Project Description

I. Introduction

The objectives of this collaborative project are to improve post-calculus students' learning of probability and statistics and to provide students with better preparation for their future careers in mathematics and statistics, mathematics education, and computer science. These objectives will be achieved by focusing on active and cooperative learning, visualization of concepts, and use of simulations in post-calculus probability and statistics courses via the adaptation and implementation of two recently developed National Science Foundation (NSF) funded materials. The materials chosen for this project are "A Data-Oriented, Active Learning, Post-Calculus Introduction to Statistical Concepts, Methods, and Theory," hereafter referred to as SCMT [21], and the "Virtual Laboratories in Probability and Statistics," hereafter referred to as VLPS [22]. The proposal team consists of Dr. Leigh Lunsford (Athens State University (ASU)), Dr. Ginger Rowell (Middle Tennessee State University (MTSU)), and for evaluation and assessment, Dr. Tracy Goodson-Espy (University of Alabama in Huntsville (UAH)). The proposed project will cover a twenty-seven month period which will include the professional development of the principle investigators (PIs) and other faculty at the institutions, the respective institutional adaptation and implementation (A&I) of the materials, the evaluation of the A&I of the materials, the assessment of students using the materials, and the dissemination of the results of the A&I.

II. Background

The reform movement in statistics education emphasizes statistical thinking, active and collaborative learning, conceptual understanding, the use of data and technology, and communication skills in order to reduce the "wide gap" that David Moore says "separates

statistics teaching from statistical practice." [7, 8]. Most of the attention has been focused on the teaching methods, course content, and use of technology in algebra-based introductory statistics courses [7, 16, 20, 24, 26]. In recent years the reform movement has also had some effect, though more limited, on post-calculus introductory probability and statistics courses. This can be seen in textbooks that are beginning to emphasize data and computer applications [9, 13]. However many post-calculus introductory probability and statistics courses are heavily front-loaded with probability theory, leaving little time for exploring statistical concepts. In a typical two-semester post-calculus introductory probability and statistics sequence statistical concepts such as statistical significance are often not introduced until the second semester [9, 14, 15]. At many smaller institutions the second semester course is oftentimes not taught and hence many of these post-calculus students are exposed to few, if any, statistical concepts. Although ASU and MTSU are very different institutions, they have both encountered such problems in these courses.

Because ASU is a small two-year institution (approximately 2700 junior and senior level students) with limited resources (the Mathematics department consists of one half-time and three full-time faculty members), it has one post-calculus probability and statistics sequence. This sequence serves a varied clientele including mathematics, mathematics education, and computer science majors, with mathematics majors being the minority of students in the class. Currently statistical concepts are typically not introduced until the second semester of the sequence. Although the first course of the sequence is taught in the Fall and Spring semesters, the second course of the sequence is taught at most every two years. Thus the majority of ASU's post-calculus students do not receive adequate exposure to applied statistics.

In contrast, by virtue of being a large school (MTSU is the second largest University in Tennessee with approximately 19,000 students), MTSU can offer more than one post-calculus introductory statistics course. A few years ago, in an effort to better prepare future math teachers

and in an attempt to meet NCTM and NCATE standards [17, 19], MTSU added a three-hour course called "Probability and Statistics" and a corresponding one-hour "Data Analysis" course, each with a Calculus I prerequisite. Approximately 250 students majoring in applied mathematics, math education, computer and other sciences take these courses each year. However, because the current Probability and Statistics course is essentially a faster-paced version of algebra-based statistics, it has not provided these mathematically inclined students with proper foundational knowledge for their future careers nor does it offer them much of a challenge.

At both ASU and MTSU, most of the non-education majors in these courses go on to careers in industry in which they will be very likely to use statistics and will certainly be required to work in a group setting, write coherent reports, and make professional presentations. In addition, the education majors finishing these courses are not receiving enough statistics training to teach statistics or AP statistics nor are they experiencing a model of data-driven, activity-based, and discovery-oriented teaching practices that they will eventually be expected to adopt as part of the NCTM Standards [19].

