Project Summary

Multidisciplinary Training in Statistics: A collaborative, inquiry-based, supportive approach to statistical reasoning and application

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Statistical analysis plays a significant role across the sciences and is arguably the most salient point of intersection between diverse disciplines given that scientists constantly communicate information on varied topics through the common language of statistics. Despite its central importance however, the teaching of statistics is limited by numerous challenges that are not easily overcome with traditional pedagogical approaches. We propose to develop an exemplary, collaborative, inquiry-based course in introductory statistics that will serve up to 100 students per semester and cross both divisional (natural and social sciences) and departmental (biology, chemistry, neuroscience, computer science, astronomy, earth and environmental science, social science) boundaries. The proposed Phase I CCLI program represents a combination of the creation of new learning materials and innovative teaching strategies which will directly and creatively tackle many of the most significant challenges currently faced by both introductory statistics instructors and students. We expect that this course will increase 1) the number of science students exposed to statistical training; 2) pursuit of advanced course work and opportunities in statistics; 3) exposure to statistical training for women and minorities

Intellectual Merit:

The proposed work will involve the creation of an innovative and uniquely supportive introductory statistics curriculum. We will be creating new learning materials and teaching strategies that are intensive enough to allow students to constantly move forward with their research, yet broad enough to force students to creatively and independently explore their scientific questions and make decisions involved in the data analytic process. The resources each student needs will be dictated by their research question and results at each stage of their work, allowing students to creatively pursue questions of greatest interest to them and in doing so, provide the skills, confidence, and inspiration to pursue advanced quantitative opportunities and experiences. Key innovations include: 1) a multidisciplinary model of statistical inquiry; 2) training in the flexible application of knowledge; 3.) analysis of data in real world contexts; 4) access to core statistical concepts through computing; 5) multilevel support; and 6) commensurate reward for an inquiry based curriculum.

Broader Impact:

The creation of a supportive, multidisciplinary inquiry-based statistics curriculum and the development of maximally supportive resources take advantage of students' natural curiosity and provide a common language for approaching questions across numerous scientific disciplines. The broader impact of this work will be more quantitatively literate individuals, and a larger and more gender and ethnically-balanced population with the kind of skills needed to communicate quantitative information across disciplines. The project can also benefit other universities in that we will be able to not only disseminate our model and experiences, but also make newly developed teaching tools and supportive resources widely available.

Multidisciplinary Training in Statistics: A collaborative, inquiry-based, supportive approach to statistical reasoning and application

1. Results of prior NSF support. Not applicable. No prior NSF support

2. Background and Context

Statistical analysis plays a significant role across the sciences and is arguably the most salient point of intersection between diverse disciplines given that scientists constantly communicate information on varied topics through the common language of statistics. Despite its central importance however, the teaching of statistics is limited by numerous challenges that are not easily overcome with traditional pedagogical approaches. As a result, statistics courses are often viewed by students as boring at best and highly stressful at worst, often requiring memorization of methods and formula not found directly relevant to the tasks required for analysis of data in real world contexts. As a consequence, students from majors that do not require statistics avoid enrollment in the introductory course with the undesirable result that students do not gain the necessary quantitative literacy to meet greater needs for strong statistical knowledge. Even for those whom an introductory statistics course is required, students may become “book-smart,” without the experience of solving real statistical problems either on their own or of their own choosing. As a result, few students actively seek out advanced course work and remain limited in their ability to creatively engage in empirical research. We strongly believe that it is of central importance to the development of future scientists that students become active scholars throughout their undergraduate education and that the vital role of statistical literacy in achieving this goal cannot be overstated.

At Wesleyan University, as well as at universities and colleges, uneven access to statistical training is often most acutely felt in the natural sciences, with few opportunities available outside of large general lecture courses sponsored by a Math Department and unlinked to the topical work within and across the sciences. To address this gap, we propose to develop an exemplary, collaborative, inquiry-based course in introductory statistics that will serve up to 100 students per semester and cross both divisional (natural and social sciences) and departmental (biology, chemistry, neuroscience, computer science, astronomy, earth and environmental science) boundaries. The proposed Phase I CCLI program represents a combination of the creation of new learning materials and innovative teaching strategies that will directly and creatively tackle many of the most significant challenges currently faced by both introductory statistics instructors and students.

3. Challenges and Innovations

3.1 Discipline specific training vs. a multidisciplinary model of inquiry

The challenge: The days of “silo” science have ended—collaboration and inter-disciplinarity are now viewed as essential for solving the most important problems faced in the U.S. and across the world (National Academies, 2004). The shift away from the solitary researcher to team research with scholars collaborating with others within and across disciplines has occurred in the natural sciences, computing sciences, engineering, the social sciences and the humanities (Wuchty, Jones, & Uzzi, 2007). Curriculum that imparts this kind of inclusive and flexible thinking and communication will best foster the development of students who will not only be able to engage in interdisciplinary scholarship, but will also be among the most scientifically literate citizens in our society. In the face of these realities, however, statistical training generally remains at the poles of discipline-specific instruction or generic mathematical training, with few models that truly create the necessary dialogue across disciplines.

