Discovery Learning Projects in Introductory Statistics
Project Summary

This proposed Type II project extends research and curriculum development performed in an NSF Phase I CCLI project conducted from 2007 – 2010. In Phase I, co-PI's produced Instructor and Student Guides for implementing discovery learning projects in introductory statistics courses at college and Advanced Placement (AP) secondary levels. They also developed and validated three instruments: a content knowledge test, a self-efficacy scale for statistical tasks, and a scale for perceived usefulness of statistics. Five college and AP secondary pilot instructors used the materials; student outcomes were measured using the 3 instruments and were compared to prior student outcomes for each instructor in a quasi-experimental control-vs.-treatment design. Results showed significant gains, particularly in student self-beliefs and also in content knowledge. Results also showed variable effect among instructors, as well as interaction among three variables: instructor, student achievement level, and use of the materials.

In the proposed Type II project, curriculum materials will be revised to add flexibility and to be usable at all high school grades. The control-treatment design will be repeated with a pilot group expanded to a geographically diverse nationwide sample, including 8 college, 3 AP secondary, and 20 early secondary instructors. In addition, the project team will update existing instruments to more accurately measure student knowledge and attitude gains achieved by participating in the discovery projects. The team will also create a new instrument to measure teacher orientation toward facilitating these projects. Finally, the team will introduce a qualitative component to the research design. The project goals are as follows:

1. Promote vertical integration and wider university utility of Discovery Project Curriculum Materials: Adapt project guides to early secondary curricula; make college guides more flexible.
2. Revise quantitative instruments from Phase I and use these to analyze student outcomes.
3. Use qualitative research to explore interactions among teachers, students and discovery projects.
4. Widely disseminate improved curricular materials and quantitative/qualitative research results.

The project will start in Fall 2010 and conclude in 2014. During the first year, the team will focus on curriculum development and instrumentation. Pilot testing and data collection will take place Fall 2011–Spring 2013. Analysis of research findings and dissemination will take place in 2013 and 2014.

The **broader impact** of the Type II project includes deeper vertical integration and a large-scale, nationwide verification of the exploratory results in student gains. Thirty-one instructors and as many as 1,000 students will participate directly in the Type II pilot project; this includes 8 college, 3 AP and 20 early secondary teachers and their students. Many others will have access to the dissemination efforts, facilitating improved outcomes in introductory statistics, thereby creating potential for extremely broad impact, as many liberal arts, business and education majors require undergraduate statistics coursework, as do STEM majors in health sciences and engineering. Secondary mathematics curricula increasingly expose students to statistical topics. Statistics-based research informs pharmaceuticals licensing, political polls, climate research and other thorny, real-world issues. Innovative teaching methods for introductory statistics will benefit many citizens, primarily those in non-STEM disciplines.

The **intellectual merit** of the proposed Type II project is based on a plan to extend the successful research and instrumentation from Phase I. The Student Project Guide and Instructor Project Guide are currently being edited with commercial publication prospects through WH Freeman, who have also expressed interest in publishing the revisions proposed in the Type II project. The three Phase I instruments will be revised, and an additional measure of teacher orientation toward facilitating discovery research projects will be developed. Data collection from Phase I concluded in December 2009, from which three research articles are in preparation. The large sample of students and teachers in the proposed Type II project will allow those Phase I results to be confirmed, generalized, and refined in a more extensive pilot.

Discovery Learning Projects in Introductory Statistics
Project Description

Overview

The Type II proposal "Discovery Learning Projects for Introductory Statistics" extends and leverages the research and curriculum development performed in an NSF Phase I CCLI project conducted from 2007 – 2010 by PI's from North Georgia College & State University (NGCSU). The proposed project expands the pilot group to a nationwide sample, deepens the vertical integration to include all high school grades, and adds flexibility to the Discovery Projects Curriculum Materials ("**DPCM**") developed in Phase I.

In Phase I, Co-PI's Spence and Sinn produced an Instructor's Guide and two Student Guides for implementing discovery learning projects in introductory statistics courses. They also developed and validated three instruments: a content knowledge test for regression and t-test topics, a scale measuring self-efficacy for statistical tasks, and a scale for perceived usefulness of statistics. A group of pilot instructors used the DPCM; student outcomes were measured using the three instruments. Results showed significant gains, particularly in student self-beliefs and also in content knowledge.

The project will start in Fall 2010 and conclude in 2014. In the first year of the grant, an advisory panel of statisticians, mathematicians, and educators will meet to lend their expertise and advice to the project. The project team will update existing instruments, revise college DPCM, develop early-secondary DPCM, and create a new instrument for teacher effectiveness. Pilot testing will take place Fall 2011–Spring 2013, according to the various schools' and instructors' academic schedules. Analysis of research findings and dissemination efforts will take place in 2013 and 2014. Throughout the Type II project, Phase I results will continue to be disseminated in training and outreach efforts. Thus, the project goals are as follows:

1. Promote vertical integration and wider university utility of DPCM: Adapt project guides to early secondary curricula, and make college level guides more flexible.
2. Revise quantitative instruments from Phase I and use these to analyze student outcomes.
3. Use qualitative research to explore interactions among teachers, students and discovery projects.
4. Widely disseminate improved curricular materials and quantitative/qualitative research results.

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Results from Prior NSF Support

The current proposal is for an expansion of the work performed in the NSF CCLI Phase I Grant, Award #0633264, *Authentic, Career-Based, Discovery Learning Projects in Introductory Statistics*. The NSF granted $175,756.00 to fund this project, for which work began on June 1, 2007 and is schedule to be completed May 31, 2010. The award has resulted in the following tasks and work products:

1) *Three instruments to measure student outcomes in statistics courses*
   Co-PIs Spence and Sinn developed three instruments to measure student outcomes in statistics courses. These instruments were a content knowledge instrument, an instrument to measure student perceptions of the usefulness of statistics, and an instrument to measure students' statistics self-beliefs (self-efficacy). All three instruments were validated, subjected to factor analysis, and revised appropriately prior to being used to evaluate student results in both control and treatment groups with the pilot instructors in the project. An article regarding the design, analysis, and validation of these instruments is in preparation for submission to the journal *Applied Measurement in Education* (AME).

