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Undergraduate Statistics Education and the National Science Foundation

Megan R. Hall and Ginger Holmes Rowell
Middle Tennessee State University

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Abstract

This paper describes 25 National Science Foundation supported projects that have innovations designed to improve education for students majoring or minoring in statistics. The characteristics of these projects and the common themes which emerge are compared with the American Statistical Association's (ASA) guidelines for developing statistics education curricula for majors and minors and for teaching the corresponding statistics courses. Through this analysis, we are able to see how the last decade of NSF supported projects in statistics education exemplify these ASA guidelines.

1. Introduction

During the last decade, the National Science Foundation (NSF) has provided financial support for a number of projects which emphasize improving undergraduate statistics education. Concurrently, educators and researchers in the field have been defining and revising curriculum standards that have resulted in nationally recognized guidelines for teaching statistics. Inspired by George Cobb's 1993 review of twelve NSF sponsored statistics education projects, this paper seeks to review NSF projects from 1993 to 2004 focused on undergraduate statistics education beyond the algebra-based introductory course and to compare the characteristics of those projects with current statistics education recommendations. First, we review the development of the American Statistical Association's (ASA) (2002) *Curriculum Guidelines for Undergraduate Programs in Statistical Science*, and then describe some NSF Division of Undergraduate Education (DUE) programs which operated from 1993 to 2004. Throughout that time, NSF has supported over 150 grants which directly affect statistics education, 52 of which focus beyond the algebra-based introductory statistics course. From those 52 grants, 25 projects are discussed in comparison with the ASA Curriculum Guidelines. Through descriptions of these projects, we are able to see how NSF has been supporting projects in statistics education which meet the ASA guidelines.

2. ASA Curriculum Guidelines

For many years, the efforts of statistical educators were focused on graduate programs because of the difficulty of the material and the idea that statisticians are defined by the advanced degrees they hold (Minton 1983). However, as technology reduced the difficulty found in statistical analyses, the expected increase in undergraduate statistics programs did not happen (Higgins 1999). The resulting problem was a lack of visibility and acceptance of statistics as a discipline (Minton 1983). The solution was to create viable undergraduate degree programs in statistics (Marquardt 1987).

The American Statistical Association (ASA) has been aware of the need for undergraduate statistics education reform, and since 1979 has made several attempts to set up curriculum guidelines for undergraduate programs in statistics (Snee 1993; Bryce, Gould, Notz, & Peck 2001; Bryce 2002). The most successful of these attempts was the launching of the Undergraduate Statistics Education Initiative (USEI) in 1999, spurred by the February 1999 issue of *The American Statistician*, in which Robert Hogg and James Higgins addressed the plight of undergraduate statistics education. The USEI group organized a symposium for the 1999 Joint Statistical Meetings for which six papers addressing statistics in undergraduate education were written (Bryce 2002). G. Rex Bryce, Robert Gould, William Notz, and Roxy Peck (2001) addressed the needs of Bachelors of Science students, by recommending skills undergraduates should gain from statistical science programs. These recommendations have been integrated into the ASA's *Curriculum Guidelines for Undergraduate Programs in Statistical Science*, which received approval from the ASA Board of Directors on December 2, 2000 (Bryce 2002).

According to ASA's curriculum guidelines, "Undergraduate statistics programs should emphasize concepts and tools for working with data and provide experience in designing data collection and in analyzing real data that go beyond the content of a first course in statistical methods" (ASA 2002, p. 1). To do this, the ASA guidelines list five skill sets undergraduates should possess upon commencement, modeled after the recommendations set forth by Bryce, et al (2001). They are statistical, mathematical, non-mathematical, computational, and substantive area skills. Statistical skills include statistical reasoning, experimental design, exploratory data analysis, and formal inference procedures, while probability and statistical theory are listed under mathematical skills. Calculus, linear algebra, and rigorous proof methods are also necessary mathematical foundations. Non-mathematical skills, such as communication and collaboration, require students to speak clearly, write well, work well in teams, and organize and manage projects and data collection processes. Such skills require more than a sequence of math courses. Computational skills include familiarity with statistical software, statistical computing, communication software, data management, and algorithmic problem solving. Last but not least, substantive area skills come from experience in an application area such as survey sampling, industrial design, or nonparametric methods. Additionally, the use of real data in meaningful contexts is emphasized along with the synthesis of theory, methods, and applications. Participation in an internship, capstone course, and/or consulting experience can round out students' statistical experience (Bryce, et al. 2001, ASA 2002).

3. National Science Foundation Programs

The National Science Foundation (NSF), with a mission which includes providing "research, guidance, and support for U.S. science and mathematics education," (NSF 1996a, p.6), has also been addressing needs in undergraduate education through its Directorate for Education and Human Resources (EHR). While no part of the science, technology, engineering, and mathematics (STEM) pre-school through post-graduate education spectrum is independent, NSF (1996b) believes undergraduate education maintains the entire system because teachers, technical workers, and professional practitioners are educated and prepared at the undergraduate level. Because of the importance of undergraduate education, EHR established the Division of Undergraduate Education (DUE). DUE has supported a number of programs focused on various aspects

of undergraduate education including instructional equipment, curricular improvement, technology education, pre-service and in-service teacher education, and faculty enhancement. All of the projects and programs reviewed in this article are, or were, supervised by DUE. However, because we cannot cover all DUE programs ever to exist, we have limited this article to programs most directly affecting undergraduate statistics education.

One influential program sponsored by DUE was the Instrumentation and Laboratory Improvement Program (ILI), created "to increase the range and quality of modern laboratory equipment and to provide equipment-based learning opportunities for undergraduate students," (NSF 1998a, p.8). At its inception in 1985, ILI only accepted applications from four-year colleges and universities and was later restructured to allow proposals from two-year institutions. During the program's first decade, over 4,700 grants, ranging from $5,000 to $100,000, were awarded for the purchase of instructional laboratory equipment (NSF 1998a). ILI operated until 1998, when it was integrated into the current Course, Curriculum, and Laboratory Improvement Program (CCLI) (NSF 1998b). The ILI projects chosen for this article established laboratories and developed materials for their use in statistics courses.

