement

of a new theoretical framework that occupies "the space between essentialism and social

construction" (Trauth, Quesenberry, and Morgan 2004).

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[9] See the online explanation of selection criteria provided by Thomson Reuters
http://wokinfo.com/essays/journal-selection-process/ [accessed 6/22/2015] for
additional details.

Citations are often used as a metric of the importance or impact of publications. The last column of Table 2 shows the aggregate number of citations to the Web of Science indexed articles by each Principal Investigator. Like the publication data, the citation counts tend to be highly skewed and for the most part correlate with the number of publications.

Table 2: Publication Outcomes of ITWF-funded projects

Grant Number	PI	Grant Title	Type/ Level[a]	Total Articles	Total Citations
0204246	Eileen Trauth	ITWF A Field Study of Individual Differences in the Social Shaping of Gender and IT	A/W	17	104
0089989	Linda Werner	ITW Retaining Women in Computer Science Programs The Impact of Pair-Programming	I/C	11	96
0204430	Debra Major	ITWF Climate for Opportunity and Inclusion Improving the Recruitment, Retention and Advancement	A/W	8	93
0089959	Joanne Cohoon	ITW Departmental Factors in Gendered Attrition from Undergraduate IT Majors	A/C	7	13
0203127	Joanne Cohoon	ITWF Factors Concerning Recruitment and Retention of Women Graduate Students in Computer Science and Engineering	A/C	7	13
0420533	Margaret Burnett	ITWF Gender HCI Issues in Problem-Solving Software	I/C	6	24
0120055	Roli Varma	ITWF Why So Few Women in Information Technology A Comparative Study	A/C	4	4
0204464	Joshua Rosenbloom	ITWF Characteristics and Career Paths of Current IT Workers	A/W	3	20
0305898	Roli Varma	ITWF Cross Ethnic Differences in Undergraduate Women's Preference for Information Technology	A/C	3	3
0420365	Donald Davis	Collaborative Research ITWF - Creating an Inclusive Learning Environment Enhancing Retention of Women and Minorities in Computer Science	I/C	2	9
0120111	Catherine Weinberger	Information Technology Workforce - ITWF Entry, Earnings Growth, and Retention in IT Careers An Economic Study	A/C	2	7
0302692	Anne O'Leary-Kelly	ITWF The Influence of Professional Identification on the Retention of Women and Racial Minorities in the IT Workforce	A/W	2	7
0305859	Jean Robinson	ITWF Toward Gender Equitable Outcomes in IT Higher Education Beyond Computer Science	A/C	1	57
0089963	Sandra Katz	ITW: Learning Behaviors and Background Characteristics that Promote Retention of Women and Minorities in Undergraduate Computer Science Programs	I/C	1	6
0090043	Jane Margolis	ITW Out of the Loop Why are so few underrepresented minority high school students learning computer science	A/P-C	1	5

Table 2: Publication Outcomes of ITWF-funded projects

0120092	Pascale Carayon	ITW-ITWF Paths to Retention and Turnover in the IT Workforce	A/W	1	4
0090004	Shirley Malcom	ITW Bringing Women and Minorities into the IT Workforce The Role of Non-Traditional Educational Pathways	A/C	1	2
0418165	WANDA SMITH	ITWF Collaborative Research African Americans in IT Improving the Graduate Education and Workforce Piplelines	A/C	1	1
0090000	Andrea Houston	ITW: Attracting Women into the Information Technology Workforce through Technology Immersion	I/P-C	1	1
Total				79	469

Sources and Notes: The data in this table were compiled by searching the Web of Science Database by author name for the names of all PI's listed on ITWF-funded grants. To be included in the count articles had to be published after the start date of the ITWF awarded and the title had to indicate that the article was concerned in some way with the IT workforce. All forward citations to these articles were then identified and counted. The Web of Science analysis was completed during March and April 2015.

[a] This column indicates whether the the study was an intervention (I) or analytical study (A) and what point in the education-workplace continuum it studied: Pre-College (P-C), College (C) or the Workplace (W).