2) *Curriculum materials to facilitate discovery learning projects in statistics*
   During the first stage of curriculum materials preparation an interdisciplinary team of instructors was assembled, representing the fields of biology, business, criminal justice, education, nursing, physical therapy, psychology, and sociology. These instructors prepared a list of current, relevant research constructs in their fields, chosen with the condition that students would be able to measure and use these constructs in relatively short-term project in the course of a semester. Instructors on the interdisciplinary team also provided validated instruments or procedures for measuring their constructs, as well as a list of potential research explorations. Phase I co-PIs Spence and Sinn then authored curriculum materials for statistics discovery projects, incorporating the input from the interdisciplinary team. The materials included an Instructor's Guide, Student Project Guide, and Student Technology Guide. Spence and Sinn submitted these guides to Freeman Publishers, who have expressed interest in publishing them, pending revisions that are now in progress. A letter of intent for publication from Freeman is provided.

3) *Pilot of curriculum materials and research data collection*
   Five pilot instructors participated (three at a 4-year college, 1 at a 2-year college, and 1 at a high school). Each pilot instructor taught one or more sections of their statistics course without using the discovery project curriculum materials that we had developed. These made up the 'control' sections of the study. Each pilot instructor then taught one or more sections of a statistics course in a subsequent semester (or year, in the case of the high school) using the discovery project materials, after a series of meetings and a brief training session. These sections were the 'treatment' sections. The three instruments described above were administered to students in both control and treatment sections to measure content knowledge, statistics self-efficacy, and perceived usefulness of statistics. The data collected were organized and entered for analysis. Some treatment sections were completed by the end of the 2008-2009 academic year; however, the last treatment sections, taught by one of the 4-year college instructors, were completed during Fall semester 2009. One of the 4-year college instructors was unable to complete the scheduled treatment sections due to health complications, leaving data collected from 4 pilot instructors.

4) *"Make It Real" Statistics Teaching Workshop*
   In January 2009, Co-PIs Spence and Sinn conducted a statistics teaching workshop, "Make It Real", which was attended by 19 high school teachers of AP Statistics. The workshop was one full day with a follow-up component online. Teachers who so desired received PLUs (continuing education credits) for their participation. Teachers were provided with curriculum materials developed by Spence and Sinn, and they were given an opportunity to experience these projects hands-on with guidance from workshop facilitators, which included Spence and Sinn, as well as four of the pilot instructors, including Brad Bailey, who is co-PI on the current Type II proposal.

5) *Ongoing dissemination of activities and findings at professional meetings and conferences*
   Teaching materials and ongoing research about their impact on student outcomes are the topic of several past and upcoming (accepted and scheduled) conference presentations, as noted below. (*Venue was a national meeting or conference. †Work is published in conference proceedings.)
   - *Mathematical Association of America (MAA) MathFest, July 2008
   - Partnership for Reform in Science and Mathematics (PRISM), Accepting the STEM Challenge Conference, September 2008
   - †Teaching Matters Regional Conference on Collegiate Teaching, April 2008
   - Georgia Council of Teachers of Mathematics (GCTM) Conference, October 2009
   - †Georgia Association for Mathematics Teacher Educators (GAMTE), October 2009
   - *Joint Meetings of the MAA and American Mathematical Society (AMS), January 2010
   - *Association for Mathematics Teacher Educators (AMTE), January 2010
   - *National Council of Teachers of Mathematics (NCTM), April 2010

6) *Quantitative analysis of data collected from pilot instructors for journal dissemination*
   A sample follows of the analyses that were conducted based on the data collected from pilot instructors, ending in December 2009. The broad univariate analyses, in conjunction with a detailed description of the teaching methods and materials themselves, provide the basis for a manuscript now in preparation for submission to the *Journal of Statistics Education* (JSE). The more detailed multivariate analyses are the basis for a manuscript currently in preparation for the *Journal of Research in Mathematics Education* (JRME). These journals have been selected for their alignment with the type of content and level of depth evident in the manuscripts now in progress. Due to page limitations in the current proposal, only a small subset of these manuscripts is provided.

Abbreviated Data Analysis Results: Partial Content of Manuscripts in Progress

The three student outcomes measured were statistics content knowledge, perceived usefulness of statistics, and statistics self-efficacy. These were measured for participating pilot instructors' control and treatment sections of elementary statistics. Treatment sections were taught using discovery project curriculum materials. Data for control and treatment groups (for all instructors combined) were first analyzed using t-tests. Similar t-tests were then conducted by instructor. Results of the t-tests are below, with these conventions: CK = Content Knowledge; PU = Perceived Usefulness; SE = Self-Efficacy.

Main Scales – Combined Groups

Instrument	Control			Treatment			*t*	*p*
	N	Mean	SD	N	Mean	SD		
CK	138	6.78	2.44	172	7.21	3.08	1.36	.088
PU	137	50.42	10.05	172	51.40	11.24	0.81	.208
SE	129	59.64	14.24	172	62.57	11.61	1.86	.032