The innovation: We propose several innovations that will assure that this introductory statistics course not only serves students from diverse majors, but more importantly sparks communication, reasoning and collaboration that clearly cross the traditional disciplinary boundaries. First, students will have the opportunity (and expectation) of working with cutting edge data representing several scientific disciplines. Specifically, we will provide data and supporting resources (e.g. data documentation, scientific literature, grant applications describing the research, etc.) for studies that are made accessible by Wesleyan faculty (e.g. from grants funded by NSF, NIH, NIDA, etc.), and data made publically accessible through leading archives. Second, great care will be taken to present common terminology/vocabulary used across the different disciplines for similar statistical concepts. This inclusive and comparative approach to vocabulary will allow students to widely communicate about computational issues with each other and with faculty across the university (Nolan & Temple Lang, 2009). Third, students will be expected to actively engage in the dissemination of their work through ongoing classroom, laboratory and informal discussion as well as a final, scientific poster presentation. To accomplish these goals, course materials will be developed in consultation with a “Statistics Advisory Board” made up of faculty across natural and social science departments (Biology, Chemistry, Neuroscience and Behavior, Molecular Biology and Biochemistry, Astronomy, Earth and Environmental Science, Mathematics, Sociology, Government, Economics, Psychology) and an expert advisory board made up of accomplished scientists, educators and professionals. Class sessions will be conducted with as much interaction with and between students as possible. Activities to promote collaborative behavior inside and outside of the classroom will include conceptual mini-lectures as needed using examples from research questions and data currently under investigation by individual students; promotion and facilitation of group work and encouragement for unlimited discussion among students.

3.2 Training students to flexibly apply their knowledge (learning by doing)

The challenge: It can be reasonably argued that the specific goal of statistics education is to train students to understand and apply statistical methods (Bryce, Gould, Notz, & Peck, 2001). However, while many courses teach either the mathematics or application of methodology, few convey the necessary skills of approaching a scientific problem from a statistical perspective (Nolan & Temple Lang, 2009). In this way, the “tools” that students are commonly provided within the introductory curriculum often do not serve them well given real world challenges. As Wild (p. 325) noted, “the biggest holes in our educational fabric, limiting the ability of graduates to apply statistics, occur where methodology meets context (i.e. the real world)” (Wild, 2007). Not surprisingly, students often feel defeated by the statistics learning process because they feel they are not able to use what they have learned in powerful and significant ways. Instead, learning is often akin to the temporary memorization of method and vocabulary that does not generalize beyond the course (Nolan & Temple Lang, 2009). While instructors work tirelessly to present diverse and compelling examples and exercises to students, traditional pedagogy cannot convey the same “rich, complicated context, extraneous information, and decision-making issues present in the experience of real application” (Nolan & Temple Lang, 2009).

The innovation: This course will be taught as a student-driven, inquiry-based endeavor designed to provide meaningful, relevant, real and engaging statistical experience. Students will be intensively "supported" through the experience of statistical inquiry and introduced to appropriate methods, skills and information based on their own project, rather than being guided through "canned" exercises. The examples presented to the class will be based on individual student experiences, and much of the more detailed instruction will take place "after the fact", that is in the context of the questions and needs that the students' work generates (Kester, Kirschner, & Van Merrienboer, 2004). In this way, like professional scientists, they will "decompose their topic, identify key components; abstract and formulate different strategies for addressing it; connect the original question to the statistical framework; choose and apply methods; reconcile the limitations of the solution; and communicate findings" (Nolan & Temple Lang, 2009). To accomplish this, we will provide students with a range of current data sets that are complex in their design and/or measurement, represent one or more of several disciplines, and can be used to identify and test a nearly unlimited number of research questions. Based on the student's choice of data, each will generate testable hypotheses, conduct a literature review on their topic of interest, work to refine or broaden their research questions based on information they collect, prepare data for analysis, select and conduct descriptive and inferential statistical analyses; and evaluate, interpret and present research findings. These activities will not be presented or experienced as distinct stages, but rather, as a series of ongoing interactive tasks. An array of supportive resources will be put into place (e.g. class and laboratory sessions, web based materials, individual tutoring, group discussion and numerous collaborative opportunities) that are intensive enough to allow students to constantly move forward with their research, yet broad enough to force the students to creatively and independently explore their scientific questions and make the decisions (and in many cases the mistakes) involved in the data analytic process.

3.3 A laundry list of tools vs. training from a "need to know" perspective

The challenge: As described by Nolan and Lang (2009), comprehensive reviews of leading introductory statistical texts across the natural and social sciences reveal an almost exclusive emphasis on sets of rules developed in the 1950s for various test statistics (e.g., *z*-test, one sample *t*-test, two sample *t*-test, paired *t*-test, and various non parametric tests). Class content follows by describing these procedures, with the success of the course often measured by students and faculty based on how far through the "laundry list" one moves. Unfortunately, students too often approach this sort of statistical training as a compulsory endeavor in which methods are mastered from a thin and factual perspective, while a more flexible and creative understanding of their application remains elusive (Nolan & Temple Lang, 2009). Further, a perusal of contemporary scientific literature across the natural and social sciences demonstrates that research in any given topical area utilizes a small subset of these introductory methods and more importantly, commonly employs many other statistical methods that students generally have no exposure to until late stages of graduate and post graduate training. These realities have sparked debate as to whether we are achieving the goals of basic statistical literacy by focusing on a prescribed list of methods and whether ambitious changes should be made to statistical training (Cobb, 2007).

The innovation: The proposed course will be organized according to the processes and skills involved in statistical inquiry, rather than a prescribed list of statistical formula and procedures. Although basic themes such as scales of measurement and descriptive and graphical representation of data can be considered reasonable building blocks in all areas of inquiry, specific methods needed to test hypotheses and/or explore the empirical structure of data will be introduced as the student's scientific questions dictate their presentation. Thus, once course content moves past the basic themes underlying data management and hypothesis testing, students will be provided with opportunities to learn to evaluate what tools would be most appropriate for their research question(s). In this way, they will be both engaged in the decision making process of statistical inquiry and will develop a greater background for engaging in these types of decisions in the future. While each student will not utilize the entire menu of procedures available for training in the course, through collaboration with peers and group discussion, they will be exposed to the variety of methods, each maximally anchored in statistical application. This innovative "need to know" approach will build confidence and an ability to evaluate data and seek out appropriate tools for the questions at hand.