Only three of the projects that resulted in at least one publication were interventions. These three projects addressed the use of pair-programming in introductory computer science classes, creating more inclusive environments in computer science and gendered approaches to human computer interfaces. Among the analytical projects there is a greater diversity of topics and approaches, but most dealt with factors influencing the recruitment and retention of women and minorities in college or the workplace.

Citations are of course only one metric of influence. It is possible, for example that articles describing interventions led to their replication in other places. By itself this diffusion of instructional techniques would not be reflected in any of the evidence we can observe.

4.2 Broader Impacts Beyond Publication

Publication data are inevitably an indirect method of assessing the impacts of a line of research. Seeking to capture less tangible, but no less important, effects of the ITWF program we attempted to contact the Principal Investigators for all ITWF-funded projects asking them to respond to a short series of questions about the research that the program had supported and their assessment of the impacts of the funding they had received on understanding of the issues and on their own careers. Working from the list of Principle Investigators developed for our bibliometric investigation, we conducted Google searches to locate current email addresses for as many of the PIs as we could. This resulted in a list of 38 individuals with valid email addresses who were contacted initially in November

2014. For those who did not respond we followed up with 2 additional email messages reiterating our request for information.

We received responses from 13 of the Principal Investigators we contacted. Given the nature of our inquiry we suspect that those who responded are positively selected for their interest in the goals of the ITWF program and more likely to have had positive and productive experiences. To this extent, they cannot be interpreted as representative. Nonetheless, they provide a partial indication of other ways in which the program affected scholarship.

For several of the scholars we contacted, ITWF funding proved to be a turning point in their careers, having a substantial impact on the trajectory of their scholarship. Catherine Weinberger, for example, wrote:

> The short version is that before I got the ITWF grant, I was working from home with barely enough funding to cover child care and a home computer. After I got this funding I had the infrastructure to pursue a full-scale research agenda (personal correspondence, Dec. 2014).

The ITWF grant supported two waves of a longitudinal survey and Dr. Weinberger has continued to collect data from more than six hundred respondents over a ten-year interval. Another respondent, Lecia Barker observed that the ITWF-grant "largely shaped" her research career. "I've continued this work ever since the first ITWF grant (not exclusively, but primarily)" (personal correspondence, Jan. 2015). From responses of this type we can conclude that some ITWF funds nurtured great depth of scholarship with a minimal initial investment.

For other, more established scholars, the ITWF project was instrumental in a shift in research focus that lead to an ongoing interest in the issue of diversity in IT education and careers. For Jane Margolis, the ITWF funding enabled her to investigate how occupational

fields become segregated and inequality is produced through specific processes at work in Computer Science and IT. She was also able to extend the scope of this research from higher education into primary and secondary education public schools. This work has led to two widely-cited books and an ongoing collaboration with Los Angeles Public Schools to expand exposure to computing to more minority and female students (personal correspondence, Dec. 2014).

For Margaret Burnett, the ITWF grant started a whole new subarea of research on gender and Human Computer Interaction. "Starting with the ITWF funding," Burnett writes, "I've been working on this for the past 10 years, with numerous publications…I greatly appreciate the NSF funding that made this path possible" (personal correspondence, Nov. 2014). Parallel to those investigators whose career paths benefitted from ITWF funding, investigators whose research paths shifted due to ITWF funding were also likely to report great depth of focus on issues characteristic of underrepresentation in the IT workforce.

In a few instances the responses illustrate the unpredictable nature of research. As Peter Cappelli observed, "…our project was essentially killed by [contacts at the U.S.] Census [Bureau] who made access to the data so difficult that it was pretty much impossible to finish the project" (personal correspondence, Nov. 2014). Having encountered this obstacle Cappelli did not pursue further research related to the IT workforce.