While the PIs in no way undervalue theory, especially probability theory, their experience in industry and with teaching probability and statistics has lead them to question the order of topics in traditional post-calculus introduction to probability and statistics courses. The PIs believe that the clientele of their courses would benefit from an earlier inclusion of statistics in the courses. Furthermore, the PIs believe that the lecture-only teaching method is one-dimensional, does not reach all types of learners, and does not develop many of the skills needed for their students' future careers. Alternatively, the PIs have found simulations, visualizations, collaborative projects, and active learning strategies to be useful in building students' probabilistic intuition and understanding. In addition, these teaching methods also provide

stronger preparation for future careers where students will be expected to work in teams, to "think outside of the box" to come up with new solutions, and/or to apply new teaching techniques in the classroom. These types of teaching methods are also endorsed by professional organizations including the ASA, MAA, NCATE, and NCTM [3, 4, 17, 19]. Thus the PIs believe it is important to use these teaching methods for their students who will be future teachers in mathematics *and* for their students going on to professional careers in industry.

With the recent funding of SCMT and VLPS and others [2, 11, 23], the NSF has fostered the development of reform-oriented educational materials for post-calculus probability and statistics courses. With its emphasis on activity-based learning, the PIs have chosen SCMT to facilitate the early inclusion of statistics into their post-calculus courses. They will also be using VLPS in these courses to provide simulation and visualization opportunities to help build students' probabilistic intuition and understanding.

II.1. Description of SCMT

Rossman, Chance and Ballman [21] are developing curricular materials for a two-course post-calculus sequence that provides a balanced introduction to statistical concepts, methods, and theory by using a hands-on integration of computer technology for discovery learning and analysis of real data. The course materials are designed to introduce both content and pedagogy that will better prepare students for careers in statistics or teaching. Using these materials, students will experience the process of statistical investigation in a complete cycle starting with collecting data, determining the best method for analysis, conducting the analysis, making inference, and interpreting the results. Of particular importance is the fact that the SCMT course sequence is designed so that the first course in the sequence provides a self-contained post-calculus introduction to statistics.

II.2. Description of VLPS

Siegrist [22] has developed an interactive, web-based resource for students and teachers of probability and statistics. The VLPS contains a collection of web-based software modules that function as virtual laboratories in probability and statistics. These modules improve student understanding of probability and statistics concepts by enhancing the traditional mathematical and data analysis approach with simulation. Included are dice, coin, and Galton board simulations as well as classic problems such as the Monty Hall Let's Make a Deal Problem [27] and Buffon's Needle Experiment. The Java-based simulation applets provide a rich environment for illustration of important probability concepts such as the Central Limit Theorem. In addition, the VLPS web-site contains notes and homework problems, some of which are suitable for an introductory level post-calculus probability and statistics course.

II.3. The Team Approach

The project team consists of three highly qualified PIs. With her industrial experience and close connections to industry in the neighboring high-tech city of Huntsville, Lunsford brings insight into the types of challenges that will be faced by students seeking careers in technology related fields. Recently returned to academia, she is committed to improving how mathematics is taught at all levels. By virtue of her project management experience, the team has chosen Lunsford as the team "leader." Rowell has taught probability and statistics for over six years. Throughout that time she has incorporated a variety of group activities and active learning strategies into her classes. Both Lunsford and Rowell are familiar with statistics education reform efforts and have participated in workshops (as participants and presenters) and acted as advisors on statistics education initiatives. Goodson-Espy brings her mathematics education expertise to the team. She has also taught mathematics for over 14 years including post-calculus probability and statistics. Goodson-Espy and Rowell have also worked to create links and

relationships between middle and high schools and higher education. The PIs believe that each member provides a necessary component to make a cohesive team.

Although ASU, MTSU, and UAH are quite different institutions, their respective administrations believe that the PI's working as a team will enhance the A&I of the above materials (please see the attached letters of support). First, because the courses in which the materials are being implemented serve the same types of students, the proposal team will be able to co-develop and use many of the same adaptations of the materials thus allowing for a more efficient adaptation of the materials. Second, the team will have more than one instance of implementation per semester. This will enable the team to quickly determine the best practices for implementation of the materials and evaluation of students. Third, the opportunities for professional development in using these materials will be possible for not only the PIs and other faculty members at each institution but also for faculty outside the institutions via a team-planned and implemented summer workshop (Summer 2004). Fourth, by working as a team, the PI's will be able to co-deliver in-service training for teaching probability and statistics to local high-school teachers via distance learning facilities. The team approach also provides the project with a more objective assessment both in terms of student assessment and in terms of overall project evaluation. Because Dr. Goodson-Espy will not be teaching any of the classes and because she is affiliated with a different university, she will be in a position to provide objective evaluation of the project. Lastly, it is hoped that this project will act as a springboard for future education-oriented collaborations between the three institutions.