The goal of the Course and Curriculum Development Program (CCD), developed in 1988, was "to revitalize the content, conduct, and quality of undergraduate education in [STEM] through new and innovative approaches to all aspects of the undergraduate learning experience," (NSF 1995, p.11). CCD has contributed to the production of textbooks, software, and other materials, as well as the development of numerous courses and sequences of courses. From its inception until 1996, CCD funded almost 800 grants totaling $102 million. Projects that did not develop curricular materials either promoted or facilitated adoption and adaptation of such materials at other institutions (NSF 1995). The CCD projects selected for this article developed materials for post-calculus introductory statistics, regression analysis, and a capstone course in statistics.CCD was integrated into CCLI in 1998 (NSF 1998b).

The Course, Curriculum, and Laboratory Improvement Program (CCLI), established in 1998, is just as its name implies: a combination of CCD and ILI. At its birth, proposals requesting funds for curricular development and for purchasing instructional laboratory equipment were still accepted (NSF 1998b). But more than just combining two programs, NSF's goal in creating CCLI was "to stimulate and motivate faculty members so that creative teaching and pedagogical scholarship become a part of the 'faculty culture' at all institutions," (NSF 2003a, p.6). To accomplish such a challenging goal, CCLI had four tracks: Educational Materials Development (EMD), Adaptation and Implementation (AI), National Dissemination (ND), and Assessment of Student Achievement (ASA) (NSF 1998b, NSF 2003b).

A goal of the EMD track was to improve undergraduate STEM education and student learning through the development of innovative educational materials like courses, curricula, or laboratory materials that would incorporate effective teaching practices and be suitable for national distribution (NSF 2003a). EMD projects discussed in this paper focus on statistical concepts, real data, computing skills, and consulting experiences and develop technology rich resources for teachers. CCLI's Adaptation and Implementation (AI) track existed to encourage faculty to adapt exemplary materials, practices, and techniques developed at other institutions and implement them at their own (NSF 2003c). The AI projects described here adapt course materials for first courses for statistics majors, client disciplines, and the entire statistics curriculum. National Dissemination projects were intended to support dissemination of exemplary STEM educational materials through professional development opportunities for faculty, which provide materials, follow-up activities, networks of faculty, and evaluation protocols (NSF 2003a). These projects have often been workshops or short courses, some of which are described later. Lastly, Assessment of Student Achievement projects promoted the evaluation and assessment of student learning in the STEM disciplines and encouraged the development and use of authentic assessment tools (NSF 2003b). These four tracks of CCLI were retired in fiscal year 2006, making room for a cyclical model of knowledge production and improvement with five supporting components: teaching and learning research, learning materials development, faculty enhancement, innovative materials implementation, and assessment of learning

innovations (NSF 2005a).

The Advanced Technological Education (ATE) program targets technician education and encourages projects to include collaboration between two- and four-year colleges, universities, secondary schools, business, industry, or government. Funded projects have addressed curricular development, created Centers of Excellence providing systems-based approaches to technological education, and performed studies that promoted better understanding of the issues of technological education (NSF 1998b).

From 1988 until 1998, the Undergraduate Faculty Enhancement (UFE) program provided funding for a wide range of development opportunities for college faculty, such as workshops, short courses, and seminars. Over 500 workshop grants, ranging from $10,000 to $500,000, provided faculty opportunities to interact with experts in their fields, learn new experimental techniques, and to explore new teaching methods and technologies (Marder, McCullough, Perakis 2001). In this paper, the UFE projects described connect faculty with industrial statisticians and provide training for faculty teaching pre-service teachers and the social sciences. Another program focused on pre-service teachers was the Collaboratives for Excellence in Teacher Preparation (CETP), which ran from 1993 until 2001, and promoted the recruitment and development of future teachers (NSF 1999).

A relatively new DUE program is the National Science Digital Library (NSDL), whose goal is to develop a comprehensive repository of the highest quality science, technology, engineering, and mathematics education materials. This powerful collection of learning materials, ranging from kindergarten to the graduate level, provides opportunities for both formal and informal life-long learning (NSF 2005b) and can be accessed at www.nsdl.org. The Consortium for the Advancement of Undergraduate Statistics Education (CAUSE) statistics education digital library is an NSDL grant project described in this paper.

4. Selected NSF Projects

4.1 Project Characteristics

To provide an update on George Cobb's review of NSF projects in statistics education sponsored between 1990 and 1992, we searched NSF's Award Search webpage (www.nsf.gov/awardsearch/) using the keyword "statistics" for projects funded between 1993 and 2004. We found 158 grants whose primary focus was statistics education, while projects indirectly affecting statistics education were left for other articles. Fifty-two of the 158 grants target students majoring in statistics or studying statistics within a client discipline. Thirty-five percent of those 52 were funded by Instrumentation and Laboratory Improvement, 23% by CCLI Educational Materials Development, 15% by CCLI Adaptation and Implementation, 13% by Course and Curriculum Development, 6% by Undergraduate Faculty Enhancement, and 2% by each of Advanced Technological Education, CCLI National Dissemination, National Science Digital Library, and Collaboratives for Excellence in Teacher Preparation. The median award value is $63,997. The Appendix lists each grant with additional information such as monetary value, program support, and principal investigator. Additional information about these projects can be found by using the NSF Awards Search webpage (http:www.nsf.gov/awardsearch/) and entering the award number in the "Search Award for" dialog box. We do not claim that this list is exhaustive as we could have unintentionally overlooked grants. If you received funding for a project you believe fits the nature of this article and was not included, please accept our apologies.