Sub-Scales – Combined Groups

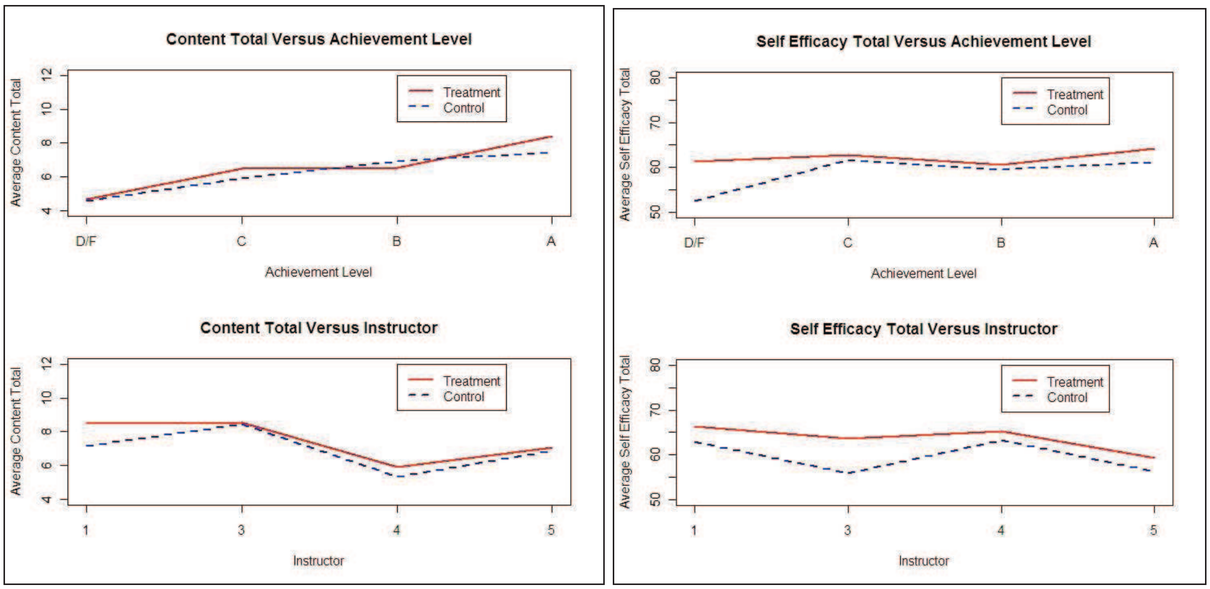
Sub-Scale	Control		Treatment		*t*	*p*
	Mean	SD	Mean	SD		
CK: Regression	1.99	1.17	2.20	1.47	1.37	.086
CK: t-Test Usage	3.21	1.52	3.46	1.84	1.30	.097
CK: t-Test Inference	1.58	.988	1.55	.951	−0.25	.425
SE: General	16.99	4.30	18.01	3.93	2.10	.018
SE: Regression	20.55	5.25	22.14	4.59	2.74	.035
SE: t-Tests	22.10	5.73	22.42	5.22	0.50	.308

Instruments and Sub-Scales by Instructor (Partial List due to Page Limit Constraints)

Scale	Instructor	Control			Treatment			*t*
		N	Mean	SD	N	Mean	SD	
CK – Entire Instrument	**1**	41	7.17	2.365	24	8.50	3.093	1.817**
	3	20	8.45	2.762	28	8.54	2.502	0.110
	4	33	5.33	1.708	44	5.93	2.546	1.233
	5	43	6.86	2.178	76	7.05	3.253	0.385
CK – t-Tests	**1**	41	3.54	1.398	24	4.33	1.949	1.756**
	3	20	4.50	1.638	28	4.93	1.464	0.934
	4	33	2.91	1.284	44	3.05	1.656	0.407
	5	43	2.58	1.314	76	2.88	1.657	1.087
PU – Entire Instrument	**1**	41	50.59	10.361	24	54.88	9.014	1.751**
	3	20	49.35	9.016	28	46.75	12.183	-0.850
	4	32	51.41	9.339	44	53.30	10.064	0.843
	5	43	50.23	10.963	76	50.92	11.722	0.321
SE – Entire Instrument	**1**	32	62.97	15.073	24	66.38	9.221	1.044
	3	20	55.95	20.289	28	63.71	12.304	1.523*
	4	33	63.21	9.512	44	65.25	9.022	0.951
	5	43	56.23	12.569	76	59.39	14.398	1.250
SE – General Statistics Concepts	**1**	32	17.94	4.272	24	19.33	3.116	1.414*
	3	20	16.45	6.057	28	18.64	3.540	1.452*
	4	33	17.39	3.316	44	18.95	2.853	2.168**
	5	43	16.26	4.042	76	16.80	4.505	0.680
SE – Linear Regression	**1**	32	21.50	5.292	24	22.71	3.520	1.024
	3	20	18.75	6.995	28	23.04	4.393	2.420**
	4	33	22.30	3.917	44	22.09	3.771	-0.239
	5	43	19.35	4.825	76	21.66	5.346	2.411**

$*p < .10$ $**p < .05$

It became clear during the preliminary data analysis that the impact of these curriculum materials and discovery projects varied a great deal by instructor. It also appeared that student outcomes varied by the student's overall achievement level in the class, as represented by the student's final grade in the course; i.e., the impact of the projects may have been different for 'A' students than for 'B' or 'C' students, and so on. The mean plots below show the control and treatment outcomes by achievement level and by instructor. Similar plots were constructed for all instruments and sub-scales. The 'D' and 'F' categories in achievement level were combined because relatively few of either grade were assigned. It is worth noting that mean content knowledge and self-efficacy were higher in the treatment groups for all 4 instructors, though the magnitude of the effect varied by instructor.