3.4 Computing as a window into core statistical concepts

The challenge: The technological explosion of the past two decades has revolutionized statistics. There is now widespread agreement that introductory students need to learn statistical programming (American Statistical Association, n.d.). This has both expanded the scope of what students should be exposed to and has created additional challenges for how statistical software can or should be incorporated into the curriculum. Not surprisingly, opinions differ widely both across substantive disciplines and even within individual departments about the specific statistical software program that should be taught. Many introductory statistics courses now cover the practical aspects of using a single statistical software package. Unfortunately, this exposure is most often directly targeted at a basic knowledge about the particular package, rather than being used as a platform for the more important goal of conceptual reasoning with data. Currently, what is needed is a more general and translatable approach to statistical programming that provides students with the <u>flexible skills</u> to explore data and formulate and test scientific questions (Nolan & Temple Lang, 2009).

The innovation: We believe that computing should be viewed as a central skill that greatly expands a student's capacity for not only statistical application, but for engaging in deeper levels of quantitative reasoning. In contrast to the contemporary pedagogical approach of introducing a single, statistical software program with "canned" exercises for the students to repeat, our goal will be to use statistical computing as a critical building block for statistical and scientific reasoning and creativity. To accomplish this, we will train students on the use and translation of three commonly used statistical software packages across the natural and social sciences (SAS, Stata and SPSS), focusing on the commonality and patterns that will provide them with a powerful, general viewpoint and more flexible understanding of data management and statistical analysis (Nolan & Temple Lang, 2009). Importantly, although some common statistical software packages have developed a point and click interface that allows students to bypass more formal logic syntax, we will employ only the logic syntax-based approaches to statistical computing in an effort to train students to fully engage in the decision making process of scientific inquiry (e.g. the connection to the logic of data management and the choices made in statistical analysis and general model building). To accomplish this, numerous translational resources will be developed that provide students with appropriate syntax for achieving a host of data management and analytic tasks of use in the pursuit of answers to question of the greatest interest to them. These materials will be delivered in multimedia formats (e.g. modular web based video of programming basics across software platforms) that allow students to quickly and easily select appropriate materials based on their individual needs. In addition to media resources, we will make individualized instructional support available 15 hours a day (i.e. tutoring and on-line program debugging support) throughout the semester to minimize common frustrations experienced when first working with data and maximize productive experiential learning. Rather than producing students who can think about statistics from a software-specific perspective, this innovative approach to training will allow students to more flexibly discuss statistical issues with instructors, tutors, mentors and peers across a variety of scientific disciplines.

3.5 Serving the masses: multilevel support for large groups of students

The challenge: Introductory Statistics courses play a critical role in the curriculum across the natural and social science disciplines by providing skills that facilitate work in higher-level courses, access to the scientific literature and experiences in empirical research. One of the main challenges that universities face, however, is that the integration of statistical software training has made it necessary to offer individual statistical sections to small groups of students (e.g. 15 to 20 per class). There is in fact a strong negative association between the number of students in a class and the expectation of tackling independent projects. Thus, introductory statistics now represents one of the most costly courses in the curriculum. Each semester at Wesleyan University, for example, approximately 180 students are enrolled in one of 7 statistics course sections in different departments. Even with this substantial commitment of faculty and IT resources, these courses remain uncoordinated with one another, and departments often do not have the faculty strength to offer statistics despite its importance for their advanced courses. This uneven access to statistical training is currently felt most acutely in the natural sciences, with few opportunities available outside of a large general lecture course sponsored by the Math Department and unlinked to the topical work of their disciplines. Based on data from the past 5 years (i.e. graduating classes from 2003-2008), only 1/3 of science majors completed a basic statistics course during their undergraduate training, less than 20% when it was not required for their major.

The innovation: We propose to move beyond the traditional model of instruction to create the necessary resource infrastructure that will effectively support larger groups of students. Specifically, although in-class sessions will be lead by a single instructor, student support and instruction will be shared among a multidisciplinary team of laboratory instructors, tutors, and peer support. Diverse web based resources will also be developed to provide supportive user friendly tools. For example, on-line materials will differ from statistics textbooks. Instead of being organized around discreet statistical topics, the resources that we develop will be carefully organized according to candidate steps and decisions in the research process, structured enough to keep students moving forward, but flexible enough to create the need for full immersion in the research process. What resources each student needs will be dictated by the research question and results at each stage of data management and analysis, allowing students to creatively pursue questions of greatest interest to them. Rather than reading arcane statistical manuals, students will be provided with syntax for the different statistical software programs which they will be able to select and cannibalize for their own purposes. Class sessions will teach the fundamental principles underlying statistical methods, data management, and analysis. Laboratory sessions will permit students to work on the statistical programming required for their individual projects with in-person support from laboratory instructors both for broad issues related to choosing an appropriate statistical method, as well as specific issues related to statistical programming (e.g., data management, syntax development, and solving programming errors). Tutors will be available 15 hours a day for additional support and working groups will be facilitated among students who are using the same data set and/or statistical software. Multimedia resources will further provide step by step instructions for programming tasks that are common across areas of research inquiry (e.g., calling in data sets, recoding and computing new variables, saving and storing new data sets, syntax files, and statistical output).