The projects discussed in the text of this article were chosen based on several criteria: 1) characteristics that exemplify the recommendations of the ASA Curriculum Guidelines, 2) models of successful NSF projects in the programs they represent, and 3) sufficient available follow-up information on the project, including the project update found from using the NSF DUE Project Information Resource System (PIRS) webpage search (https://www.ehr.nsf.gov/pirs_prs_web/search/). Specifically, we intend to highlight 25 projects

(funded through 31 grants) that focus on conceptual understanding with theoretical background, experience with real problems and real data, computational skills, or communication skills. We have no intention of ranking the quality of these projects, as many times the availability of information determined which projects were included in the discussion. The projects are discussed according to their placement in the curriculum beginning with first courses for majors, followed by advanced courses, courses in client disciplines, learning resources, and faculty enhancement.

4.2 Introductory Post-Calculus Probability and Statistics

A common introduction to statistics for majors and minors is the two-course mathematical statistics sequence. While these courses provide a strong base in statistical theory, the USEI guidelines insist that a first course also provides students with experience in statistical thinking and literacy as do non-mathematical introductions (Bryce, et al. 2001). Reformers have overlooked this course and its students until recently (Rossman, Chance 2004). NSF funding suggests the same as only one-third of the grants included in this study that address a post-calculus introduction to statistics occurred prior to 2000. Since that time, NSF has sponsored several of these projects, as educators are recognizing the importance of firm foundations for statistics majors and minors.

Two of the funded projects intended for post-calculus introductory statistics are Kyle Siegrist's "The Probability/Statistics Object Library" (DUE #0089377) and its companion "Virtual Laboratories in Statistics" (DUE #9652870) developed at the University of Alabama, Huntsville. The "Probability/Statistics Object Library" is a collection of free applets and building blocks of applets which are stand alone versions of real experiments intended to illustrate concepts and methods. They can be dropped into web pages, supplemented by text, or modified with additional programming to meet an individual audience's needs (Siegrist 2005). The "Virtual Laboratories in Probability and Statistics" website is an example of how the Object Library components can be used. Each module in the Virtual Lab contains text explaining probabilistic or statistical content with mathematical background, simulations through interactive applets, and real data sets, involving data analysis and computation. The project focus is to provide students a more well-rounded statistical experience through mathematics, simulation, and data analysis (Siegrist 2000). The projects can be found at http://www.math.uah.edu/stat and require the *MathML* or *MathPlayer* programs, which are freely downloadable from the website.

California Polytechnic State University's Allan Rossman and Beth Chance, with some assistance from Karla Ballman, also received funding for a post-calculus introductory statistics project. Their book, "Introduction to Statistical Concepts, Applications, and Methods" (ISCAM), supported by the NSF grants "A Data-Oriented, Active Learning, Post-Calculus Introduction to Statistical Concepts, Methods, and Theory" (DUE #9950476, #0321973), encourages active exploration of statistical concepts through the use of real data from real studies. Discovery-based, collaborative learning activities introduce concepts and applications through investigation of statistical procedures and properties, while building on students' mathematical background to teach theory. Probability concepts are only introduced in the context of the statistical ideas they support, technology is used frequently for simulation and computing purposes, and oral and written communication skills are emphasized through projects and reports. Ultimately, the goal of this project is for students to perform the statistical process enough times to be better able to apply their knowledge to a wide array of areas and problems (Rossman, Chance 2004).

These three projects have had a national impact throughout the statistics education community. An example is the NSF grant "Collaborative Research: Adaptation and Implementation of Activity and Web-Based Materials into Post-Calculus Introductory Probability and Statistics Courses" (DUE #0126401, #0126600, #0126716, #0350724) by Tracy Goodson-Espy, Ginger Rowell, and Leigh Lunsford. This project adapted the materials from the Virtual Labs and from ISCAM to fit the post-calculus level introductory statistics courses at the University of Alabama at Huntsville, Middle Tennessee State University, and Athens State University, respectively (Lunsford 2004).

Deborah Nolan and Terrence Speed, of the University of California, Berkeley, developed a project to teach mathematical statistics using case studies, called "Broadening the Scope of Statistical Education through Technology" (DUE #0127557). They created a computing environment with graphical user interfaces (GUI) and the R programming language. Students applied statistical methods to real problems with real data, experienced computing and simulation exercises, and wrote reports of their analyses (Nolan, Lang 2003). A similar project by Jenny Baglivo, "A Course in Computer Intensive Statistical Methods for Mathematical Sciences" (DUE #9555178), produced a textbook of *Mathematica* laboratories for emphasizing statistical computing in the mathematical statistics sequence at Boston College (Baglivo 2000).

4.3 Advanced Statistics Courses

A variety of advanced courses in statistics are available to undergraduate majors and minors. Some courses focus on specific topics like regression analysis or nonparametric methods, while others cover a broad range of topics in a specific application area, such as business statistics or biostatistics. Capstone courses, internships, or consulting experiences provide students with the necessary practice to make an effective transition to the work force. Such diversity of advanced courses yields a variety of related NSF projects.

W. Robert Stephenson, Dianne Cook, Mark Kaiser, and William Meeker recognized advancements being made in technology and statistical methods and designed a project to incorporate them in advanced statistical methods courses. Through "Beyond Traditional Statistical Methods" (DUE #9751644), they created stand alone modules that are modeled after actual applications in science and engineering, employing real problems and data, that illustrate correct inferential techniques and uses of new statistical methods. Lesson plans, homework assignments, and authentic assessments accompany the modules, which can be used individually or combined to create an entire course. Such a class has been institutionalized at Iowa State University, where the project took place (Duckworth, Stephenson 2002). Like the projects by Siegrist, Rossman, and Chance, this project also has had an impact beyond the university at which it was developed. For example, "Biostatistics: A Second Statistics Course Preparing Undergraduates for Research" (DUE #0410586) by Bessie Kirkwood of Sweet Briar College used the modules to teach Biostatistics and to prepare students for further research in statistics (Kirkwood 2005).

At the University of Minnesota, Twin Cities, Ralph Cook provides an example of projects dealing with applied methods courses. His project "Graphical Paradigms for Teaching and Using Statistics" (DUE #9354678, #9652887) developed a graphical way to teach regression analysis that includes theoretical underpinnings. He produced a textbook, software, and teaching aids to assist educators in teaching regression through graphs, with homework problems that use real data. The software, designed for computing and analyses, is provided freely over the Internet at the project website, http://www.stat.umn.edu/arc/ (Cook 2001).