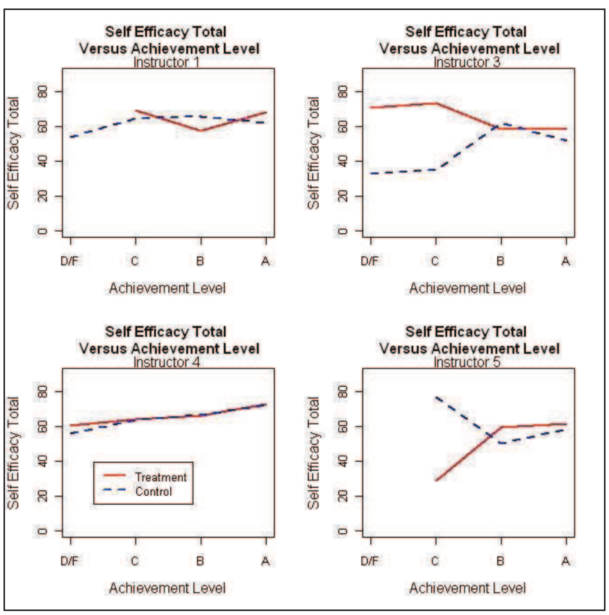
Because there were potential instructor and achievement level effects, data were then analyzed using a multivariate nested design with crossed factors. The crossed factors were instructor and treatment group (control or treatment). Then student achievement level was a nested factor within instructor × treatment. The reason for nesting achievement level within instructor and treatment was that instructors often display different standards for grading. After examining the distribution of grades for each instructor, it appeared that this was the case. Some instructors routinely gave a grade of A to only 2 or 3 students, accounting for less than 10% of the students in the section. Yet others often gave a grade of A to over one third of the students in their sections. Considering this observation combined with the fact that these grades were assigned in different academic settings (high school, 2-year college, 4-year college), it was reasonable to interpret that a given grade for one instructor did not necessarily have the same meaning as that same grade had for another instructor.

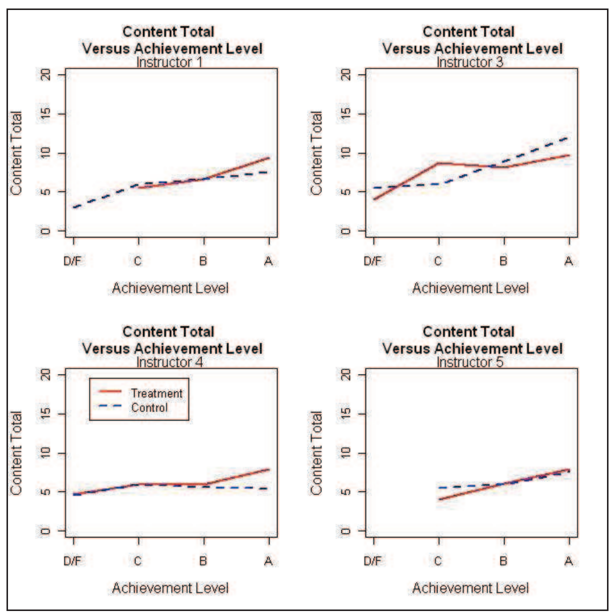
The results for the multivariate nested linear model are shown below for the three main instruments. Similar analyses were conducted for sub-scales. The results shown include statistics for the model, intercept, main effects (treatment and instructor), interaction effect (treatment × instructor), and achievement nested within the interaction.

Source	Dependent Variable	*F*	*p*
Model	Content Knowledge Self-Efficacy Perceived Usefulness	3.473 4.022 2.427	.000 .000 .000
Intercept	Content Knowledge Self-Efficacy Perceived Usefulness	707.808 2800.994 2789.110	.000 .000 .000
Treatment	Content Knowledge Self-Efficacy Perceived Usefulness	0.396 2.393 2.579	.530 .062 .109
Instructor	Content Knowledge Self-Efficacy Perceived Usefulness	3.392 7.155 1.006	.019 .000 .390
Treatment × Instructor	Content Knowledge Self-Efficacy Perceived Usefulness	0.749 7.895 3.619	.524 .000 .014
Achievement Level ***within*** Treatment × Instr	Content Knowledge Self-Efficacy Perceived Usefulness	2.420 4.122 2.676	.001 .000 .000

The overall model was significant for all three measures, as was the contribution of achievement level within the interaction of treatment × instructor. Further, the interaction of treatment × instructor was significant for self-efficacy and perceived usefulness.

For each instrument, the mean plots for control and treatment groups by achievement level are also shown for each instructor individually. Similar plots were constructed for all instruments and sub-scales.





The plots help to visualize some of the interplay between instructor, treatment, and achievement level. For example, instructors 1 and 4 had greater content knowledge gains among 'A' students than among students of other achievement levels. However, instructor 3 only saw content knowledge gains among 'C' students. Other contrasts and interactions are also evident.

In summary, the successful research and curriculum development efforts from Phase I have created a strong foundation for the proposed Type II project.

Assessment of Need: Literature Review

Development of pedagogically sound statistics instruction is essential. Increasing recognition has been given over the last decade to the importance of statistical literacy among all citizens. Statistics education has emerged as its own field, with the study of statistics highly relevant to both mathematics and science, yet distinct from each and providing a critical link between the two (Ben-Zvi & Garfield, 2008). It is also the case that the content of introductory statistics courses has changed dramatically, both because more sophisticated concepts are covered and because technological tools have helped to shift the focus from the minutiae of statistical computations to the more fundamental meaning of the statistics constructs being used (Kirk, 2007).

Researchers and educators have often suggested improvements to statistics teaching methods, especially those that focus on implementing the scientific method through authentic statistical experiences (Bryce, 2005). The consensus among many researchers is that statistics is taught most effectively with real data (Cobb & Moore, 1997). In particular, there is greater benefit to students' learning when they collect their own data rather than merely working with data already collected by others (Hogg, 1991). This finding parallels the suggestion by many researchers that statistics education should be student-centered (Roseth, Garfield, & Ben-Zvi, 2008). In short, as Roseth et al posit, "statistics instruction ought to resemble statistical practice" (p. 1).

When best-practice pedagogies have been implemented in statistics courses, the results have been positive for achievement and for improved attitudes toward statistics. For instance, students who have participated in all aspects of statistical research– collecting data, performing analyses, and communicating results– have demonstrated benefits in exam performance and in students' evaluations of the course (Smith, 1998). Further, research suggests that apprentice learning, wherein students complete real-world mathematics in authentic settings, develops better conceptual understanding and better knowledge transfer to non-mathematical and non-school settings (Boaler, 1998). Findings also suggest that statistics courses based on more constructivist models improve student attitudes toward statistics and that personal relevance is important for successful learning in statistics (Mvududu, 2003). One case study revealed that students learned more from a real-world project than from any other instructional component of a statistics course; the project also fostered an increase in student motivation (Yesilcay, 2000).

