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Enhancing students' scientific and quantitative literacies through an inquiry-based learning project on climate change

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Abstract: Promoting sustainability and dealing with complex environmental problems like climate change demand a citizenry with considerable scientific and quantitative literacy. In particular, students in the STEM disciplines of (biophysical) science, technology, engineering, and mathematics need to develop interdisciplinary skills that help them understand the social dynamics of environmental problems and solutions. To this end, this study examines how participation in a semester-long inquiry-based learning project that involves sociological research on climate change beliefs, attitudes, and behaviors enhances the scientific and quantitative literacies of STEM students. The results suggest that participation in a sociological inquiry-based learning project helps STEM students to (a) improve their knowledge of scientific and statistical principles and processes, (b) hone their scientific research skills, and (c) gain respect for sociology specifically and social science more generally. While the inquiry-based learning project described here deals with climate change, educators can adapt it to deal with other environmental social science research topics (e.g., water use, energy conservation, food security, sustainability).

Keywords: scientific literacy, quantitative literacy, climate change, interdisciplinary learning, inquiry-based learning, survey research

I. Introduction.

Understanding the complexity of global environmental problems, such as climate change, and proposed solutions, such as sustainability, usually requires collaboration across disciplinary boundaries by a range of scholars and stakeholders who are scientifically and quantitatively literate. Within the general public, promoting sustainability and dealing with pressing environmental problems is likely to be more effective with a citizenry that is scientifically and quantitatively literate and supportive of the interdisciplinary work necessary to address and understand complex problems as well as support their solutions. All of this suggests that we need continued improvement in the education of university students, especially those in the STEM disciplines of (biophysical) science, technology, engineering, and mathematics who may apply their knowledge and skills to deal with environmental challenges in the future. Specifically, we need STEM majors who are scientifically and quantitatively literate and who are sufficiently literate in social science to collaborate with social scientists and better understand the social implications of their own technical work.

One way to achieve this is to increase the quantity and quality of experiences for university-level STEM students to conduct interdisciplinary, hands-on research on pressing environmental problems of our day. Such a strategy has an additional benefit of helping to retain strong students in the STEM disciplines—especially those from historically underrepresented groups (Alper, 1993; Uriarte et al., 2007)—since such hands-on projects increase students' interest in science and illustrate the application of science in their everyday lives (U.S. National Research Council, 2003, 2007).

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To this end, this study addresses the following question. *What is the role of social science in the education of students in the STEM disciplines? More specifically, can participation in a semester-long inquiry-based learning project that involves sociological research on climate change enhance the scientific and quantitative literacy of STEM students?* Answering these questions is increasingly important not only for dealing with the complex environmental problems and solutions mentioned above, but also in the short term for promoting interdisciplinary teaching and learning on university campuses (e.g., Chandramohan & Fallows, 2009; Klein, 2010) and amid mounting pressure to provide evidence of the value-added of a broad liberal arts curriculum (e.g., Arum & Rokso, 2011; U.S. Department of Education, 2006).

Drawing upon existing social science education research and specifically employing insights on inquiry-based learning, this study empirically examines how participating in authentic, inquiry-based sociological research about climate change beliefs, attitudes, and behaviors may improve STEM students' scientific and quantitative literacy by helping them see how basic research processes (e.g., research design principles, sampling, measurement, and statistical analyses) span different disciplines. This project was administered in a junior-level course on environmental social science in Michigan State University's Lyman Briggs College (LBC), a residential learning community for the study of science and society. Begun in 1967, LBC offers STEM students an interdisciplinary curriculum that integrates the natural sciences with the social sciences and humanities to deepen their understanding of science.

After briefly reviewing the relevant social science education research in the next section, the third section details the research design, measurement instruments, student samples, procedures, and analytical techniques employed. After describing the course and the semester-long inquiry-based learning project the students completed, the fourth section then presents the results of the quantitative analyses of pretest and posttest data. The final section discusses this study's limitations and implications, as well as the promise of similar inquiry-based learning projects on other environmental topics for preparing STEM majors to effectively work on such complex environmental problems and solutions in the future.

II. Relevant Scholarship.

With a general shift in higher education from focusing on teaching (i.e., what instructors do) to focusing on learning (i.e., what students do) (e.g., McKinney, 2008; Svinicki, 1999), faculty and administrators increasingly promote active learning in which students learn by doing something (e.g., Mohamed 2008; Pedersen, 2010) and collaborative learning in which students learn by working with their peers (e.g., Johansen, Scaff, & Hargis, 2009; Parrott & Cherry, 2011).