A joint project from William Swallow, Kimberly Weems, and William Hunt of North Carolina State University (NCSU) and Nagambal Shah and Monica Stephens of Spelman College established a partnership between academia, industry, and government. "Collaborative Research: Training Environmental Statisticians Using Complicated Data Sets to Make Informed Environmental Decisions" (DUE #0229344, #0230471) provided students consulting opportunities with federal, state, and local environmental agencies, offering experience applying technical skills to real problems and the chance to develop communication skills. The partnership aimed to show that NCSU, a large university with a thriving Environmental Statistics program, could help develop such a program at Spelman College, a small liberal arts college (Shah, Stephens 2004).

A common example of an advanced course for statistics majors is a capstone course. Such courses integrate all the experiences, knowledge, and abilities students should have upon graduation. John Spurrier, of the University of South Carolina (USC), developed such a course through his project "A Capstone Course in

Statistics" (DUE #9455292). In his course, students work for a hypothetical company and complete assignments that require them to design an experiment, collect and analyze data, and submit oral and written reports, just as they would in a real job. Spurrier published a textbook with eleven capstone experiences that can be integrated individually into existing courses or combined to create a single course. The course at USC has since been institutionalized and is a requirement for graduation for all statistics majors (Spurrier 2001). Daljit Ahluwalia, Bonnie Ray, and Bruce Bukiet completed a similar project at New Jersey Institute of Technology. "Capstone Courses and Projects in Applied Mathematics and Statistics" (DUE #9651404) established a computing laboratory with space for physical experiments and modules in which students learned how mathematics and statistics are used in industry (Ahluwalia, Ray, Bukiet 2000).

4.4 Statistics Taught in the Client Disciplines

One characteristic that makes statistics unique among other disciplines is its wide range of application areas. Many other disciplines, such as business, science, and engineering, use statistics heavily in their research; they are "clients" of statistics. NSF has awarded several projects to educators and researchers outside of the discipline of statistics that address statistical needs of students in these client disciplines.

Engineering is an area of study that is heavily involved in statistics and allows for unique approaches to teach the subject. For instance, "Quality Engineering Laboratory" (DUE #9751244) by Ajit Tamhane and Bruce Ankenman of Northwestern University received funds to establish a laboratory where students actually manufactured staple removers and collected and studied data on the process. Through these hands-on experiences, students learned control charts, gage repeatability and reproducibility, and experimental design from real, relevant data in the manufacturing context (Tamhane, Ankenman 2001). At the University of Texas, Pan American, Douglas Timmer and Miguel Gonzalez also created an environment where students could be involved in the manufacturing process through "Web-Based Active Learning Modules for Teaching Statistical Quality Control" (DUE #0341290). In this project, modules were developed that gave students experience with a virtual manufacturing process and allowed them to analyze real data from a company that networked their data to the university (Timmer, Gonzalez 2004).

Along the lines of the virtual environment, an economics lab was developed that provided simulations of market environments, allowing students to conduct a variety of computerized experiments, through "Experimental Economics Laboratory with Statistical Software" (DUE #9352756) by Gregory Lilly of Elon University. Students had access to faster, easier data collection, data storage, computing, better experimental control, and several statistical packages, including graphics (Lilly 1993). Another project addressing Business Statistics is "Improving Statistical Education through Visualization" (DUE #9554967) by Ronald Tracy, David Doane, and Kieran Mathieson from Oakland University, which produced *Visual Statistics 2.0* software and textbook containing 21 learning modules. Each module is designed to engage students in active, self-discovery learning through exercises, scenarios, animation, and real data (Tracy, Doane, Mathieson 2001).

"Computer Based Teaching in Epidemiology and Statistics" (DUE #9981001) by Erika Friedmann and Mark Tomita of City University of New York, Brooklyn College teaches epidemiology and statistics using real health data from large national data sets and research databases accessed over the Internet. A computer laboratory was created so that students could analyze this data using SPSS technology. Also, a number of SPSS tutorials were created (Friedmann, Tomita 2002). Utilizing technology and providing experience with real data are critical to statistics education in any discipline, and these projects show that other disciplines agree.

4.5 Statistics Across the Curriculum

To this point, we have discussed projects according to the level of education they address. We began with

math and statistics majors in their first statistics course, followed by those taking advanced courses, and moving on to students learning statistics from client disciplines. However, there are projects that address students at all educational levels. Next we will briefly describe three projects that deal with whole curricula in statistics.

Robert Arnold and Randall Fuller of Colgate University used funds for their project "Computers to Support Quantitative Analysis/Statistics across a Biology Curriculum" (DUE #9851563) to purchase 16 laptop computers for mobile labs that can travel to any classroom. The computers were used to introduce scientific writing and the use of statistics in freshman through junior level courses. Students analyzed their own data using a statistical software package, wrote papers, and designed experiments (Arnold, Fuller 2001). The "Technology Enhanced Core Project" (DUE #9950848) by Edward Reeves and Rebecca Katz reformed eight different classes in the sociology program at Morehead State University. Students in this program learned advanced research skills, bivariate and multivariate inferential statistics, and communication skills through hands-on learning activities (Reeves, Katz 2002). Another NSF-supported project that crosses curricula, disciplines, and institutions is "CAUSEweb" (DUE # 0333672) directed by Dennis Pearl at The Ohio State University. CAUSEweb, run by the Consortium for the Advancement of Undergraduate Statistics Education (CAUSE), is an ever growing digital library of over 1,000 different instructional materials for statistics education, found at http://www.causeweb.org. The materials in this library cover high school through graduate levels of education, approximately 20 different application areas, and numerous statistical topics.(Green, McDaniel, Rowell 2005).