3.6 Reward for a uniquely time consuming endeavor

The challenge: College courses are organized and delivered in the form of a “credit-hour” which most often represents the number of hours spent in class each week. As a rule of thumb, instructors expect students to spend a proportionately equal amount of time each week outside of class on readings, assignments and other course related activities. Unfortunately, this narrow structure restricts the innovative design and delivery of an introductory statistics curriculum due to the disproportionate amount of time that is needed for active engagement in inquiry based statistical training outside of structured class session. In short, when a typical class schedule includes at least 3 other courses, students find themselves unable to immerse themselves appropriately in the activity of statistical inquiry.

The innovation: The innovative statistical training we propose must be successful in the context of numerous other academic and extracurricular activities. Although students in this course will spend the usual 3 hours per week, on “in class” training, an additional 10 hours of supported laboratory work, individual tutoring sessions, collaborative work with peers and independent research effort will be expected. Thus, the course will represent fully 50% of a student’s curriculum for the semester and will be rewarded with the commensurate number of credit hours.

3.7 Attracting students from underrepresented groups

The challenge: There have been many initiatives aimed at the recruitment and retention of women and underrepresented minorities in science and engineering disciplines. However, the NSF has reported that African Americans, Native Americans, and Hispanics together comprise only 5.8% of all employed persons with PhDs in science and engineering disciplines and that women hold <18% of all tenured positions in these same fields (National Science Foundation - Division of Science Resources Statistics, 2004). Importantly, many underrepresented minority students exit science early during their academic tenure; of those who intended to major in science or engineering, only 27% of minorities completed such programs, compared to 46% of non-minorities (Huang, Taddese, Walter, & National Center for Education Statistics, 2000; National Science Foundation - Division of Science Resources Statistics, 2004). As part of a multi-institution initiative with support from the Howard Hughes Medical Institute (HHMI) and the National Institutes of Health (NIH), Wesleyan University has undertaken a detailed analysis of retention and diversity in the sciences. Our initial focus has been on the life sciences, and our experience, common across our peer institutions, is that the representation of under-represented students diminishes significantly during the first year in introductory courses. Notably, of the numerous reasons indicated for early departure from science and engineering programs, the most often cited reason is uninspiring or unsuitable pedagogical practices (Handelsman, 2005; Seymour, Hunter, Laursen, & Deantoni, 2004).

The innovation: We expect that our innovative approach to statistical training will assist in not only retaining women and students from underrepresented groups in the sciences, but more generally attracting them to more quantitatively rigorous fields of study. During early iterations of the course, we will evaluate whether it attracts a more diverse student body than our traditional mathematics statistics courses. As the infrastructure and delivery of the course is more completely developed, we will put into place substantial recruitment efforts meant to engage women and underrepresented students during their *freshman* year, so that their experiences may maximally impact their undergraduate trajectory. To accomplish this, we will partner with Wesleyan's Ronald E. McNair Post-Baccalaureate Achievement Program, funded by the U.S. Department of Education. This program assists students from underrepresented groups in preparing for and achieving success in postgraduate education and focuses especially on science and mathematics, serving underrepresented students (first generation college students from low income families, and African American, Hispanic, Native Hawaiian or other Pacific Islander, and Native American students) interested in pursuing STEM graduate education. *Our goal will be to not only attract these students to the proposed course, but to prepare and inspire them to pursue advanced quantitative training.*

3.8 Introductory statistics as the alpha rather than the omega

The challenge: Many recent attempts at modernization of introductory statistics curriculum have been undertaken with the assumption that for the vast majority of students, this will be their one and only opportunity for statistical training. As such, courses moving furthest from the traditional coverage of basic statistical methods now employ pedagogy with a focus on the student as a consumer of statistical information rather than users of statistical tools. Whether focused on the more traditional mathematical computation or the modern consumer oriented approach, it is unlikely that any single course will prepare students for the large amount and complexity of statistical information they will encounter as professionals and as citizens.

The innovation: The cross-discipline innovations we propose have a larger purpose which is to link students to a wide range of additional opportunities to utilize and further develop statistical literacy both at the undergraduate level and beyond. These opportunities will take the form of further coursework tied to modern state-of-the-art methods (spectral analysis, growth mixture modeling, hierarchical linear modeling, decision tree methods, latent class and latent transition analysis, geographic information system methods, etc.) as well as a myriad of hands-on research opportunities designed to strengthen their statistical skills. As an example, the Quantitative Analysis Center at Wesleyan has developed a summer research program in statistical inquiry that provides those students with an introductory statistical background a further opportunity to enhance their skills in data analysis and statistical literacy. Also, given that students will have the opportunity in our innovative introductory course to work with data sets that are of central interest to science faculty at Wesleyan, the course will be an important source for faculty to directly recruit students into their research labs for more advanced research and data involvement. This experience will take place within the undergraduate program as well as through our BA/MA program that allows our undergraduates the option to spend a tuition-free fifth year focusing on research and advanced course work. We will also be utilizing the prominent members of our advisory board to provide valuable connections to extant data, research internships, and various other forms of advanced study and experience. *Importantly, we expect all of these opportunities beyond the introductory course to continue to draw on the extensive web based resources developed for the course as well as continued access to individual tutoring through the Quantitative Analysis Center.*