II.4. Current Changes at ASU and MSTU

Both Lunsford (ASU) and Rowell (MTSU) have started to make changes in the way they teach their post-calculus probability and statistics classes. They have both experimented with using the VLPS as a demonstration tool and as a part of homework assignments. Since a large

percentage of their students are computer science majors (who are also getting a minor or a double major in mathematics), they have found them to be much more interested and intrigued by the VLPS applets rather than a traditional lecture. In addition, Lunsford and Rowell have volunteered their respective institutions as testers for the materials being developed by Rossman and Chance for SCMT.

In the Spring of 2001, Lunsford modified an SCMT activity to introduce the notion of tests of significance. Because of the successes of using this activity and the VLPS as a demonstration tool, she intends to incorporate more activities from SCMT and use the VLPS for more than demo purposes in the coming academic year. The ASU Mathematics Department is committed to having a data driven, activity-based probability and statistics sequence. They have shown their support for Lunsford's teaching changes by modifying the numbering (from MA431 to MA331), the prerequisites (removing the prerequisite of completing the entire calculus sequence), and the name (removing "Theory of" and adding "Applications of") for the first course of their probability and statistics sequence.

Rowell also plans to use SCMT materials in the Probability and Statistics course in the fall of 2001. In addition, she is working with a senior colleague at MTSU to run a test implementation of some of the VLPS simulation activities into the one-hour Data Analysis course during the 2001/2002 academic year. MTSU has shown their support of Rowell's teaching changes by awarding an internal grant (May 2001) to purchase 25 copies of *Minitab* for the Department of Mathematical Sciences computer lab.

Although Lunsford and Rowell have individually begun to incorporate these materials into their classes on a limited basis, their departments recognize the need for a systematic approach to incorporating these materials in their respective institutions. Because these materials call for different pedagogical approaches (using technology, group activities, etc.), their

departments see the need for professional development of the faculty for successful institutional A&I of the materials. In particular, a major purpose of this proposal is to prevent the faculty who teach these courses from having to "reinvent the wheel" when using these materials especially with regards to using technology, evaluation of student performance by non-traditional means (other than tests), and classroom management of group activities.

III. Project Goals and Outcomes

Goals and outcomes of the project include:

- The development of post-calculus probability and statistics courses that produce well-educated students and that meet larger departmental and institutional goals of preparing students for the modern world (as citizens and in their careers).
- The integration of technology and group-based activity work into the courses for the purpose of enhancing student learning.
- The enhancement of student communication skills through oral and written reports and presentations.
- The improvement and implementation of non-traditional student assessment techniques.
- An increase in other science majors who take these courses (biology, chemistry, etc.).
- The development of joint teacher training programs between ASU, MTSU, and UAH.
- The implementation of the pedagogical techniques and/or the A&I materials into other courses at the respective institutions.
- A contribution to the on-going discussion in the mathematics community concerning what mathematical topics should be included in reform-oriented courses to improve overall student understanding of undergraduate probability and statistics.

IV. Project Details

The project will be for a period of twenty-seven months starting in the summer of 2002. The first year will concentrate on professional development of the PIs, initial A&I of the materials, evaluation of the A&I, and assessment of student understanding of concepts using the materials. The second year will focus on institutional A&I of the materials via professional development of other faculty members at ASU and MTSU and refinement of the A&I. Both Lunsford and Rowell will have course releases from teaching and the assistance of a student worker during the two academic years of the project. The Project Timetable below gives a timeline for project progress.

Table 1 - Project Timetable

DATE	PROJECT MILESTONE
Summer 2002	Attend Rossman and Chance's SCMT Workshop, San Luis Obispo, CA. Team Meeting: Discuss A&I strategies including evaluation and assessment; Begin adaptation of SCMT and VLPS materials for classes.
Fall 2002	Teach first courses with adapted materials. Team Meeting: Evaluate A&I; Refine adaptations.
Spring 2003	Attend Joint MAA/AMS Meeting for professional development/dissemination. Teach second courses with adapted/refined materials. Team Meeting: Evaluate A&I; Plan informal workshop.
Summer 2003	Hold informal training workshop for ASU and MTSU faculty. Team Meeting: Evaluate A&I; Refine adaptations. Attend Mathfest or JSM for dissemination/professional development purposes.