4.6 Faculty Enhancement

Other projects that reach farther than specified groups of students are NSF's funded projects for faculty enhancement. Some of these projects in statistics are intended to help faculty who teach statistics but may not have a background in the subject. The Mathematical Association of America (MAA) received funding from NSF through its grants "MAA: Comprehensive Professional Development Program for Mathematics Faculty" (DUE #0089005) and "Professional Enhancement Program (PREP)" (DUE #0341481). These projects sponsored 49 workshops between 2001 and 2005 for mathematics faculty across the nation to enhance their teaching skills. Four of these workshops dealt specifically with statistics education, 2 addressing introductory statistics, and 2 addressing advanced statistics (Pearson 2004). The PRE-STAT workshops (DUE #9752749) organized by Mike Perry of Appalachian State University provided a similar opportunity for college faculty who teach pre-service and in-service teachers. The goal was to help math educators implement an effective statistics curriculum and to develop guidelines and activities for such a curriculum (NSF 1998c).

Because faculty teaching statistics in other disciplines most likely do not have formal statistical training, enhancement opportunities are critical to improve teaching. J. Theodore Anagnoson of California State, Los Angeles received funds for his project "Two One Week Workshops for Social Science Faculty on Exploratory Data Analysis Using Microcomputers" (DUE #9255461). Twenty social scientists with varying levels of statistical background were admitted to weeklong workshops covering exploratory data analysis techniques using the statistical package *Stata*. The goal was to provide faculty with alternatives to traditional statistical instruction methods (Anagnoson 1993).

Roxy Peck's innovative workshops, "Improving Statistical Education: Faculty Enhancement through Collaboration" (DUE #9455055), paired college statistics faculty with industrial statisticians to discuss needed improvements in statistical education. The pairs made on-site visits to each environment, each learning the conditions of the other to better understand how to meet educational needs. They also created case studies based on actual practices to be used in statistics courses and explored ways the two groups can support each other through open communication and collaboration. Her project allowed students to experience authentic applications and data in context (Peck 1995).

5. Conclusions

In this review of a decade of NSF DUE funding which affects undergraduate statistics education, we describe characteristics of 25 projects that focus on statistics majors and minors in both statistics/mathematics departments as well as in other client disciplines. Through this process, pedagogical themes emerged particularly related to course instruction to enhance the teaching of statistics for a variety of course-levels: introductory post-calculus statistics courses, advanced statistics courses, and advanced statistics in client disciplines. These themes included using real data and real applications, integrating technology effectively by providing experience with statistical computing and simulation, involving students in real consulting type environments as one of several ways of developing and improving communication skills, and promoting understanding of statistical theory through the application of mathematical background to carefully constructed statistics lessons in appropriate classes. It is apparent that NSF has been extremely involved in the improvement of undergraduate statistics education, and the projects that have been sponsored are aligned with recommendations from USEI and ASA.

Appendix: Summary Project Information

	Title	Principal Investigator	Start Date	NSF Program	Award Amount	Institution

Award Number						
0101686	Lexington Collaborative for Revitalizing and Improving Middle Mathematics (LCRIMM)	Lillie Crowley	July 1, 2001	CETP	$300,000	Univ. of Kentucky
9350693	Renovation of the Undergraduate Statistics Curriculum	Roxy Peck	June 1, 1993	ILI	$30,000	California Polytechnic S.U.
9351541	Statistics Electronic Classroom (SEC) for Instruction in Quantitative Methods in Psychology	David J. Weiss	July 1, 1993	ILI	$28,192	California State, LA Univ.
9352756	Experimental Economics Laboratory with Statistical Software	Gregory A. Lilly	August 1, 1993	ILI	$26,697	Elon Univ.
9350819	Improving Undergraduate Instruction in Statistics in the Social Sciences	James F. O'Connor	September 1, 1993	ILI	$23,495	Eastern Kentucky Univ.
9450998	A Laboratory for Numerical Computation	Robert Pervine	June 1, 1994	ILI	$27,197	Murray State Univ.
9551659	Implementing an Interactive Computer Laboratory to Support Discovery-Based Statistics Courses for Liberal Arts Students and Future Teachers	Anne D. Sevin	June 1, 1995	ILI	$29,941	Framingham State College
9551745	Computerizing the Research and Statistical Training of Undergraduate Psychology Students	Mark Johnson	June 1, 1995	ILI	$23,221	U. of Alaska Anchorage
9551184	Undergraduate Statistical Laboratory	Anthony A. Salvia	September 1, 1995	ILI	$20,942	Penn State, Univ. Park
9551942	Mobile Psychology Lab for Mercy College's Bronx Majors in Psychology, Sociology, and Behavioral Science	James Towey	September 1, 1995	ILI	$30,871	Mercy College
9651404	Capstone Courses & Projects in Applied Mathematics & Statistics	Daljit S. Ahluwalia	July 1, 1996	ILI	$28,724	New Jersey Institute for Technology
9651091	Visualizing and Writing Mathematics	James Callahan	July 1, 1996	ILI	$49,067	Smith College
9651276	The Development of an Undergraduate Psychology Computer Laboratory	Janet Kottke	July 1, 1996	ILI	$60,000	California State Univ., San Bernardino
9751644	Beyond Traditional Statistical Methods	W. Robert Stephenson	July 1, 1997	ILI	$57,000	Iowa State Univ.
9751407	A Computer Laboratory for Mathematics Instruction	John Buoni	August 1, 1997	ILI	$41,118	Youngstown State Univ.
9751114	Development of an Intranet to Enhance the Instruction of Research Methodology in Psychology	John Govern	September 1, 1997	ILI	$16,530	Towson Univ
9751244	Quality Engineering Laboratory	Ajit Tamhane	September 1, 1997	ILI	$28,367	Northwestern Univ.
9851563	Computers to Support Quantitative Analysis/Statistics Across a Biology Curriculum	Robert M. Arnold	June 1, 1998	ILI	$21,799	Colgate Univ.
9851492	Infusing Technology into the Psychology Curriculum: A Model Laboratory to Promote Scientific Thinking	William Lammers	September 1, 1998	ILI	$22,621	Univ. of Central Arkansas
9354678	Graphical Paradigms for Teaching and Using Statistics	Ralph D. Cook	December 1, 1993	CCD	$204,922	UMN, Twin Cities
9455292	A Capstone Course in Statistics	John D. Spurrier	June 1, 1995	CCD	$29,960	USC, Columbia
9554967	Improving Statistical Education through Visualization	Ronald L. Tracy	June 1, 1996	CCD	$99,951	Oakland University
	A Course in Computer Intensive Statistical	Jenny A.	July 1,			Boston