4. Past Piloting of Proposed Innovations

Dr. Lisa Dierker, a PI on this proposal, has created an experimental course employing several of these innovations (i.e. providing students with access to cutting edge data, creating a maximally supportive course structure that allows students to explore research questions of their choosing, and introduction of appropriate methods, skills and information based on individual projects). To date, however, this has been available to very small numbers of students. The course was first offered at Wesleyan University as an experiment in spring 2003 to 10 students. A modified version of the initial course has been taught during 3 subsequent semesters. Student evaluations of this small course have been enormously positive. Comments clearly indicated that the goals of stimulating interest, improving the experience of learning statistics, and facilitating the pursuit of statistical research beyond students' experience at Wesleyan University were achieved. Further, students found outlets for their empirical class projects in undergraduate publications as well as in peer reviewed journals. Several have presented work at national conferences. Importantly, it has also opened numerous doors in the area of applied statistical inquiry. For example, as a direct result of experiences provided by this course, Seth Samuels (Wesleyan '06) was selected for a healthcare statistical analyst position with Analysis Group, Boston, MA upon graduation. May Chao (Wesleyan '06) is currently working in healthcare research in the Taiwan branch of TNS, the largest international custom research company. In summary, this small experimental course confirmed for us that the proposed approach to statistical inquiry can be delivered successfully, as students were able to quickly master sufficient computing skills that allowed them to work relatively independently and be in charge of exploring their own ideas and questions, flexibly access and manipulate data, and perform and interpret statistical tests. *In the proposed course, we are looking not just to emulate these successful curricular features now tested with small groups of students from a single discipline, but to extend them to large numbers of students from diverse areas of science.*

5. Wesleyan as an Ideal Setting for the Proposed Curricular Innovations

At no time in Wesleyan's 175-year history has science and quantitative literacy been a more important part of the liberal arts education. Indeed, it has long been recognized that liberal arts colleges have a tradition of student -faculty interactions that is wholly consistent with the collaborative model used in modern scientific research and technology. Much teaching is done in the context of the laboratory as evidenced by the frequency with which Wesleyan undergraduates appear as coauthors on peer -reviewed articles (e.g. since the year 2000, Wesleyan undergraduates have coauthored more than 70 publications in peer-reviewed scientific journals). This student effort is an integral part of the Wesleyan science research enterprise, the excellence of which is clear from the success with which Wesleyan faculty receive grant support. Wesleyan ranks number one among private liberal arts colleges in total federal money for research with a total of $19,288,000 for the period 2001 -2005. Further, recognizing the importance of bridges between disciplines in catalyzing important scientific advances in academia and industry, Wesleyan works to emphasize the development of interdisciplinary skills and conceptual frameworks by our students. Science at Wesleyan provides undergraduates with outstanding opportunities for research, and membership in active, extramurally funded research groups. In the NSF Survey of Earned Doctorates, during the three-, five-, and ten-year periods ending in 2004 (the most recent data available), Wesleyan ranks in the top ten of baccalaureate colleges in the numbers of students going on to obtain a Ph.D. in the sciences.

6. Proposed Steps and Products

We propose to:

1. Identify large data sets and supporting documentation representative of diverse disciplines.
2. Develop supportive web based resources that students can utilize during the course and as they move into advanced training.
3. Train tutors who will provide one-on-one support to students outside of classroom and laboratory sessions.
4. Work with students trained in statistics as well as advisory board members to identify points of conceptual and practical difficulties that students have with quantitative reasoning and application and devise pedagogical methods that mitigate these difficulties.
5. Develop an array of mini lectures both foundational and those that can be selected on an as needed basis throughout the semester.
6. Present the course to 100 students in spring of 2010.
7. Convene an expert Advisory Board charged with planning how innovations will be delivered (Fall 2009) and modified based on an external evaluation (Spring 2011). See *Evaluation* details below.

Intellectual Merit

The proposed work will involve the creation of an innovative and uniquely supportive introductory statistics curriculum. We will be creating new learning materials and teaching strategies that are intensive enough to allow students to constantly move forward with their research, yet broad enough to force students to creatively and independently explore their scientific questions and make the decisions involved in the data analytic process. What resources each student needs will be dictated by their research question and results at each stage of their work, allowing students to creatively pursue questions of greatest interest to them and in doing so, provide the skills, confidence, and inspiration to pursue advanced quantitative opportunities and experiences. Key innovations include: 1) a multidisciplinary model of statistical inquiry; 2) training in the flexible application of knowledge; 3.) analysis of data in real world contexts; 4) access to core statistical concepts through computing; 5) multilevel support; and 6) commensurate reward for an inquiry based curriculum.

Broader Impact

The creation of a supportive, multidisciplinary inquiry-based statistics curriculum and the development of maximally supportive resources takes advantage of students' natural curiosity and provides a common language for approaching questions across numerous scientific disciplines. The broader impact of this work will be more quantitatively literate individuals, and a larger and more gender and ethnically-balanced population with the kind of skills needed to communicate quantitative information across disciplines. The project can also benefit other universities not only through dissemination of our model and experiences, but by making newly developed teaching tools and supportive resources widely available.

We are particularly well prepared to undertake this ambitious project due to an assembled team of accomplished educators and scientists with a wide range of experience in training of statistics across individual disciplines (See *Personnel Section* below). Because of the complementary expertise of our team members, and the resources available at Wesleyan University, we are well positioned to successfully complete the proposed work.

7. Development and Evaluation

The evaluation will be conducted by experienced researcher evaluation staff affiliated with Wesleyan's PIMMS (Project to Increase Mastery of Mathematics and Science) Program (see attached letter). Since 1983, PIMMS has been designing and evaluating educational curriculum aimed at promoting mathematics and science education.