Social scientists have long utilized active learning strategies and techniques in their university courses. At the most general level, this includes different ways of facilitating class discussion (often of controversial topics) (e.g., Yamane, 2006). Social scientists also employ other active learning techniques such as role-playing (e.g., Teixeira-Poit, Cameron, & Schulman, 2011), task exercises (e.g., Nguyen & Trimarchi, 2010), and simulations (e.g., Steck et al., 2011). Further, social scientists often promote collaborative learning via group research projects (e.g., Longmore, Dunn, & Jarboe, 1996) and problem-based learning activities (e.g., Ross & Hurlbert, 2004).

Given the call for more education research in social science (Albers, 2008; Whitman et al., 2007), the call for more inquiry-based learning in social science (e.g., Atkinson & Hunt, 2008), and the increasing importance of social science for understanding our complex environmental problems and their solutions, my interest here is to examine the role of sociological inquiry-based learning in promoting scientific and quantitative literacy (see Rusche & Jason, 2011). Most broadly, inquiry-based learning follows an apprenticeship model whereby students perform manageable versions of authentic research with the guidance of the course instructor (Vajoczki et al., 2011). Inquiry-based learning in the STEM disciplines—especially in laboratory courses—increases students' scientific literacy (e.g., Brickman et al., 2009; Derting & Ebert-May, 2010; Handelsman et al., 2004). Social scientists utilize inquiry-based learning projects that last for a few class meetings or span the entire semester (e.g., McKinney & Busher, 2011; Raddon, Nault, & Scott, 2008).

Parallel to, and often integrated with, the promotion of inquiry-based learning is the promotion of quantitative or statistical literacy within the social science curriculum (e.g., Grawe, 2011; Lindner, 2012; Wilder, 2009). Indeed, several studies examine how the analysis of available data may increase students' quantitative literacy (e.g., Burdette & McLoughlin, 2010; Himes & Caffrey, 2003). Further, demanding that students formally present posters describing their research may help them hone their scientific communication skills (e.g., Levine-Rasky, 2009).

Since effectively dealing with the complex environmental problems and solutions of our day calls for STEM majors who are scientifically and quantitatively literate and have at least basic social science skills, this study empirically examines the effectiveness of participation in a sociological inquiry-based learning project for increasing the scientific and quantitative literacy of STEM students. Given the importance and salience of global environmental problems, the STEM students participating in this inquiry-based learning project investigated the climate change beliefs, attitudes, and behaviors of other college students.

III. Methods.

A. Research Design.

The participants in this study are juniors and seniors in Michigan State University's Lyman Briggs College who have completed similar introductory STEM courses in mathematics, chemistry, and biology as well as a freshman-level course introducing them to basic concepts, theories, and methods in the history, philosophy, and sociology of science (HPS). Some students take a year of physics in their first two years, though most of these students—especially those in the popular majors of human biology and physiology—take their physics courses as juniors or seniors. Their STEM courses have smaller enrollments, allow for greater faculty-student interaction, and involve more active and collaborative learning than do most STEM courses in MSU's College of Natural Science.

This study utilized a quasi-experimental design, which is illustrated in Figure 1. In essence, the design is a compromise between a one-group pretest-posttest design and an untreated control group design with pretest and posttest (e.g., Cook & Campbell, 1979). It is essentially a one-group pretest-posttest design with a posttest measure from an untreated control group. Briefly, pretest and posttest data were gathered from the students in the experimental group: the 27 students in my "The Natural Environment: Perceptions and Practices" course who participated in the sociological inquiry-based learning project, which is described in section 3.3). Posttest data also were gathered from a control group of 130 students in five other similar HPS courses: "Topics in History, Philosophy, and Sociology of Science," "Technology and Culture," two sections of "Topics in History of Science," and "Science Technology, and Public Policy." Limited course time and logistical reasons precluded gathering pretest measures from the control group prior to the beginning of the semester.