9555178	Methods for Mathematical Sciences Students	Baglivo	1996	CCD	$102,310	College
9652870	Virtual Laboratories in Statistics	Kyle Siegrist	January 1, 1997	CCD	$110,542	U. Alabama Huntsville
9652887	Graphical Paradigms for Teaching and Using Statistics	Ralph D. Cook	July 1, 1997	CCD	$124,657	UMN, Twin Cities
9752622	A New Course in Statistical Process Control Integrating an Industrial Production Facility as the On-Line Laboratory	Ronald W. Garrett	February 1, 1998	CCD	$89,083	Grand Valley S.U.
9752058	Computer Simulations of Industrial Statistical Application for Undergraduates and Technicians	David Shellabarger	October 1, 1997	ATE	$262,800	Lane CC
9950476	A Data-Oriented, Active Learning, Post-Calculus Introductions to Statistical Concepts, Methods, and Theory	Allan J. Rossman	June 1, 1999	EMD	$252,828	Dickinson College
0089377	The Probability/Statistics Object Library	Kyle Siegrist	January 1, 2001	EMD	$158,755	U. Alabama, Huntsville
0089004	Statistical Applications for the Mathematics Curriculum	George Cobb	January 1, 2001	EMD	$149,927	Mt. Holyoke College
0127398	Transforming Biological and Engineering Statistics at >Penn State	William L. Harkness	February 1, 2002	EMD	$75,000	Penn State, Univ. Park
0321973	A Data-Oriented, Active Learning, Post-Calculus Introductions to Statistical Concepts, Methods, and Theory	Allan J. Rossman	April 10, 2002	EMD	$142,500	California Polytechnic State Univ.
0127557	Broadening the Scope of Statistical Education through Technology	Deborah A. Nolan	May 15, 2002	EMD	$350,000	Univ. of California, Berkeley
0230803	Stem and Tendril: Vertically Integrated Statistics Laboratories	Andrew Poje	January 15, 2003	EMD	$74,836	CUNY, Staten Island
0229344	Collaborative Research: Training Environmental Statisticians Using Complicated Data Sets to Make More Informed Environmental Decisions	Nagambal D. Shah	February 15, 2003	EMD	$246,137	Spelman College
0230471	Collaborative Research: Training Environmental Statisticians Using Complicated Data Sets to Make More Informed Environmental Decisions	William Swallow	February 15, 2003	EMD	$247,249	North Carolin State U.
0231322	Conceptual Statistics: Engaging Students in Statistical Discovery	W. Robert Stephenson	May 15, 2003	EMD	$74,976	Iowa State Univ.
0341157	Integration of Probabilistic and Statistical Design Methods into Engineering Design Courses	Xiaoping Du	February 15, 2004	EMD	$67,994	Univ. Missouri-Roll
0341290	Web-based Active Learning Modules for Teaching Statistical Quality Control	Douglas Timmer	March 1, 2004	EMD	$74,907	Univ. of Texas, Pan Am.
9950848	Technology Enhanced Core Project	Edward Reeves	August 1, 1999	AI	$89,177	Morehead State Univ.
9952508	Computer Laboratory for Undergraduate Research Courses in Behavioral Sciences	Jarl Ahlkvist	May 15, 2000	AI	$32,952	Johnson State College
9981001	Computer Based Teaching in Epidemiology and Statistics	Erika Friedmann	June 1, 2000	AI	$99,993	CUNY, Brooklyn
0126401	Collaborative Research: Adaptation and Implementation of Activity and Web-Based Materials into Post-Calculus Introductory Probability and Statistics Courses	Tracy Goodson-Espy	June 1, 2002	AI	$36,886	U. Alabama, Huntsville
0126600	Collaborative Research: Adaptation and Implementation of Activity and Web-Based Materials into Post-Calculus Introductory Probability and Statistics Courses	Ginger H. Rowell	June 1, 2002	AI	$33,939	Middle Tennessee State Univ.
0126716	Collaborative Research: Adaptation and Implementation of Activity and Web-Based Materials into Post-Calculus Introductory	Myrtis L. Lunsford	June 1, 2002	AI	$25,433	Athens State Univ.

	Probability and Statistics Courses					
0350724	Collaborative Research: Adaptation and Implementation of Activity and Web-Based Materials into Post-Calculus Introductory Probability and Statistics Courses	Myrtis L. Lunsford	July 11, 2003	AI	$17,490	U. Alabama, Huntsville
0410586	Biostatistics: A Second Statistics Course Preparing Undergraduates for Research	Bessie Kirkwood	July 15, 2004	AI	$35,974	Sweet Briar College
0089005	MAA Comprehensive Professional Development Program For Mathematics Faculty	J Michael Person	April 1, 2001	ND	$966,291	MAA
0341481	Professional Enhancement Program (PREP)	J Michael Pearson	February 1, 2004	ND/NSDL	$462,690	MAA
9255461	Two One Week Workshops for Social Science Faculty on Exploratory Data Analysis Using Microcomputers	J. Theodore Anagnoson	April 1, 1993	UFE	$76,642	California State LA Univ
9455055	Improving Statistics Education: Faculty Enhancement Through Collaboration with Industry	Roxy Peck	January 1, 1995	UFE	$121,775	California Polytechnic S.U.
9752749	PRE-STAT Project	Mike Perry	May 1, 1998	UFE	$59,992	Appalachian S.U.
0333672	CAUSEweb: A Digital Library of Undergraduate Statistics Education	Dennis Pearl	October 1, 2003	NSDL	$824,945	Ohio State Univ.

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References

Ahluwalia, D., Ray, B.K., and Bukiet, B.G.(2000), "*Capstone Courses and Projects in Applied Mathematics and Statistics #9651404,"* DUE PIRS Search Engine.Retrieved March 2, 2005 from https://www.ehr.nsf.gov/pirs_prs_web/search/RetrieveRecord.asp?Awd_Id=9651404.