The American Statistical Association sponsored a project, the Guidelines for Assessment and Instruction in Statistics Education (GAISE), through which recommendations were developed for best practices in statistics teaching (Franklin & Garfield, 2006). These recommendations included the use of real data and the fostering of active learning. Also among the guidelines offered was the stipulation that "teachers of statistics should rely much less on lecturing, [and] much more on the alternatives such as projects" (Guidelines for Assessment and Instruction in Statistics Education [GAISE], 2005, p. 4). In agreement with this recommendation, Landrum and Smith (2007) suggest as a best practice "that students receive some 'hands-on' experience with a research project. An ideal situation would be to finish a complete project that included data collection and analysis" (p. 52). Nevertheless, although the use of projects has been increasingly recommended as a sound pedagogical practice in statistics, many instructors still do not incorporate projects into their statistics courses (Landrum & Smith).

Research also suggests that instructors in statistics courses would do well to consider variables from the affective domain as an integral—not peripheral—part of the statistical learning process. A meta-analysis of 113 mathematics education studies found a significant influence of attitude toward mathematics upon achievement in mathematics (Ma & Kishor, 1997). In a review of the literature surrounding motivation to learn mathematics, Middleton and Spanias (1999) report that careful design of instruction can strongly influence student motivation for mathematics achievement, which increases the likelihood that students will choose to take future mathematics courses. They maintain: "Students must understand that the mathematics instruction they receive is ***useful***, both in immediate terms and in preparing them to learn more in the fields of mathematics and in areas in which mathematics can be applied… Use of ill-structured real-life problem situations in which the use of mathematics facilitates uncovering important and interesting knowledge promotes this understanding" (p. 81, emphasis added). This summation reflects many goals of the current initiative, including that of promoting students' sense of the usefulness of statistics by experiencing real-world applications of statistics and its methods.

Finally, a wealth of evidence connects students' mathematics achievement with their self-beliefs in mathematics (e.g., Pajares & Schunk, 2001, 2002). Of particular interest in the current study is the construct of students' mathematics self-efficacy, or students' beliefs about their ability to carry out mathematical tasks (Pajares & Miller, 1994). Findings suggest that self-efficacy beliefs play a role in people's career choices, especially in mathematics and science related fields (e.g., Hackett, 1995; Zeldin & Pajares, 2000). Further, research suggests that mathematics self-efficacy may be as reliable as mental ability in predicting mathematics performance (Pajares & Kranzler, 1995). Well-established social-cognitive theory maintains that authentic mastery experiences exert the strongest influence on the development of one's self-efficacy beliefs (Bandura, 1997). Thus, authentic research experiences encountered in the study of statistics are expected to have a positive impact on students' statistical self-beliefs, thereby also fostering higher achievement in statistics.

Assessment of Need Based on Phase I Results

The work completed in the first phase of the current initiative has highlighted four areas in which our research needs to be continued, extended, and revised. First, the target audience of instructors and students needs to be expanded. Second, the curriculum materials should be revised and extended. Third, the instruments should be revised. Finally, a qualitative component is needed in the research design. The previously described the work in Phase I provides the foundation for these needs, as explained below.

The academic setting in Phase I was limited to three pilot instructors from a single 4-year college, one instructor from a 2-year college, and one instructor from a high school, all of which were located in Georgia. Both colleges were state schools. The classes involved at the high school level were all sections of Advanced Placement (AP) Statistics. This limited number of academic settings and limited number of instructors provided the initial motivation to expand the target audience.

The workshop conducted in Phase I was very well received, and several teachers indicated that similar projects, but smaller in scope, would be useful even for 9th and 10th grade mathematics classes. This created additional motivation for expanding the target audience. The National Council of Teachers of Mathematics (NCTM) outlines a set of curriculum standards for mathematics students in grades K – 12, which include content standards and process standards. The content standards specify standards in five strands, one of which is data analysis and probability; and the process standards specify standards in five areas, including problem solving, communication, and representation. Many states have aligned their state content standards with these national standards, including the specification of the strands in each grade level. For instance, in the southeast, Georgia and all her neighboring states have data analysis content standards for grades 9 – 12. Discovery learning materials in statistics will not only support the content standards in data analysis, but will also support the process standards by providing avenues for students to engage in mathematics tasks not readily available in traditional curricula. The materials developed in Phase I can be adapted so that a version appropriate to early secondary settings is available.

Therefore, the first need is an expanded target audience. One goal of the proposed expansion is to facilitate a nationwide implementation representing more geographically diverse collegiate settings. These settings should include private and public institutions that vary in their size, affiliations, and student demographics. Another goal of the proposed expansion is facilitate vertical integration by targeting high school classes not only for students of AP Statistics, but also for early secondary students. This vertical integration will require additional curriculum development, described below.

The second need is revision and expansion of the discovery project curriculum materials developed in Phase I. The current materials pose the two discovery projects in sequence, with linear regression first and t-tests second. Some dependencies also exist between the first and second projects as facilitated by the student and instructor guides. However, many college statistics courses are organized so that only one of these two topics is covered in a semester. Some instructors also prefer to cover these topics in a different order. In particular, pilot instructors in Phase I were required to cover linear regression first to implement the projects as written; results showed far more substantial gains for linear regression than for t-tests, possibly because by saving t-tests for last, instructors were more rushed covering that material near the end of the term. Thus, the materials could be improved by de-coupling the two projects and facilitating each one independently as a stand-alone project, thereby allowing instructors to implement either or both, and in any order. Such a revision might also allow for better measurement of the t-test project's impact, as instructors could cover either topic first. For early secondary settings, the guides should be streamlined to have a less open-ended focus and a more targeted, guided-discovery approach by offering more project structure and detail than the materials that were previously developed for AP and college students.