7.1 Formative Evaluation

Throughout the development and piloting of the course, ongoing, formative assessment will take place. First, a general syllabus, laboratory outlines, and supporting materials and resources will be planned and evaluated by an expert advisory board made up of accomplished educators, and professional and academic scientists with a wide range of experience in training of statistics across individual disciplines. We will also recruit undergraduates who have previously received introductory statistical training to assist in the development of the course and identify gaps in their ability to tackle real world data driven research questions. Once the course is implemented, formative evaluation will build on the standard online Instructor & Course Evaluation System at Wesleyan University which provides anonymous feedback to instructors for course improvement at the end of the semester. This end of the semester feedback will further be supplemented with ongoing student evaluation of course components via a wiki-based webpage that will allow immediate comment on confusion, frustration, and problems encountered throughout the semester. Accessible by all students in the course, students will be encouraged to make constructive comments about their work and experiences. This detailed qualitative log will be evaluated throughout the semester by course and laboratory instructors. Following the first piloting of the course, the PI's along with the advisory board will evaluate feedback and modify instruction strategies and materials.

7.2 Summative Evaluation

Details of specific gains that are expected for the students and how these gains will be measured are described below. Briefly, a quasi experimental design will be used to evaluate the new course. Each department currently offering introductory statistics at Wesleyan (Math, Psychology, Economics, and Government) will continue to offer these courses during the pilot period, providing the opportunity to use this traditional statistics curriculum as control/ comparison groups. Measures will be administered at the beginning (pre-test) and end (post-test) of each statistics course across the university, at graduation and 1 year post graduation. Measured outcomes will include the following:

Change in attitudes toward statistics: In that the course is directly aimed at students developing confidence in their ability to work with and disseminate real world data, a standardized assessment of students' attitudes toward statistics (i.e. Survey of Attitudes Toward Statistics -- SATS) will be used (Schau, 2003). The test contains twenty-eight questions that reflect four subscales - Affect, Cognitive Competence, Value, and Difficulty. We expect to see greater gains relative to traditional statistics courses in terms of student's positive attitudes, feelings of security toward statistics and the value placed on statistical literacy.

Increase in science students exposed to statistical training: As previously mentioned, uneven access to statistical training is most acutely felt in the natural sciences, with few opportunities available outside of large general lecture courses sponsored by a Math Department and unlinked to the topical work within and across the sciences. Based on data from the 2011 graduating class forward, we will examine changes in the percent of science students who complete a basic statistics course during their undergraduate training.

***Increased pursuit of advanced course work and opportunities in statistics*:** Anecdotal evidence suggests that students who have never considered a career in scientific research have discovered such interests after engaging in mentored statistical training and research. Given that the course atmosphere will closely resemble a research setting, we anticipate that students will discover an interest and aptitude for work with data across the sciences and that they will be more likely to engage in further statistical work compared to students taking traditional introductory statistics courses. To evaluate this outcome, we will assess engagement in advanced course work, empirical research, senior honors theses, and other quantitative opportunities. We also evaluate increases in student dissemination of their work through student journals, conference presentations and as collaborators on peer-reviewed publications.

Increased exposure to statistical training for women and minorities: From inquiry-based exposure to statistics, a larger and more gender/ethnically-balanced population of students who pursue quantitative research experiences is expected. Working with our Director of Institutional Research, Michael Whitcomb, we will assess how gender and ethnicity are associated with enrollment in the proposed course compared to our more traditional statistics courses. Further, we will track progress of our students into and through their majors following the course. Our analysis will evaluate students according to socio -economic status (low income or first - generation -college), gender, as well as ethnic background. Success will be judged by increased student enrollment in statistics, retention of students in the sciences, GPA performance, student research exposure and co-authorship of empirical publications, and progress into continuing education and quantitative careers.

We expect to **disseminate** these results through a comprehensive webpage for the Quantitative Analysis Center, as well as through educational presentations at meetings.

Our longer term goal would be to evaluate this innovative statistics curriculum through a controlled trail in which students are randomly assigned to the new course, a course through the Math Department or an introductory statistics course provided by one of two disciplines consistently offering an introductory course for their majors (Economics and Psychology).

8. Connections to CCLI Goals

This proposed Phase I CCLI program is innovative, in that it will lead to the creation of a novel teaching environment and curriculum, and is interdisciplinary, in that its goal is to facilitate communication, reasoning and collaboration that clearly cross the traditional disciplinary boundaries. This fits in well with the CCLI program, which is based on a cyclic model showing the relationship between knowledge production and improvement of practice in undergraduate STEM education. Our proposal builds on the model by utilizing an expert team and advisory board, the combination of whose skills will lead to new educational materials and teaching strategies, setting the stage for the development of new and exciting faculty expertise in statistics education. Further, the proposed course will particularly benefit students in a wide array of STEM degree programs including Biology, Microbiology, Biochemisty, Chemistry, Neuroscience and Behavior, Astronomy, Earth and Environmental Science, Computer Science and Mathematics. To our knowledge, this paradigm is original as a way of introducing students to statistics quantitative reasoning. Further, this project will advance knowledge and understanding of not only statistical reasoning and associated skills, but will introduce students to the points of quantitative intersection across disciplines.

While this course will be piloted by the PI's, the materials and supportive training infrastructure will be designed in such a way that other faculty can easily follow the framework and utilize the newly developed resources. Importantly, our goal will not be to deliver a course whose success is tied to individual instructors being facile in all programming software or methods. Instead, we will be developing a strong infrastructure of resources and expertise that can be drawn on by both instructors and students. In this way, the course will not only develop vital student expertise, but will develop faculty expertise in terms of their ability to mentor students, engage in the use of statistical and methodologic vocabulary across disciplines and develop expertise across leading statistical software packages.