American Statistical Association. (2002), *Curriculum Guidelines for Undergraduate Programs in Statistical Science*. Retrieved March 2, 2005 from http://www.amstat.org/education/index.cfm?fuseaction=Curriculum_Guidelines.

Anagnoson, J.T.(1993), "Two One Week Workshops for Social Science Faculty on Exploratory Data Analysis Using Microcomputers Abstract #9255461."Retrieved March 2, 2005 from NSF Online Database http://www.nsf.gov/awardsearch/.

Arnold, R.M., and Fuller, R.L. (2001), "*Computers to Support Quantitative Analysis/Statistics Across a Biology Curriculum #9851563,"* DUE PIRS Search Engine. Retrieved March 2, 2005 from https://www.ehr.nsf.gov/pirs_prs_web/search/RetrieveRecord.asp?Awd_Id=9851563.

Baglivo, J. (2000), "*A Course in Computer Intensive Statistical Methods for Mathematical Sciences Students #9555178,"* DUE PIRS Search Engine. Retrieved March 2, 2005 from https://www.ehr.nsf.gov/pirs_prs_web/search/RetrieveRecord.asp?Awd_Id=9555178.

Bryce, G. R.(2002), "Undergraduate Statistics Education: An Introduction and Review of Selected Literature," *Journal of Statistics Education*, v10, n2.Retrieved June 10, 2005 from http://www.amstat.org/publications/jse/v10n2/bryce.html.

Bryce, G. R., Gould, R., Notz, W.I., and Peck, R.L. (2001), "Curriculum Guidelines for Bachelor of Science Degrees in Statistical Science," *The American Statistician*, 55, 7-13.

Cobb, G.W. (1993), "Reconsidering Statistics Education: A National Science Foundation Conference," *Journal of Statistics Education*, v1, n1.Retrieved March 2, 2003 from http://www.amstat.org/publications/jse/v1n1/cobb.html.

Cook, R.D. (2001), "*Graphical Paradigms for Teaching and Using Statistics #9652887,"* DUE PIRS Search Engine. Retrieved March 2, 2005 from https://www.ehr.nsf.gov/pirs_prs_web/search/RetrieveRecord.asp?Awd_Id=9652887.

Duckworth, W.M., and Stephenson, W.R.(2002), "Beyond Traditional Statistical Methods," *The American Statistician*, 56, 230-233.

Friedmann, E., and Tomita, M. (2002), "*Computer Based Teaching in Epidemiology and Statistics #9981001,"* DUE PIRS Search Engine.Retrieved March 2, 2005 from https://www.ehr.nsf.gov/pirs_prs_web/search/RetrieveRecord.asp?Awd_Id=9981001.

Green, L.B., McDaniel, S.N., and Rowell, G.H. (2005), "Online Statistics Resources Across Disciplines," *Journal of Online Learning and Teaching*, pending publication.

Higgins, J.J. (1999), "Nonmathematical statistics: a new direction for the undergraduate discipline," *The American Statistician*, 53, 1-6.

Kirkwood, B. (2005), "Biostatistics: A Second Statistics Course Preparing Undergraduates for Research #0410586," DUE PIRS Search Engine. Retrieved July 20, 2005 from https://www.ehr.nsf.gov/pirs_prs_web/search/RetrieveRecord.asp?Awd_Id=0410586.

Lilly, G. (1993), "Experimental Economics Laboratory with Statistical Software Abstract #9352756." Retrieved March 2, 2003 from NSF Online Database http://www.nsf.gov/awardsearch/.

Lunsford, M.L.(2004), "Collaborative Research: Adaptation and Implementation of Activity and Web-Based Materials into Post-Calculus Introductory Probability and Statistics Courses #0350724," DUE PIRS Search Engine.Retrieved March 2, 2005 from https://www.ehr.nsf.gov/pirs_prs_web/search/RetrieveRecord.asp?Awd_Id=0350724.

Marder, C., McCullough, J., and Perakis, S.(2001), "Evaluation the National Science Foundation's Undergraduate Faculty Enhancement Program. "Retrieved March 21, 2005 from http://www.nsf.gov/pubs/2001/nsf01123/nsf01123_1.pdf.

Marquardt, D.W. (1987), "The Importance of Statisticians," *Journal of the American Statistical Association*, 82, 397, 1-7.

Minton, P.D. (1983), "The Visibility of Statistics as a Discipline," *The American Statistician*, 37, 284-289.

National Science Foundation. (1995), "Division of Undergraduate Education Program Announcement and Guidelines," nsf9610, NSF EHR DUE. Retrieved September 2, 2005 from http://www.nsf.gov/pubs/stis1995/nsf9610/nsf9610.txt

National Science Foundation. (1996a), "The Learning Curve: What We Are Discovering About U.S. Science and Mathematics Education," Report nsf9653, National Science Foundation, Directorate for Education and Human Resources, ed. Larry E. Suter.Retrieved May 12, 2005 from http://www.nsf.gov/pubs/1996/nsf9653/nsf9653.htm.

National Science Foundation. (1996b), "Shaping the Future: New Expectations for Undergraduate Education in Science, Mathematics, Engineering, and Technology," Report nsf96139, National Science Foundation, Directorate for Education and Human Resources.Retrieved May 12, 2005 from http://www.nsf.gov/pubs/stis1996/nsf96139/nsf96139.txt.

National Science Foundation. (1998a), "A Report on an Evaluation of the National Science Foundation's Instrumentation and Laboratory Improvement Program," Report nsf9833, National Science Foundation Division of Undergraduate Education. Retrieved May 26, 2005 from http://www.nsf.gov/pubs/1998/nsf9833/ili-toc.htm

National Science Foundation. (1998b), "Undergraduate Education Science, Mathematics, Engineering, Technology Program Announcement and Guidelines," nsf9845, NSF EHR DUE. Retrieved May 12, 2005 from http://www.nsf.gov/pubs/1998/nsf9845/nsf9845.txt

National Science Foundation. (1998c), "Directory of NSF-Supported Undergraduate Faculty Enhancement Projects." Retrieved May 26, 2005 from http://www.nsf.gov/pubs/1998/nsf98108/.