The third need is revision of the instruments. The content knowledge and self-efficacy instruments originally developed reflect only what students have learned about mathematical statistics concepts, but they do not reflect what students have learned about sampling, data collection, and research methodology. Pilot instructors indicated that these were areas where they saw tangible benefits to their students. Revised instruments should include these facets of students' learning, thus reflecting more fully and accurately the content knowledge and self-efficacy gains achieved from the discovery projects. Adapted versions of both instruments also need to be developed for the early secondary setting, where more narrowly focused materials will be implemented. In addition, the perceived utility instrument should be revised. The initial instrument referred to the usefulness of statistics explicitly in the context of students' future careers. Results from this instrument were mixed, possibly because many students, especially those in high school, may not yet be able to envision the details of a future career clearly enough to gauge the applicability and relevance of statistics to that career. The revised instrument will more appropriately measure students' perceptions of the usefulness of statistics in everyday life, without tying these data to the students' perceptions of their future careers. With these proposed changes to the instruments for student outcomes, we should be able to assess the impact of the discovery project curriculum materials with greater precision. Finally, an instrument needs to be developed to measure an instructor's orientation toward facilitating discovery projects in statistics. The impact of the discovery projects in Phase I varied significantly by instructor. The proposed instrument will gauge multiple aspects of the instructor's orientation, including proficiency at refining research constructs, degree of structure imposed on projects, extent and type of student advising provided, ability to operationalize student research ideas, and capacity for identifying an appropriate research design. With such an instrument, statistical analysis can be conducted to determine how the instructor's orientation is related to student outcomes, as well as which aspects of the instructor's orientation, if any, promote or constrain student achievement or attitudes. Also, if any aspects of instructor orientation are found to foster significantly better student outcomes, instructors can be made aware of these, and future instructor training can be adapted to help instructors develop these capacities and habits. Such an instrument would be of interest in mathematics education literature as well.

The fourth need is the addition of a well-defined qualitative data collection and analysis plan to the overall research design. Pilot instructors in Phase I made a number of observations about student experiences and the results of carrying out discovery projects. However, these observations added up merely to anecdotes rather than to an empirical body of knowledge about how the discovery projects played out within the complex interaction among different teachers, students, and classroom environments. Because the teachers and students possessed different styles and preferences, yielding different dynamics in each classroom, these interactions shaped the impact of the discovery projects as they were implemented. The instructor's pedagogical practices and execution of the project directly impacts student learning outcomes. Portability of the materials will also be more successful if we can formatively evaluate best practices for the implementation of the project. To gain a richer, fuller picture of what is taking place as different teachers implement these projects with their students, a qualitative research component is in order. This qualitative research may also inform revisions to the instrument proposed to measure instructor orientation for facilitating discovery projects (described above).

Project Implementation Plan

As established above, co-PIs and project personnel in the proposed effort will expand the target audience, revise the discovery project curriculum materials for both collegiate and secondary settings, revise the instrumentation for measuring student outcomes, introduce an instrument to measure instructor orientation, continue quantitative analysis of student outcomes using the new instruments, and implement a qualitative research plan to gain more insight into the ways that the discovery projects contribute to student outcomes in statistics. In support of these goals, the project plan includes the additional details below, followed by a summary of the research methodology and a timeline of the main project tasks.

Eight college instructors nationwide will pilot the revised curriculum materials. Letters of support document the intended participation of instructors from colleges in California, Massachusetts, New York, Oregon, Pennsylvania, and West Virginia. In addition, three high school instructors of AP Statistics and twenty high school instructors of early secondary mathematics will pilot the appropriate version of the revised materials. These instructors will be selected from schools in Cherokee, Dalton, Fannin, Forsyth, Gilmer, Murray, Pickens, and Whitfield Counties. Letters of intent are given by Forsyth County and by North Georgia Regional Educational Service Agency (RESA), which serves the remaining counties.

An advisory panel will convene to review curriculum materials and implementation methods, and to provide feedback and suggestions on these aspects of the project. Members have been invited to serve on the panel based on their expertise in education, statistics, mathematics education, statistics education, and K-12 curriculum. The invited members, all of whom have accepted, include Dr. Jackie Miller (Statistics Education, Ohio State University), Dr. Adam Molnar (Mathematics/Statistics, Bellarmine University), Dr. Lissa Pijanowski (K-12 Curriculum, Forsyth County Schools), Dr. Allan Rossman (Statistics, California Polytechnic State University), Dr. Julia Sharp (Statistics, Clemson University), and Dr. Ellen Usher (Education/Mathematics Education, University of Kentucky). Letters of support and intent from each panel member are included. The panel will meet once onsite at NGCSU during the first semester of the project and will convene subsequently by teleconference two or three times as needed during the first two years of the project. The panel will be organized and chaired by Dr. Karen Briggs, a pilot instructor from Phase I and senior project personnel in the proposed Type II grant.

In addition to serving on the advisory panel, Dr. Julia Sharp (Statistics, Clemson University) will serve as a statistics consultant on the grant. She will advise the co-PIs on instrumentation, validation, collection and organization of data, quantitative research design, data analysis, and interpretation. Dr. Sharp has provided a letter of intent and will have an active role for all 4 years of the proposed project.

Dr. Kenzie Cameron will serve as external evaluator for the project. Dr. Cameron is a Research Assistant Professor at Northwestern University Feinberg School of Medicine. Dr. Cameron is an experienced quantitative and qualitative researcher who has worked as lead PI and co-PI on several large NIH grant projects. Her research specialization of communication includes an extensive knowledge base for quantitative research in the social sciences and a thorough understanding of qualitative research designs. Her expertise will inform the grant project and provide an objective evaluation of progress. Dr. Cameron will prepare an evaluation report each year during the course of the project; she will also visit NGCSU concurrently with the Advisory Panel as the project is launched.

Research Methodology

The proposed project has both quantitative and qualitative research components, described below.