Beyond the effects that the ITWF program had on individual careers it also helped to foster an active community of researchers interested in issues of race and gender in IT. The ITWF program contributed to the establishment of an institutional infrastructure that has sustained discussion, research and activism devoted to diversifying computer science

education and IT careers. Bobby Schnabel, a Principal Investigator funded by the ITWF

program credits NSF funding as instrumental in the formation of the National Center for

Women in Information Technology (NCWIT), a non-profit community of more than 600

universities, companies, non-profits and government organizations.[10] NCWIT's annual

conference provides a meeting place where educators, employers, and scholars can

exchange ideas, identify best practices, and connect with one another. Moreover its Social

Science Advisory Board provides a forum for ongoing discussion of relevant scholarship

and a conduit to connect theory and practice.

5. Discussion

This examination of the NSF ITWF program illuminates two issues. On the one

hand, this exploration should help to make clear the challenges inherent in providing a

holistic assessment of the impacts of a research-funding program. On the other, it is a

cautionary tale about the difficulties of transforming research funding into practically

useful knowledge that can be effectively deployed to address social challenges.

At first glance, the publication and citation data examined above might suggest that

the intellectual merit of the ITWF program was mixed at best. Further analysis suggests

that such a conclusion is premature. A more nuanced evaluation would begin by

acknowledging that research, by its nature, leads to surprising and unanticipated results.

Some of these prove to be dead ends. A large number of the projects funded by the ITWF

program appear to have left little lasting mark in terms of published and visible

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[10] For more information about NCWIT consult their website https://www.ncwit.org
[accessed 14 August 2015].

scholarship, but this may be true of many areas of research. Research is inherently risky, and a program that funds only successful projects may well be taking too few risks, which could predictably lead to missing out on truly transformative lines of investigation. There are few other comprehensive assessments of a portfolio of research projects against which to compare the ITWF program's publication impacts. Until other similar programs are assessed we cannot adequately judge the publication impacts of the ITWF program.

Although many of the projects funded by the program did not result in publications, a significant number of projects supported by the program appear to have been relatively influential, and have helped to codify and shape current understanding of the challenges and obstacles to broadening participation in computer science and IT careers.

Looking beyond publications, the broader impacts of the ITWF funding are more readily apparent. First, a number of researchers funded by the program remarked on the importance of ITWF grant funding in shaping their research agenda and careers. Many of these individuals have continued to explore issues of race and gender in IT and Computer Science. Second, ITWF funding was instrumental in the establishment of NCWIT, which provides a forum for fostering increased representation of women in IT careers. Because of the ITWF program and the activities of NCWIT there is an active and connected group of scholars who continue to study, write about, and seek to bring about change in the participation of women and minorities in IT education and careers.

Despite these tangible impacts on the research community, the understanding resulting from research to date has not, of course, translated directly into interventions capable of producing a substantial change in the composition of the IT workforce. As reflected in the success of a few computer science departments in increasing women's

participation, most notably at Harvey Mudd College, there are institutional changes that can be made that have an impact.[11] The failure of these changes to be broadly adopted presumably reflects the fact that implementing change is contingent on a variety of incompletely understood factors including the willingness of academic institutions to make changes in recruitment, curriculum, financial aid, instruction and other aspects of the educational experience. More generally, mechanisms for scaling and diffusing pedagogical innovations remain more art than science.

While the tangible consequences of the ITWF program on women's participation in the IT workforce remain elusive, the publications and scholarship to which it gave rise remain central to the ongoing conversation about underrepresented groups in computing; a fact that becomes apparent from the responses of a number of the scholars who received support from the program.

Stepping back from the impacts on the IT workforce and looking at the program in its totality, this investigation also suggests some of the challenges inherent in NSF's model of investigator-driven research as a mechanism for addressing societal problems. Because the phenomena ITWF-funded investigators sought to examine were poorly reflected in existing data sets, many of the projects were obliged to collect survey, interview, or observational data about factors that influenced individual choices about education and career paths, as well as experiences in the workplace. The one-off, and in some cases haphazard, efforts at data collection that resulted might have been more productive if there

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[11] National Public Radio, "How One College is Closing the Computer Science Gender Gap," 1 May 2013
http://www.npr.org/sections/alltechconsidered/2013/05/01/178810710/How-One-College-Is-Closing-The-Tech-Gender-Gap [accessed 14 August 2015].

had been an effort to better define the key questions that these studies were investigating and the development of a stronger infrastructure for the collection and documentation of data. Such an effort would, however, require a very different model of research funding.