There is no reason to believe there is a systematic difference in the scientific and quantitative literacy of students in the experimental group (enrolled in my course) and of those in the control group (enrolled in one of the five similar HPS courses). All of these 157 students signed up for their courses approximately nine months earlier, well before this education research project was designed. Prior to the first day of classes, none of the students in the experimental group knew they would take part in the inquiry-based learning project. Also, because the LBC curriculum is quite constrained, most LBC students have taken similar STEM classes at similar times over their academic career. Enrollment in all six courses varied between 27 and 31; all six courses had similar workloads in terms of weekly readings, classroom activities, graded essay exams, etc. An examination of the pretest measures for the experimental group and the posttest measures for the control group reveals that students in both groups had the same level of sophistication in their perceptions of science (not reported here). Though, the

	Pre-Test	Intervention	Post-Test
Experimental Group 27 students in "The Natural Environment: Perceptions and Practices" who participated in the sociological inquiry-based learning project	O_1	X	O_2
Control Group 130 students in five courses: "Topics in History, Philosophy, and Sociology of Science," "Technology and Culture," two sections of "Topics in History of Science," and "Science Technology, and Public Policy"			O_2

Figure 1. The Quasi-Experimental Design of the Study.

students in the experimental group seemed to have a slightly stronger belief that statistics will help them understand science than did those in the control group. Finally, the students in the experimental group began the semester with a relatively high level of confidence in their ability to understand science and statistics.

The pretest and posttest surveys contained groups of items measuring perceptions of scientific principles, attitudes toward the social sciences and statistics, self-assessment of scientific and statistical skills, and assessed knowledge of scientific and statistical processes. The surveys were identical with one major exception. The wording or numbers in the items used to measure scientific and quantitative literacy were changed slightly so the students in the experimental group had to make new calculations or judgments to select the correct answer on the posttest survey (rather than merely responding with their answer from the pretest survey).

The pretest survey was administered online to the experimental group prior to the first day of class. The students were asked not to use any resources (e.g., books, the internet, friends, etc.) when completing the pretest survey. Examination of the responses on the pretest survey (and comparison of these with their responses on the posttest survey) strongly suggests that experimental group students answered the questions on this survey with no assistance. At any rate, had some students used resources to answer the questions (while being prohibited from using such resources on the in-class posttest survey), this would have made it more difficult to find that participation in the inquiry-based learning project influenced their scientific or quantitative literacy. The posttest survey was then administered to both the experimental group and the control group via written questionnaire during class time in the 12th week of the semester. Timing and logistical pressures prevented administration of the posttest survey at the end of the semester. This earlier administration of the posttest survey likely leads to an underestimation of the effects of participation in the inquiry-based learning project on the knowledge, skills, and attitudes indicators described below.

B. Variables and Analyses.

Table 1 lists the names, coding, means, and standard deviations of the variables used in this study. Three types of outcome variables were examined: knowledge, skills, and attitudes. Four of these variables are composite indexes, and three are single item measures. Nine items were used to create the "variables and statistical knowledge index" (Cronbach's Alpha=.50), which measures how much knowledge students have regarding basic scientific and statistical principles and processes. Briefly, the items ask students to distinguish independent from dependent variables, evaluate sampling procedures, distinguish inductive from deductive logic, distinguish quantitative measures from qualitative measures, identify univariate statistics, interpret a correlation coefficient, and predict and interpret an R-squared value. Correct answers to the items were coded as 1 and all other responses as 0, so the resulting index ranges from 0 to 9.

The three skills variables asked students to either assess or rate their confidence in various scientific and statistical skills. The "interdisciplinary research skills self-assessment" variable is a single item that measures how much students agree or disagree with the following statement: "I have the skills to participate in a research project that integrates social science and natural science." The responses on this item range from 1 ("strongly disagree") to 5 ("strongly agree"). Six items were used to create the "scientific and statistical skills self-assessment index" (Alpha=.84), which measures how much weaker (1="mine is much weaker") or stronger (5="mine is much stronger") students believe their following skills are compared to other LBC students: understanding scientific methods; designing a scientific study; gathering scientific data; analyzing scientific data; performing statistical analyses; and interpreting the results of statistical analyses. This index ranges from 6 ("mine is much weaker" for 6 items) to 30 ("mine is much stronger" for 6 items). Also, Two items were used to create the "confidence in scientific/statistical skills index" (Alpha=.40), which measures how much students disagree (1="strongly disagree") or agree (5="strongly agree") with the following statements: "I feel confident in my ability to understand science" and "I feel confident in my ability to understand statistics."