Fall 2003	Continue A&I of materials. Test materials with another colleague teaching the course this semester and/or next semester. Team Meeting: Evaluate A&I; Refine adaptations; Plan in-service training.
Spring 2004	Attend Joint MAA/AMS Meeting for dissemination/professional development. Continue A&I of materials. Deliver in-service training via distance learning facilities. Team Meeting: Evaluate A&I; Plan summer workshop.
Summer 2004	Team Meeting: Finalize summer workshop plans. Deliver summer workshop. Attend Mathfest or JSM for dissemination of project results.

IV.1. Courses for A&I

The primary courses at MTSU affected by the project will be the calculus-based "Probability and Statistics" and "Data Analysis" courses. The primary course affected at ASU will be the first course of ASU's probability and statistics sequence, "Applied Statistics and Probability I." The new concept for these courses will be to cover probability and statistics topics throughout the courses, using each to reinforce the other. The major change for the ASU sequence will be the delay of some probability topics in order to introduce more statistics topics. Because the second course of the ASU sequence is rarely taught, the goal is to make the first course a self-contained post-calculus introduction to probability and statistics. Thus this course will closely parallel the MTSU Probability and Statistics course. The PIs will incorporate group projects using the SCMT activities and/or VLPS, and technology including web-based Internet applications (VLPS), Microsoft Excel, and the software package *Minitab* (provided to ASU via this proposal). The courses will be taught in existing computer labs or computer projection

classrooms on the ASU and MTSU campuses (a projection system will be provided to MTSU via this proposal). It is possible that a traditional text (such as [9]) will be used in conjunction with the text being developed by Rossman and Chance [21]. Tentative topics to be covered in the courses include: Data Analysis including basic descriptive statistics, Variation, Randomness, Empirical Probability Distributions, Sample Spaces and Probability Distributions, Random Variables, Discrete and Continuous Distributions, Sampling, Inferential Statistics including Estimation and Hypothesis Testing, Introduction to Bivariate Data Analysis including Regression and One-Way ANOVA.

IV.2. First Year of the Project

The project will officially start in the summer of 2002 when the PIs (and depending on funding levels, some of their colleagues) attend a workshop offered by Rossman and Chance on using the SCMT materials. Both Rowell and Lunsford will implement SCMT and VLPS materials in their classes starting in the Fall of 2002. This early implementation will be reasonable and possible because of the PI's familiarity with the materials and their limited implementation of the materials in their classes prior to the grant period. For each semester of the 2002/2003 academic year the A&I process will entail:

- Possible modification of course topics based on assessment of the implemented A&I materials and/or pre-grant implementations of the materials.
- Determination of which activities to use from SCMT and which simulations from VLPS to support course topic development. Determination of homework, group projects, and class demonstrations associated with these materials.
- Modification (if needed) of selected materials into homework, group projects, and demos.
- Development of course calendars including testing and project days, activity schedule,

visitation days (Goodson-Espy), and identification of points in the calendar to revisit the curriculum plan and adjust as necessary.

- Communication via on-going instructor journals, regular calls, e-mails, and project website.
- Evaluation of the results of the A&I to date including modifications of materials.

Using the assessment guidance of Goodson-Espy, the team will make decisions about the combination of the SCMT and VPSL and possibly other NSF materials [2, 11] that will be most appropriate to meet specified objectives. To facilitate this process the team will meet periodically to review the A&I of the materials. Because the three campuses are located relatively close together, this can be accomplished with very little expense. The team members believe their work prior to the grant period and their early implementation and assessment during the grant period will provide better insight into the overall use of the materials.

At the end of the first year (Summer 2003), the team will hold an informal training session for their colleagues who teach the A&I courses at their respective institutions. The team members also anticipate presenting a paper at a professional conference detailing their experience to date with the A&I. Lastly, Lunsford will develop a web-site for the project. The website will contain project information including reports, assessment results, modified activities, group projects, and homework assignments. In addition to using the website for dissemination purposes, the team members also anticipate using the website as a resource for their classes.

IV.3. Second Year and Third Summer of the Project

The institutional A&I of the materials will begin via another faculty member (other than Lunsford or Rowell) teaching the affected course at least once during the academic year (03/04). Lunsford and Rowell will provide mentoring and any additional training needed for their colleagues. This will enable the team to refine the A&I to ensure that the materials will be practical for other instructors to use.