5. Conclusion

One important rationale for funding social science research is its salience in addressing societal problems. Given the rapid growth of IT employment and the centrality of this industry as a driver of economic change in the U.S. and world economies, the low and declining participation of women and other underrepresented groups among Computer Science degree recipients and Information Technology professionals had emerged by the mid-1990s as an important social concern and led to the establishment of an NSF program, the ITWF, to study and respond to this issue.

By examining the effects of this funding program on scholarship this article has sought to shed light on how basic social science research can respond to a pressing social problem. As this examination suggests, however, fully comprehending the effects of a research portfolio is a complicated process that cannot be reduced to a purely quantitative measurement. Although the publication outputs from the ITWF program may appear quantitatively modest, we have suggested that the NSF's investment in this program played an important role in encouraging a cohort of scholars to investigate issues of diversity in Computer Science education and Information Technology careers and contributed to the emergence of NCWIT, which has become a focal organization for sustaining scholarship relevant to this topic and promoting continued networking between scholars.

At the same time, our investigation highlights an important structural challenge that confronts efforts to translate social science research into practice. One key challenges affecting many of the researchers supported by the ITWF program was the absence of data they needed to understand the composition of the IT workforce, and the education and labor market flows responsible for this composition. As a result, data collection became a major focus of many projects that NSF's ITWF program funded. Such one-off data collection efforts, however, experienced problems of high fixed costs and the difficulty of assembling valid and representative samples. It is quite possible these hurdles may in part account for the limited scientific impact of many of the projects the program supported. This observation suggests a weakness of the NSF's investigator-driven funding approach in its lack of any way to coordinate data collection efforts, and suggests developing more robust mechanisms for data collection may be an important factor for more effective social science research in the future.

By requiring investigators to include a Data Management Plan in their proposals, the NSF has already taken one step toward addressing this shortcoming. A key feature of such plans is an emphasis on the curation and access to data collected with NSF funding. Nonetheless, the lack of mechanisms to coordinate data collection efforts across related investigations and the high costs of fielding well-designed data collection efforts remain. Future research should consider whether the requirement of Data Management Plans has led to greater access to investigator-collected data sets and how this has affected research in the social sciences.

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Appendix Table 1:
ITWF Funded Projects