The three attitudinal variables asked students about their thoughts regarding sociology specifically, social science generally, and statistics. The "perception of how scientific sociology is" variable is from a group of items that asked students to assess how scientific a range of ten endeavors are. These included core natural science fields such as physics and chemistry, core social science fields such as sociology, quasi-scientific fields such as medicine, and non-scientific fields such as astrology. The responses on this item range from 1 ("not at all scientific") to 5 ("completely scientific"). Three items were used to create the "favorable attitudes toward social science index" (Alpha=.64), which measures how much students disagree (1="strongly disagree") or agree (5="strongly agree") with the following statements: "Understanding the social sciences is crucial to my education," "I understand how the social sciences are related to the natural sciences," and "LBC students should receive more education in the social sciences." The resulting index ranges from 3 to 15. Finally, the "knowing statistics helps to understand science" variable is a single item that measures how much students disagree (1="strongly disagree") or agree (5="strongly agree") with the following statement: "I believe that learning statistics will help me better understand science."

In some of the statistical analyses described below, a key predictor variable and five control variables were also utilized. The key predictor variable is membership in the experimental group, coded 1 for "yes" and 0 for "no." Gender is coded 0 for male and 1 for female. Class standing ranges from 1 ("freshman) to 4 ("senior"), and cumulative GPA ranges from 1 ("less than 2.50") to 7 ("3.76 to 4.00"). A dummy variable named "completed college statistics course" measures whether students have completed (1) or have not completed (0) a junior-level statistics course for STEM majors. Finally, an Honors College membership dummy variable distinguishes those students who are members of the MSU's Honors College (1) from those students who are not members (0).

The analyses were conducted in two stages. In the first stage, paired-samples t-tests were used to analyze change on the seven knowledge, skills, and attitudes indicators across the experimental group's pretest and posttest responses. Finding statistically significant changes on these variables is reasonable evidence that participation in the sociological inquiry-based learning project had an effect. But, as an additional check in the second stage, several multivariate OLS regression models were then run to analyze variation in posttest values for students in the experimental group or in the control group. The results of analyses in this second stage provide greater confidence that whatever changes identified in the first stage were due to participation in the inquiry-based learning project and not simply a result of maturation or general education outside of the classroom over the course of the semester.

Table 1. Descriptive Statistics for Variables in the Study.

Variable	Coding	Mean	SD
Knowledge			
variables and statistics knowledge index	0 (9 incorrect answers) to 9 (9 correct answers)	4.50	1.94
Skills			
interdisciplinary research skills self-assessment	1 (strongly disagree) to 5 (strongly agree: “I have skills to participate in a research project that integrates social and natural science”)	3.77	.88
scientific/statistical skills self-assessment index	6 (“mine is much weaker” for 6 questions) to 30 (“mine is much stronger” for 6 questions)	20.04	3.75
confidence in scientific/ statistical skills index	2 (“strongly disagree” for 2 questions) to 10 (“strong agree” for 2 questions)	8.22	1.34
Attitudes			
perception of how scientific sociology is	1 (not at all scientific) to 5 (completely scientific)	3.12	.90
favorable attitudes toward social science index	3 (“strongly disagree” for 3 questions) to 15 (“strongly agree” for 3 questions)	11.24	2.38
knowing statistics helps to understand science	1 (strongly disagree) to 5 (strongly agree: “I believe that learning statistics will help me better understand science”)	4.01	.93
Key Predictor			
experimental group	0 (not in my course) to 1 (in my course)	.17	.38
Controls			
gender (female)	0 (male) to 1 (female)	.48	.50
class standing	1 (freshman) to 4 (senior)	3.37	.67
cumulative GPA	1 (less than 2.50) to 7 (3.76 to 4.00)	5.38	1.41
completed college statistics course	0 (not yet taken/completed) to 1 (have completed)	.46	.50
Honors College membership	0 (no) to 1 (yes)	.27	.44

The means and standard deviations for these variables are for the posttest survey data (N=157).

C. The Inquiry-Based Learning Project.

The 27 experimental group students were enrolled in my environmental social science course titled "The Natural Environment: Perceptions and Practices." This is a discussion-based HPS course on Americans' values, beliefs, attitudes, and behaviors regarding the biophysical environment. Like the other HPS courses in Lyman Briggs College, this popular course is offered each semester and is regularly fully enrolled. During the semester in question, this HPS course focused specifically on the topic of climate change.