9. Funding Request

We are requesting funds for supporting portions of the instructional infrastructure necessary to implement this innovative multidisciplinary statistics course and additional funds for evaluation of the curricular innovations, and communication with our advisory board members. Without these funds, the course as described will simply not happen. There are currently no available funds through Wesleyan University for the additional personnel required to provide the kind of intensive student mentoring that will be critical to the success of this large-scale supportive approach to statistical training. The success of this pilot would contribute to future decision making regarding reallocation of available resources, supportive hiring for this initiative and additional targeted fund raising that would provide long term continuity and expansion.

10. Personnel

The proposal capitalizes upon our high quality personnel.

Dr. Lisa Dierker (Principal Investigator) is a Professor of Psychology at Wesleyan University with training in chronic disease epidemiology. Her research focuses on the application of state-of-the-art statistical methods in understanding the natural history of development of nicotine dependence and other addictive behaviors. Dr. Dierker has been involved in two separate multidisciplinary collaborative research networks sponsored by the John D. and Catherine T. MacArthur Foundation and The Robert Wood Johnson Foundation, experiences that have afforded her rich collaborative relationships with leading experts in addiction research across multiple disciplines (e.g. public health, statistics, medicine, engineering, pharmacology and biology). Through a career development award from the National Institute on Drug Abuse (NIDA), Dr. Dierker has been employing promising group-based statistical methods to identify homogenous population subgroups with the goal of informing the content and timing of targeted interventions for addictive behavior. During the 2008-2009, she has been in residence as a visiting faculty member at The Methodology Center at Penn State University, an interdisciplinary NIDA and NSF funded center focused on the development and dissemination of cutting-edge statistical methods. Dr. Dierker (PI) and her collaborator at The Methodology Center, Dr. Runze Li (PI), recently received a $1,000,000 grant from NIDA as part of the NIH Roadmap Initiative for Medical Research (2007-2011) which supports their work on the extension and dissemination of Dr. Li's innovative Functional Hierarchical Linear Modeling (FHLM) method for intensive longitudinal data (Li, Root and Shiffman, 2006; Dierker et al., under review). Dr. Dierker has shown an extraordinarily strong commitment to teaching undergraduate courses in the areas of statistics and research methods. Aside from her innovative introductory methods work, she has also developed a seminar on newly available methodologies for empirically identifying homogeneous population subgroups (e.g. FHLM, Classification and Regression Tree Analysis (CART), Latent Class Analysis (LCA), and Growth Mixture Modeling). In both 2006 and 2007, Dr. Dierker received funding from NIDA to mentor underrepresented students in their summer research program. She has also been successful in mentoring numerous students in statistical methods so that they were able to meaningful contribute to several peer reviewed publications during their time as Wesleyan undergraduates.

Dr. David Beveridge (Principal Investigator) was trained in physical chemistry at Monsanto Research Laboratory, the University of Cincinnati, the Centre de Mecanique Ondulatoire Appliquee in Paris, France, and Carnegie Mellon University. Early in his career his research program focused on studies of the structure of liquid water and aqueous solutions using theoretical physical chemistry and Monte Carlo computer simulation, funded by an NIH career development award 1972-1977, and subsequently supported by a series of research grants from the NIH Institute of General Medical Studies. At Wesleyan University, his developing interests in biological water shifted the focus of his research into molecular biophysics. In 1988, he was granted a Merit Award by the NIH, and named University Professor of the Natural Science and Mathematics. He served Wesleyan as Dean of Natural Sciences and Mathematics, 1992-1999, where his principle divisional initiatives were directed toward enhancements in the integration of teaching and research. His teaching at Wesleyan now ranges from physical chemistry, molecular biophysics, and computational biology to freshman seminars on The Scientific Method, Science and Modernism, and Scientific Ethics. In addition to research and teaching, he now serves at Wesleyan as Director of the NIH supported Training Program in Molecular Biophysics. Dr. Beveridge brings to this initiative additional senior faculty leadership in the physical sciences as well as expertise in the integration of teaching and research. This will serve to strengthen the network of interdisciplinary collaboration that will be established with this initiative.

In addition, **Dr. Jennifer Rose** (Co-Investigator) is a Research Associate Professor at Wesleyan University with extensive training in statistical methods. At Indiana University, Dr. Rose received postdoctoral training in categorical data analysis, longitudinal data analysis, and multilevel modeling. At Brown University, Dr. Rose gained extensive experience in the design, implementation, and analysis of randomized controlled trials. She has experience with measurement scale development and psychometric evaluation using structural equation modeling techniques. In addition, Dr. Rose has successfully implemented and published numerous analyses including OLS and logistic regression modeling, growth curve modeling of both continuous and categorical outcomes, multilevel modeling, latent class analysis and pattern mixture modeling of missing data. She is co-editor and contributor to the book, Multivariate applications in substance use research: New methods for new questions published by Lawrence Erlbaum Associates, a book that has become a reference for several state-of-the-art statistical methods. Dr. Rose also has strong statistics teaching credentials at the undergraduate level having offered courses at Wesleyan University, Indiana University and Rhode Island College. Dr. Rose will be responsible for assisting in the development of course materials and resources, coordinating and teaching the laboratory sessions. She will also manage and analyze data related to the outcome evaluation and work with the advisory board and PI’s in refining curricular content.

Advisory Board

The role of the advisory board will be four-fold: (1) to recommend and provide the most current data being utilized in academia, government and the private sector across multiple disciplines; (2) to review and critique course materials and resources; (3) to evaluate feedback from students enrolled in the course and assist PI's in determining appropriate changes and adjustments; and (4) to assist in linking students to additional undergraduate and graduate course work and research opportunities (e.g. summer fellowships, internships, and graduate programs) in order to provide continued training in the application of statistical methods.