Award Number	Collaborative Awards	Principal Investigator	Collaborative PIs	Title	Level	type	data collection	Awarded Amount	StartDate	Program Element Code(s)
0089930		Michael Larsen		ITW: Collaborative Research: Statistical Methodology for Studying Women and Minorities in Information Technology Careers Using CPS and SESTAT Data	Workplace	Analytical	Existing	$64,966.00	01/01/2001	2885
0090033		Karen Chapple		ITW:Mediating Careers: The Role of Labor Market Intermediaries in Facilitating the Entry, Retention, and Advancement of Women and Minorities in the Information Technology Workforce	Workplace	Analytical	Uncertain	$322,722.00	01/01/2001	2885
0090043		Jane Margolis		ITW: Out of the Loop: Why Are So Few Underrepresented Minority High School Students Learning Computer Science?	High School	Analytical	Interviews, ethnographic observation	$689,401.00	01/01/2001	2885, 1713, 1359
0119880		Ron Eglash		ITWF: Culturally Situated Design Tools	Middle School, High school	Intervention	survey	$561,013.00	01/01/2002	1713
0089941		Kathryn Bartol		ITW: Understanding Female and Minority Retention and Success in the IT Workplace: Total Rewards and Social Networks Perspectives	Workplace	Analytical	interviews, survey	$761,844.00	02/01/2001	2885, 1713
0090000		Andrea Houston		ITW: Attracting Women into the Information Technology Workforce through Technology Immersion	High School	Intervention	Survey	$352,738.00	03/15/2001	2885, 9150
0302692		Anne O'Leary-Kelly		ITWF: The Influence of Professional Identification on the Retention of Women and Racial Minorities in the IT Workforce	Workplace	Analytical	Interviews, survey	$603,942.00	06/01/2003	1397, 1713
0420448		H. Raghav Rao		ITWF: Women and Cyber Security: Gendered Tasks and Inequitable Outcomes	Workplace	Analytical	Interviews, survey	$297,021.00	06/01/2004	1713
0420533		Margaret Burnett		ITWF: Gender HCI Issues in Problem-Solving Software	College	Intervention	Assessment	$261,285.00	06/01/2004	1713
0204253		Mark Wardell		ITWF: Women in the IT Workforce: How Level is the Playing Field?	Workplace	Analytical	Survey	$419,287.00	06/15/2002	1713
0204430		Debra Major		ITWF: Climate for Opportunity and Inclusion: Improving the Recruitment, Retention and Advancement of Women and Minorities in Information Technology (IT)	Workplace	Analytical	Survey	$497,257.00	06/15/2002	1713
0196431		Paula Rayman		ITW: Women in Information Technology Workplaces: A Study of Women Computer Science Degree Recipients in the Software Industry	Workplace	Analytical	Uncertain	$584,674.00	07/01/2001	2885, 1713
0204267		Mary Good		ITWF: The Research Component of a Model Information Technology (IT) College	College	Analytical	Existing	$244,984.00	07/01/2002	1713, 7427
0204316		Donna Llewellyn		ITWF: APSIT: Alternate Pathways to Success in Information Technology	Workplace	Analytical	Institutional, survey	$257,062.00	07/01/2002	1713, 1359
0204469		Kshiti Joshi		ITWF: What Does It Take to Succeed in Information Technology? A Multi-Level Analysis of Stakeholders' Perceptions of Critical Attributes and the Effects of Stereotype Fit	Workplace	Analytical	Survey	$315,181.00	07/01/2002	1713
0305973		Elizabeth Lawley		ITWF: Understanding Gendered Attrition in Departments of Information Technology	College	Analytical	Interviews	$772,365.00	07/01/2003	1713
0306012		Peter Cappelli		ITWF: The Effects of Information Technology on Employee Demography and Training Outcomes	Workplace	Analytical	Existing	$267,728.00	07/01/2003	1713
0204464		Joshua Rosenbloom		ITWF: Characteristics and Career Paths of Current IT Workers	Workplace	Analytical	Survey	$347,176.00	07/15/2002	1713
0305146		Angela O'Donnell		ITWF: The Influence of Gender, University Majors, and Work Experiences on Perceptions and Choice of IT Careers	College	Analytical	Survey	$505,686.00	07/15/2003	1713
0305917		Laurie Williams		ITWF: Collaboration through Agile Software Development Practices: A Means for Improvement in Quality and Retention of IT Workers	College	Intervention	Assessment	$812,587.00	07/15/2003	1713
0306156		Alberto Rodriguez		ITWF: Improving the Participation and Achievement of Students in Diverse Schools by Enhancing Teacher Professional Development in Science and Learning Technologies	Elementary	Intervention	Assessment	$999,885.00	07/15/2003	1713