National Science Foundation.(1999) "Collaboratives for Excellence in Teacher Preparation (CETP) Program Announcement and Guidelines," nsf9953, NSF EHR DUE. Retrieved May 12, 2005 from http://www.nsf.gov/pubs/1999/nsf9953/nsf9953FileE.htm

National Science Foundation. (2003a), "Course, Curriculum, and Laboratory Improvement (CCLI) Educational Materials Development (EMD) and National Dissemination (ND) Tracks Program Solicitation," nsf03558, NSF EHR DUE.Retrieved May 12, 2005 from http://www.nsf.gov/pubs/2003/nsf03558/nsf03558.htm.

National Science Foundation. (2003b), "Course, Curriculum, and Laboratory Improvement (CCLI) Assessment of Student Achievement (ASA) Track Program Solicitation," nsf03584, NSF EHR DUE. Retrieved May 12, 2005 from http://www.nsf.gov/pubs/2003/nsf03584/nsf03584.htm.

National Science Foundation. (2003c), "Course, Curriculum, and Laboratory Improvement (CCLI) Adaptation & Implementation (A&I) Track Program Solicitation," nsf03598, NSF EHR DUE. Retrieved May 12, 2005 from http://www.nsf.gov/pubs/2003/nsf03598/nsf03598.htm.

National Science Foundation. (2005a), "Course, Curriculum, and Laboratory Improvement (CCLI) Program Solicitation," nsf05559, NSF EHR DUE.Retrieved May 12, 2005 from http://www.nsf.gov/pubs/2005/nsf05559/nsf05559.htm.

National Science Foundation. (2005b), "National Science, Technology, Engineering, and Mathematics Education Digital Library (NSDL) Program Solicitation," nsf05545, NSF EHR DUE. Retrieved May 12, 2005 from http://www.nsf.gov/pubs/2005/nsf05545/nsf05545.htm.

Nolan, D., and Lang, T. (2003), "Case Studies and Computing: Broadening the Scope of Statistical Education," in *Proceedings of the 2003 ISI Meeting*.Retrieved March 2, 2005 from http://www.stat.berkeley.edu/~nolan/Papers/isi03.pdf.

Peck, R. (1995), "Improving Statistics Education: Faculty Enhancement Through Collaboration with Industry Abstract # 9455055." Retrieved March 2, 2003 from NSF Online Database http://www.nsf.gov/awardsearch/.

Pearson, J.M. (2004), "*PRofessional Enhancement Program (PREP) #0341481,"* DUE PIRS Search Engine.Retrieved March 2, 2005 from https://www.ehr.nsf.gov/pirs_prs_web/search/RetrieveRecord.asp?Awd_Id=0341481.

Reeves, E., and Katz, R.(2002), "*Technology Enhanced Core Project #9950848,"* DUE PIRS Search Engine.Retrieved March 2, 2005 from https://www.ehr.nsf.gov/pirs_prs_web/search/RetrieveRecord.asp?Awd_Id=9950848.

Rossman, A., and Chance, B. (2004), "A Data-Oriented, Active Learning, Post-Calculus Introduction to Statistical Concepts, Applications, and Theory," presented at the *IASE 2004 Roundtable on Curricular Development in Statistics Education*, Lund, Sweden, June 28 – July 3, 2004. Retrieved June 6, 2005 from http://www.rossmanchance.com/iscat/RossmanChanceIASEpaper.pdf.

Shah, N., and Stephens, M. (2004), "*Collaborative Research: Training Environmental Statisticians Using Complicated Data Sets to Make More Informed Environmental Decisions #0229344,"* DUE PIRS Search Engine. Retrieved March 2, 2005 from https://www.ehr.nsf.gov/pirs_prs_web/search/RetrieveRecord.asp?Awd_Id=0229344.

Siegrist, K. (2000), "Virtual Laboratories in Statistics #9652870," DUE PIRS Search Engine.Retrieved

March 2, 2005 from https://www.ehr.nsf.gov/pirs_prs_web/search/RetrieveRecord.asp?Awd_Id=9652870.

Siegrist, K. (2005), "The Probability/Statistics Object Library #0089377," DUE PIRS Search Engine. Retrieved March 2, 2005 from https://www.ehr.nsf.gov/pirs_prs_web/search/RetrieveRecord.asp?Awd_Id=0089377.

Snee, R.D. (1993), "What's Missing in Statistical Education?" *The American Statistician*, 47, 149-154.

Spurrier, John.(2001), "A Capstone Course for Undergraduate Statistics Majors," *Journal of Statistics Education*, v9, n1. Retrieved June 10, 2005 from http://www.amstat.org/publications/jse/v9n1/spurrier.html.

Tamhane, A., and Ankenman, B.(2001), "*Quality Engineering Laboratory #9751244,"* DUE PIRS Search Engine. Retrieved March 2, 2005 from https://www.ehr.nsf.gov/pirs_prs_web/search/RetrieveRecord.asp?Awd_Id=9751244.

Timmer, D., and Gonzalez, M.(2004), "Web-Based Active Learning Modules for Teaching Statistical Quality Control Abstract #0341290. "Retrieved March 2, 2003 from NSF Online Database http://www.nsf.gov/awardsearch/.

Tracy, R.L., Doane, D.P., and Mathieson, K.R.(2001), "*Improving Statistical Education Through Visualization #9554967,"* DUE PIRS Search Engine. Retrieved March 2, 2005 from https://www.ehr.nsf.gov/pirs_prs_web/search/RetrieveRecord.asp?Awd_Id=9554967.

Megan R. Hall
Middle Tennessee State University
Murfreesboro, TN 37132
Todd101215@aol.com

Ginger Holmes Rowell, Ph.D.
Middle Tennessee State University
Murfreesboro, TN 37132
rowell@mtsu.edu