Quantitative Component. A quasi-experimental treatment vs. control design will be used to collect data for quantitative analysis during the testing phase beginning in 2011. While pure "experimental designs" are valued by scientists, educational settings often require different approaches, as human subjects ethical concerns require careful structuring of "treatment vs. control" designs, especially at the high school level. Therefore, instructors will teach their own "control group" sections the term prior to using the discovery project materials, with data collected to represent a baseline of their students' performance. The following academic term, they will teach their "treatment group" sections. This quasi-experimental design was developed for the Phase I effort and proved effective. The three revised instruments will be used to measure student outcomes in both control and treatment sections. Data analyses will be similar to those conducted in Phase I, including t-tests for overall difference of means, as well as multivariate analyses accounting for instructor, treatment, and student achievement level, as well as interactions between these variables (e.g., see section entitled *Results from Prior NSF Support*). In addition, when instructors use the discovery project materials to teach their treatment sections, they will be given the new instrument to measure instructor orientation toward facilitating discovery projects in statistics. Instructor scores on this instrument and its sub-scales will be analyzed for their association with the instructor's student outcomes.

Qualitative Component. The qualitative research component will address the following objectives:

1. understand variations in the instructor's implementation of the materials and the pedagogical guidance they provide to the students; and
2. describe students' cognition as they formulate ideas about real-world statistics and its usefulness.

The first objective can be qualitatively measured through interviewing, journaling, and direct classroom observation. All participating instructors will be asked to respond periodically to journal prompts regarding their pedagogical practices, experiences, and observations while implementing the discovery projects with their students. Locally, face-to-face interviews will be conducted with participating high school instructors. Telephone interviews and journaling will be the main source of data collection for out-of-state instructors. Four locally participating instructors will also be selected for multiple classroom observations. The journals, interview transcripts, and classroom observation transcripts will be coded and analyzed. The multiple data sources will allow triangulation of findings, and selected items will be coded and analyzed by multiple researchers to ensure triangulation of analysis.

The second objective will require the researchers to make judgments about cognitive shifts in the student. Qualitative analysis of students' work is essential for attaining this objective. Student participants will be given short-answer prompts to answer in writing throughout the project. At least six local high school students will also be interviewed. From the classroom observation data, the dialogue that occurs between the students and instructor will also be evaluated. The student written responses, interview transcripts, and classroom observation data will be coded and analyzed, again facilitating triangulation of findings.

Project Personnel

The co-PI's and senior project personnel include two mathematicians and five mathematics educators. Four of these seven participated in the Phase I effort. Each team member also has expertise in curriculum development, quantitative research methods, qualitative methods, or some combination of these.

Dr. Dianna Spence (PI) will serve as project coordinator, guiding the curriculum development, research, instrumentation and validation, and instructor training efforts. She will also perform all grant management processes (project log, reports, budget, etc.), continuing the function she served as co-PI during the Phase I grant. She is a quantitative researcher and mathematics educator with 16 years of teaching experience, as well as extensive project management experience acquired during 10 years in the software industry.

Dr. Brad Bailey (co-PI) will serve as director of quantitative research, including the coordination of data collection and analysis with all participating pilot instructors. He will also work with Dr. Spence to coordinate dissemination of research results. He is a mathematician with several publications. During Phase I, he was a pilot instructor and later assisted with teacher training workshops and data analysis.

Dr. Karen Briggs will organize and work with the Advisory Panel, coordinating meetings and teleconferences and ensuring appropriate flow of information between the Panel and PI team. She is a mathematician who served in the pilot test group during Phase I.

Dr. Sherry Hix will serve as director of the curriculum development portion of the grant, more deeply integrating these instructional methods into the high school curriculum. She will also assist Dr. Phipps with qualitative data collection and analysis. She is a mathematics educator with 15 years of high school teaching experience prior to joining the NGCSU faculty.

Dr. Marnie Phipps will serve as director of qualitative research. She is a mathematics educator with extensive qualitative research experience and prior experience as a mathematics curriculum coordinator.

Dr. Thomas Cooper will assist both Drs. Hix and Phipps in curriculum development and qualitative research tasks. He is a mathematics educator with a solid background in qualitative analysis.

Dr. Robb Sinn will collaborate with Dr. Spence on instrument development and with Dr. Bailey on the quantitative data analysis. He is a mathematics educator who was PI on the Phase I grant, co-developing the instrumentation and working as research coordinator; he will serve as an advisor to the PI team.

Measurable Objectives, Timeline, and Roles

Recall that the project goals are:

1. Promote vertical integration and wider university utility of Discovery Project Curriculum Materials: Adapt project guides to early secondary curricula; make college guides more flexible.
2. Revise quantitative instruments from Phase I and use these to analyze student outcomes.
3. Use qualitative research to explore interactions among teachers, students and discovery projects.
4. Widely disseminate improved curricular materials and quantitative/qualitative research results.

The proposed effort will take place over four years. The main project goals are linked with tasks and measurable objectives in the timeline below, together with the responsible project personnel.

Year 1: Academic Year 2010-2011		
Goal	***Task/Measurable Objective***	***Responsible Project Personnel***
#1	Revise collegiate instructor and student guides so that either linear regression projects or t-test projects can be done first and so that either project could be implemented stand-alone	Spence, Sinn
#1	Prior to scheduled pilot, beta test updated project designs in NGCSU statistics classes	Spence, Bailey
#1	Develop streamlined version of the Discovery Project Guides for “early high school” statistics curricula	Hix, Cooper
#2	Refine Phase I instruments measuring student gains in performance and attitudes toward statistics	Spence, Bailey, Sinn
#2	Adapt instruments for secondary setting	Hix, Cooper
#2	Develop teacher orientation instrument	Spence, Bailey, Sinn
#2	Validate all instrumentation at NGCSU (pre-pilot)	Spence, Bailey, Sinn
#2	Prepare pilot tester training	Spence, Bailey, Sinn
#3	Design teacher and student interview protocols	Phipps, Cooper