The team members also plan to hold in-service training sessions for high school teachers of statistics during the 2003/2004 year. The purpose of the training will be to use the A&I materials to enhance teacher knowledge of probability and statistics and to demonstrate activity-based learning and computer and web-based applications in teaching probability and statistics. The sessions will be taught in the distance learning facilities at ASU and MTSU and will service local high school teachers in north Alabama and Tennessee. Videos of the sessions will be made for use by other pre-service and in-service mathematics teachers.

The culmination of the project will be a three-day summer workshop (Summer 04) for college faculty. This workshop will be not only be open to the team's colleagues but to other college teachers in the Southeastern Region. The workshop will introduce college faculty to the materials, show them how to adapt and implement the materials into their classes, and how to use new assessment techniques with the materials. The team has asked and received commitments from Drs. Alan Rossman and Kyle Siegrist to give presentations on their materials at the workshop (please see the letters of support from Rossman and Siegrist).

As with the first year of the project, the team members will meet on a regular basis to evaluate the project progress and to plan and implement the teacher in-service training sessions and the summer faculty development workshop.

V. Assessment and Evaluation

In order to successfully evaluate the A&I of the SCMT and VLPS materials in their classes the PIs will be using an action research model [10, 12, 18] that can be applied to the study of students' understanding of probability and statistics concepts [5]. The four phases of the model are to determine:

1. *What is the problem? I.e., what is not working in the classroom?*

2. *What technique can be used to address the learning problem?*
3. *What type of evidence can be gathered to show whether the implementation is effective?*
4. *What should be done next, based on what was learned?*

Goodson-Espy will facilitate the application of the model as the project team adapts and implements the SCMT and VLPS materials. In addition to her meetings with Lunsford and Rowell, she will conduct independent observations of class activities. Some of Goodson-Espy's class visits will include interviews with individual students and interviews with student activity and project groups. The purpose of these interviews will be to gain information concerning student conceptions about probability and statistics and student attitudes towards the curricular materials and instructional techniques. Because Goodson-Espy will not be acting as an instructor for any of the classes and will therefore not be responsible for assigning student grades, it will allow students to be honest in sharing their ideas and opinions regarding the courses.

In addition to the student interviews conducted by Goodson-Espy, the team members will also utilize a variety of assessment tools to evaluate student progress and learning. In conjunction with traditional tests and/or quizzes, they may also use Interactive Web-based Conceptual Testing Applets [4], Student Homework Journals, and Group/Individual Projects that will include written reports and oral presentations. The team will also single out particular concepts for which the use of a pre-test and post-test will allow them to evaluate the success of the instructional materials for that concept. Goodson-Espy will analyze the student assessment data along with the instructor journals. The analysis of this data will enable the PIs to describe the results of the A&I in a systematic way which will allow other instructors to capitalize on successful techniques and avoid particular pitfalls.

VI. Dissemination

As specified in the project details section, dissemination will occur via presentations at professional conferences, an informal training session for ASU and MTSU faculty, in-service workshops for teachers, a summer workshop for college faculty, and a project website. The team also anticipates submitting at least one article to the Journal of Statistics Education on their findings.

VII. Results from Prior NSF Support

Lunsford has not served as a PI or co-PI on any NSF-sponsored projects. Rowell participated in the proposal writing of supported DUE#9751571, *Data-Driven Statistics Courses in an Interactive Teaching Computer Laboratory*, at Lander University, Greenwood, SC. However, she moved before the award was granted and thus did not participate in the implementation of the project.

Goodson-Espy served as PI on the NSF supported project *POWRE: Project Pathway* (9752989, 5/01/98-4/30/99, $25,512.00). This planning grant provided for the development of a program to support and encourage middle school girls' interest in science, mathematics, engineering, and technology (SMET). It included a two-week day camp at the University of North Alabama at which twenty-six entering ninth graders participated (July 13-24, 1998). Participants were provided with lively and interesting experiences in SMET areas, and the opportunities to form mentorship relationships with local professional women employed in SMET fields. Project products included a literature review, a plan for a regional Project Pathway, case studies from the pilot Project Pathway, a notebook of activities for a two-week day-camp, and a web-site. A paper, *Project Pathway: Learning the Characteristics of Intervention Programs that Challenge Middle School Girls*, is in preparation.