Award Number	Collaborative Awards	Principal Investigator	Collaborative PIs	Title	Level	type	data collection	Awarded Amount	StartDate	Program Element Code(s)
0420434		Jeffrey Stanton		ITWF: Culture Clash! The Adverse Effects of IT Occupational Subculture on Formative Work Experiences of IT Students	College	Analytical	Interviews, survey	$311,389.00	07/15/2004	1713
0203127		Joanne Cohoon		ITWF: Factors Concerning Recruitment and Retention of Women Graduate Students in Computer Science and Engineering	College	Analytical	Interviews, survey	$513,629.00	08/01/2002	1713
0204246		Eileen Trauth		ITWF: A Field Study of Individual Differences in the Social Shaping of Gender and IT	Workplace	Analytical	Interviews	$434,196.00	08/01/2002	1397, 1713
0220130		Lecia Barker		ITR: Research on Recruiting Middle School Minority and Majority Girls into a High School IT Magnet	Middle School, High school	Intervention	Survey	$424,750.00	08/01/2002	1640, 1686, 1713
0420485		Juan Gilbert		ITWF: Scholars of the Future: An Implementation Model for Increasing Diversity in Information Technology	College	Intervention	Assessment	$754,983.00	08/01/2004	1713
0204138		Danny Martin		ITWF: Mathematics Socialization & Identity	High School	Analytical	Observation	$273,160.00	08/15/2002	1713
0204222		Mladen Vouk		ITWF: WOMEN AND INFORMATION TECHNOLOGY: A Comparative Study of Young Women from Middle Grades through High School and into College	Middle School	Analytical	Interviews, survey	$500,027.00	08/15/2002	1397, 1713
0418165	0417688	WANDA SMITH	Kermith Harrington	ITWF: Collaborative Research: African-Americans in IT: Improving the Graduate Education and Workforce Pipelines	College	Analytical	survey	$544,306.00	08/15/2004	1397, 1713
0089986		Kristine Kuhn		ITW: Women and Information Systems: Modeling the Impact of Work Values, Attitudes, and Attributes on Career Choices	College	Analytical	Survey	$65,512.00	09/01/2000	2885
0089995		Paula Stephan		ITW: Retention of Women and Minorities in the IT Workforce	Workplace	Analytical	Existing	$303,771.00	09/01/2000	2885, 1713
0120111		Catherine Weinberger		Information Technology Workforce - ITWF: Entry, Earnings Growth, and Retention in IT Careers: An Economic Study	College	Analytical	Existing	$498,000.00	09/01/2001	1397, 1713
0219547		Patrick Bobbie		ITR: A Community-based Partnership for Integrated Research and Education (COPIRE)	High School	Intervention	Uncertain	$422,479.00	09/01/2002	1640, 1686, 1713, 1714
0305216		Janice Grackin		ITWF: Girl Power 21st Century: Growing Strong, Moving On	Elementary	Intervention	Assessment	$618,730.00	09/01/2003	1713
0305859		Jean Robinson		ITWF: Toward Gender Equitable Outcomes in IT HIgher Education: Beyond Computer Science	College	Analytical	Interviews, survey	$769,520.00	09/01/2003	1713, 1714
0305898		Roli Varma		ITWF: Cross Ethnic Differences in Undergraduate Women's Preference for Information Technology	College	Analytical	Interviews	$350,392.00	09/01/2003	1713
0306092		Paula Kohler		ITWF: Creating Pathways to IT Careers Through High School Career and Technical Education Programs	High School	Analytical	Institutional	$749,520.00	09/01/2003	1713
0420365	0420371	Donald Davis	Sandra DeLoatch	Collaborative Research: ITWF - Creating an Inclusive Learning Environment: Enhancing Retention of Women and Minorities in Computer Science	College	Intervention	Assessment	$167,000.00	09/01/2004	1713, 1397
0420436	0420433, 0420368, 0420312, 0420337, 0420343, 0420358	Susan Horwitz	Steven Huss-Lederman, Barbara Ryder, Maureen Biggers, Ethan Munson,Susanne Hambrusch, Susan Rodger, David Binkley	ITWF: Collaborative Research: Increasing the Representation of Undergraduate Women and Minorities in Computer Science	College	Intervention	Assessment	$360,001.00	09/01/2004	1713, 1714
0420473		Sharad Maheshwari		ITWF: BRACE: Bridging Research and Curriculum Experience	College	Analytical	Institutional	$49,647.00	09/01/2004	1713
0420505	0420321, 0420458,0420000, 0420506,0420468	Samuel Kamin	Nancy Van Cleave, Joy Lucht, Mary Califf, Vladimir Uskov,Maria Mobasseri	Collaborative Research: ITWF: Building Communities: Recruiting and Retention of Underrepresented Groups in Computer Science	College	Intervention	Assessment	$650,000.00	09/01/2004	1713, 1714