Year 2: Academic Year 2011-2012		
Goal	***Task/Measurable Objective***	***Responsible Project Personnel***
#2,4	Instrumentation journal article to disseminate analytic tools to research community	Spence, Bailey, Sinn
#2	Collect control group data from all pilot test sites ▪ 8 colleges and universities ▪ 3 high school AP Statistics classes ▪ 20 early secondary math classes	Bailey
#2	Conduct training for college pilot instructors	Spence, Bailey, Sinn
#2	Coordinate treatment groups for college instructors	Bailey, Spence
#2	Collect treatment group data from college instructors	Bailey
#3	Conduct interviews and observations in pilot instructor classrooms; code and analyze all data	Phipps, Cooper, Hix
#2	Analyze preliminary quantitative data (college sites)	Bailey, Sinn, Spence
#4	Disseminate teaching materials/methods and preliminary results at local and national conferences.	Spence, Bailey

Year 3: Academic Year 2012-2013		
Goal	***Task/Measurable Objective***	***Responsible Project Personnel***
#2	Conduct training for secondary pilot instructors	Spence, Bailey, Hix
#2	Coordinate treatment groups for secondary instructors	Bailey, Spence
#2	Collect treatment group data from secondary test sites ▪ 3 high school AP Statistics classes ▪ 20 early secondary math classes	Bailey
#3	Conduct interviews and observations in pilot instructor classrooms; code and analyze all data	Phipps, Cooper, Hix
#4	Disseminate teaching materials/methods and preliminary results at local and national conferences.	Spence, Bailey

Year 4: Academic Year 2013-2014		
Goal	***Task/Measurable Objective***	***Responsible Project Personnel***
#2	Quantitative analysis of all data collected ▪ determine overall gains in student performance and attitudes ▪ determine relationships between instructor orientation and student outcomes ▪ determine interactions among instructor, treatments, and student achievement level	Bailey, Sinn, Spence
#2, #4	Research article(s) summarizing student gains for statistics educators and mathematics educators	Bailey, Sinn, Spence
#3	Triangulate qualitative findings with quantitative results; explore impact of discovery projects for teachers and students	Phipps, Cooper, Hix, Spence
#3, #4	Publish qualitative analysis article to disseminate protocols and results to research community	Phipps, Cooper, Hix, Spence, Bailey
#4	Disseminate all findings at local and national conferences.	Spence, Bailey, Phipps, Cooper, Hix
#4	Professional development opportunity for participating secondary teachers concurrent with instructor workshops at mathematics education venues	Spence, Bailey, Sinn

Dissemination Plan

The dissemination efforts for the current project build on a successful Phase I CCLI project. WH Freeman publishers have signed a “letter of intent to publish” for the Instructor Guide and Student Guide already developed by Spence and Sinn. Further, Spence and Sinn are currently preparing research articles for submission to JSE, AME and JRME. The final drafts of the Guides and research articles will be submitted in 2010 and possibly in preparation for publication as the Type II project launches.

The dissemination for the first two years of the Type II project will focus on the research results from Phase I and the additional curriculum improvements, especially for high school classrooms. The PI’s plan to share research results at the Joint Math Meetings (JMM, New Orleans, January, 2011) and at the Joint Statistical Meetings (JSM, Miami, August 2011). Results related to curriculum and discovery learning will be shared with mathematics teachers and mathematics teacher educators at two National Council of Teachers of Mathematics regional meetings (NCTM Regionals, Atlantic City, October 2011;

Albuquerque, November 2011), the NCTM Research Presession and the NCTM Annual Meeting (Philadelphia, April 2012). Research results starting in 2013 will be analyzed for the college level pilot, so third year dissemination efforts will focus on JMM and JSM meetings. As final research results from the secondary classrooms pilot are completed at the end of Year 3, results will be shared at the Association of Mathematics Teacher Educators (AMTE) national meeting, NCTM, along with JSM and JMM. During all four years of the grant, the PI's will take advantage of inexpensive travel opportunities to local and regional meetings including the Georgia Mathematics Conference (GCTM) and the Southeast Section meetings of the MAA.

The project team will also prepare journal articles detailing work throughout the project; this includes the new and revised quantitative instruments, the qualitative research protocols, and both the qualitative and quantitative findings regarding the impact of the discovery projects on student learning and attitudes in statistics. These papers will be submitted to AME, JSM, JRME, and other appropriate journals.

WH Freeman is also interested in looking at additional materials developed for possible additional commercial publication, including updates to materials they have already published. Authors Spence and Sinn will help market the commercially published materials in conjunction with WH Freeman.

During the pilot phase, 31 teachers of statistics and their classes will utilize the Discovery Projects. Depending upon the number of sections per instructor and the respective class sizes, more than 1,000 students may be exposed to these instructional methods. Each pilot instructor will be asked to continue utilizing the methods and to share the results and methods with their entire departmental faculty.

Evaluation Plan

Dr. Kenzie Cameron of Northwestern University Feinberg School of Medicine will serve as the external evaluator. Dr. Cameron is an experienced quantitative and qualitative researcher who has worked on several large NIH grant projects as lead PI and co-PI. Cameron will visit NGCSU with the Advisory Panel at project launch. She will be responsible for working with the PI's to develop a coherent evaluation based upon the measurable objectives.

Each year one month in advance of the grant progress report due in FastLane, Dr. Cameron will submit her written report to the PI's. Dr. Cameron will have access to any and all records related to project activities. The PI's will work with the Advisory Panel, senior project personnel and Dr. Cameron to ensure that the work outlined in the proposal is completed in a timely and professional manner, and that all measurable objectives are met or exceeded.

Capacity

North Georgia College & State University is a primarily undergraduate institution with approximately 5,500 students. NGCSU's Mathematics & Computer Science Department includes mathematicians, mathematics educators and computer scientists. The two PI's plus five senior project personnel include mathematicians and mathematics educators with extensive research experience in both quantitative and qualitative methods, as well as extensive experience in curriculum development. With the addition of the Advisory Panel, Statistics Consultant, and External Evaluator, the project team is both highly qualified and well equipped to conduct a research and curriculum development project of this size and scope.

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