Wesleyan Faculty: Dr. Martha Gilmore (Astronomy and Earth & Environmental Science), Dr. Michael Singer (Biology), Dr. Wendy Rayack (Economics), Dr. John Kirn (Neuroscience and Behavior), Dr. Marc Eisner (Government), Dr. Daniel Long (Sociology).

Dr. Lisa L. Harlow received her Ph.D in Psychometrics from UCLA and is a Professor at the University of Rhode Island, teaching over 3,000 students for the past 20+ years. She is a recipient of the American Psychological Association Division 5 Jacob Cohen Distinguished Teacher and Mentor Award. Her main focus is on increasing interest, diversity, understanding, and retention in science-related fields. She has over 100 publications and $6,000,000 in grants on advancing science, health, and minority training in quantitative science. She serves as Editor of LEA Multivariate Application Book Series; Associate Editor of Psychological Methods; and co-organizer of Quantitative Training for Underrepresented Groups.

Dr. George Cobb is the Robert L. Rooke Professor of Mathematics and Statistics at Mount Holyoak College who has successfully engaged students from widely diverse academic backgrounds in courses that explore statistics. His books on the topic include: *Introduction to Design and Analysis of Experiments* (Springer Verlag, 1998), and *Statistics in Action: Practical Principles for a World of Uncertainty* (Key Curriculum Press, 2003). He was chair of the focus group on statistics of the Mathematical Association of America and of the Joint Committee on Undergraduate Statistics of the Mathematical Association of America and the American Statistical Association. He also served on the committee that founded the *Journal of Statistical Education* and then was its associate editor for five years. More recently he served on the Committee on Applied and Theoretical Statistics of the National Academy of Sciences and as president of the American Statistical Association.

Additional Advisory Board Members: To be named from a long list of Wesleyan alumni prominently involved in the use of data across diverse disciplines: For example, Lael Brainard (Wesleyan '78), a Brookings Institute senior fellow from 2001 to 2009, served as the vice president and director of the Global Economy and Development program from June 2006 to March 16, 2009 and nominated by President Barack Obama to be under secretary of the Treasury for international affairs; Seth Samuels (Wesleyan '06), Healthcare Statistical Analyst at Analysis Group, Boston, MA); Joshua S. Boger (Wesleyan, '73, Parent, Class of '06, '09), founder and retired CEO and President of Vertex Pharmaceuticals, Inc. Cambridge, MA; Shonni J. Silverberg, MD. (Wesleyan, '76), Professor of Medicine, Division of Endocrinology & Metabolism, Columbia University College of Physicians & Surgeons, New York, NY.

11. Timeline

Fall 2009 – Course development. Academic Affairs is providing Dr. Dierker with a reduced teaching load that will assist in developing the proposed course. During fall 2009, in consultation

with project staff, Dr. Dierker will develop the supporting materials and resources. The first laboratory handbook will be written and data sets and supporting documentation from multiple disciplines will be collected. Online video tutorials to support in-class training on each of the three statistical computing software (SAS, Stata and SPSS) will be developed. Advisory board will provide initial feedback on course materials.
Spring 2010 – Small course. The course will be delivered to 20 students (i.e. one laboratory section). Final development of laboratory modules and finalization of resources and support personnel will be completed at this time. Students in the small course will be trained as tutors/TA's for the launching of the full course. A log of difficulties encountered by the students will be kept.
Summer 2010 – Meeting with advisory board and review of student products.
Fall 2010 – Full course. The multidisciplinary course will be taught to 100 students. Pre/post test data will be collected on enrolled students as well as a comparison group of students registered in existing discipline specific introductory statistics courses. Again, a detailed qualitative log of difficulties encountered by students will be recorded and evaluated throughout the semester.
Spring 2011 –Data analyses of pre/post test data and dissemination of preliminary findings to advisory board. Course materials will be modified based on these results as well as more general experience and feedback. The infrastructure for collecting follow-up data on students will be put in place. Decisions will be made about additional resources and data sets for fall 2011.

12. Other Resources

The classroom for this course is a fully equipped multimedia room. It includes a dual large screen computer projection system with Sympodium® pen display, document camera, and a "Personal Response System" (PRS). It is also equipped with an automatic lecture recording and dissemination system that will allow students to review class material outside the regularly scheduled meetings. The PRS will improve our ability to actively engage students during class meetings and facilitate participation which often not easy to achieve in large courses. Lab sections will take place in two computer classrooms with individual student workstations (20 and 33 seats).

The Quantitative Analysis Center at Wesleyan further facilitates the integration of quantitative teaching and research activities, and assists faculty in implementing the "Logical Reasoning" and the "Quantitative Reasoning" key capabilities as outlined in faculty legislation passed on March 1, 2005. In service to the proposed course, the QAC will provide data management, and programming resources; demonstrations and workshops on the use of software; and tutorial services (one-on-one, small groups) to students working on course assignments. Additional Information Technology staff will assist in creating the course web site which will include organized and efficient support to students and instructors by providing access to data, schedules, statistical software resources, and other curricular materials.

The Digital Imaging/Photography service facilities of the Division of Natural Sciences and Mathematics will be available for printing of student research posters at a subsidized rate.

In addition, Wesleyan University will provide a fundraising coordinator who will solicit financial support from our alumni in order to sustain, upgrade, and further modernize statistical training at Wesleyan. This effort will be dedicated to creating an endowment that will ensure that this curricular initiative will be successful and remain at the cutting edge of innovation for many years to come.

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