Award Number	Collaborative Awards	Principal Investigator	Collaborative PIs	Title	Level	type	data collection	Awarded Amount	StartDate	Program Element Code(s)
0089957		Sylvia Beyer		ITW: Predictors of Women's Interest and Retention in Undergraduate IT Majors	College	Analytical	Survey	$428,367.00	09/15/2000	2885
0089959		Joanne Cohoon		ITW: Departmental Factors in Gendered Attrition from Undergraduate IT Majors	College	Analytical	Interviews, survey	$568,042.00	09/15/2000	2885, 1713
0089963		Sandra Katz		ITW: Learning Behaviors and Background Characteristics that Promote Retention of Women and Minorities in Undergraduate Computer Science Programs	College	Intervention	Assessment	$473,742.00	09/15/2000	2885
0090006		Sandra Gregerman		ITW: Information Technology Pathways in Academe: Identifying Barriers for Women and Students of Color	College	Analytical	Survey	$520,660.00	09/15/2000	1713, 2885
0090026		Robert Schnabel		ITW: Attracting and Retaining Women in Information Technology Programs: A Comparative Study of Three Programmatic Approaches	College	Analytical	Observation, existing data	$715,321.00	09/15/2000	1359, 1713, 2885
0119839		Paula Leventman		Information Technology Workforce - ITWF: Multiple Pathways toward Gender Equity in the Information Technology Workforce	Workplace	Analytical	Survey	$674,700.00	09/15/2001	1713
0089989		Linda Werner		ITW: Retaining Women in Computer Science Programs: The Impact of Pair-Programming	College	Intervention	Assessment	$282,220.00	10/01/2000	1713, 2885, 7427
0090004		Shirley Malcom		ITW: Bringing Women and Minorities into the IT Workforce: The Role of Non-Traditional Educational Pathways	College	Analytical	Survey	$598,613.00	10/01/2000	2885, 1713
0120055		Roli Varma		Information Technology Workforce - ITWF: Why So Few Women in Information Technology?: A Comparative Study	College	Analytical	Uncertain	$108,426.00	10/01/2001	1713
0120056		Phyllis Bernt		Information Technology Workforce - ITWF: Getting the Media Message: The Portrayal of Gender, Race, and Information Technology in the Media Environment of Middle School Students	Middle School	Intervention	Survey	$556,000.00	10/01/2001	1713
0120093		Dorothy Bennett		Information Technology Workforce - ITWF: Designing for Diversity: Investigating Electronic Games as Pathways for Girls into Information Technology Professions	High School	Intervention	Assessment	$426,739.00	10/01/2001	1713
0120096		Patricia Thomson		Information Technology Workforce - ITWF: Information Technology Educational Pathways of African Americans: A Synthetic Study with NELS 1988-2000 Data and Case Studies	High School, College	Analytical	Existing	$415,302.00	10/01/2001	1713
0120138		Russell Stockard		ITWF: Stretching Horizons: Upward Bound Programs in Stimulating Information Technology Education and Career Aspirations among Underrepresented Minorities	High School	Analytical	Survey	$200,000.00	10/01/2001	1713
0119858		Louis Tornatzky		Information Technology Workforce - ITWF: Catching Up: A Longitudinal Study on Latino Participation in the Information Economy	Pre-College	Analytical	Uncertain	$660,000.00	10/01/2001	
0120092		Pascale Carayon		ITW - ITWF: Paths to Retention and Turnover in the IT Workforce: Understanding the Relationships Between Gender, Minority Status, Job and Organizational Factors	Workplace	Analytical	Survey	$699,992.00	11/15/2001	1713
0089972		Jacquelynne Eccles		ITW: Women, Minorities, and Technology	Primary, secondary	Analytical	Existing	$608,578.00	12/01/2000	1397, 2885
0204398		Katherine Lambert		ITWF: Girls are IT!	Pre-Colege	Intervention	Interviews	$692,035.00	12/15/2002	1705, 1713