Throughout the semester, the students in this course read and discussed works on the social causes and effects of climate change and on the dynamics of climate change public opinion, media coverage, and politics. They also participated in a sociological inquiry-based learning project that asked them to investigate climate change public opinion at MSU. As a part of a collaborative team consisting of four or five students, they worked to answer an intriguing research question about the climate change attitudes, beliefs, and behaviors of students in MSU's three residential colleges. On the first day of class, the students were given the handout displayed in Table 2, which laid out in approximate chronological order the tasks that students would complete individually, in their teams, and as a class throughout the semester as part of the inquiry-based learning project.

In the first two weeks of the semester, the students explored their personal interests in climate change public opinion and quickly formed collaborative teams with like-minded peers to create a unique research question. The research questions for the six collaborative teams are displayed in Table 3. Between weeks three and five, the teams wrote and revised survey questions and made decisions about the overall structure and design of the survey. Between the sixth week and tenth week of the semester, we administered the survey online. Giving the respondents approximately four full weeks to respond allowed the students to achieve a sample size of 428 completed surveys. In the eleventh week of the semester, the students were led through a brief tutorial in basic univariate, bivariate, and multivariate statistics and in the SPSS software the students were using on their laptops in the classroom. During weeks twelve and thirteen, the teams analyzed their data and interpreted the results of their analyses. During weeks fourteen and fifteen, the teams prepared and revised their own research posters and reviewed the research posters of other teams. Finally, in the sixteenth week of the semester, the teams presented their research posters at the LBC Research Symposium.

At the beginning of the semester, I performed a more managerial role vis-à-vis the project; as the semester went on, I shifted to perform a more advisory role. Since these STEM students were going to do sociological research on a topic for which they had little expertise (i.e., climate change public opinion), I began the semester with an analogy that I was like the head of a climate change public opinion research group and they were its members who would carry out the actual work. I guided them toward manageable research questions and helped them as they struggled with the first draft of their survey items. Once the students became more proficient with the measurement of their concepts though, I transitioned to more of a consultant, giving advice and suggestions about the wording and ordering of survey questions as I do in any paid or pro bono consultancy. Thus, the students came to exercise a great deal of responsibility—tempered by my guidance and advice—for the creation of the entire survey, its administration, and the eventual analysis of their data.

IV. Results.

Table 4 presents the results of the paired-sample difference-of-means t-tests within the experimental group to assess change in knowledge, skills, and attitudes over time between the pretest survey and the posttest survey. Compared to just prior to the start of the semester, students in the twelfth week of the inquiry-based learning project had greater knowledge of scientific principles and basic statistics—as seen in the values in the first row of the table. In other words, students' knowledge of scientific and statistical principles and processes significantly improved. Of the nine knowledge items, they went from answering approximately

Table 2. (Roughly) Chronological List of Tasks for Our Inquiry-Based Learning Project.

Keep the following conditions in mind as you read the list of tasks below:
- Each team's research question must deal with individuals' values, perceptions, beliefs, policy preferences, and/or behaviors with regard to climate change.
- We will create and administer an online survey via surveymonkey.com to students in Michigan State University's three residential colleges.
- We will analyze our survey data with SPSS statistical software.
- Each team will create a formal research poster to display the results of its analyses.

Those tasks you will do individually are identified with an "I," those you will do in your research team are marked with a "T," and those we will do together as a class are marked with a "C."

<u>Project Preparation and Research Proposal Tasks</u>

Explore your personal interest in one or more climate change topics (I)
Join a research team with a shared interest in an important climate change topic (I)
Create a compelling research question that your team will answer with data from our online survey (T)
Write up a brief research proposal as a team (T)

<u>Survey Construction Tasks</u>

Write the necessary survey questions you think should be included in the survey for you to have data to answer your team's research question (I, T)
Examine our pooled survey questions (C)
- Look for redundancies or contradictions
- Look for logical groups of similar survey questions
- Think about the logical ordering of the survey questions within a section
- Think about the logical ordering of the sections of survey questions

Create multiple revisions of our lists of pooled survey questions until we finalize the list of selected survey questions, the wording of these survey questions, and the ordering of these questions (C)
Write all the necessary directions for individual questions and sections of questions (C)
Write a brief introductory paragraph introducing the survey (C)
Pre-test the final version of the survey after it is posted online (I, C)
Create our numerical coding scheme (C)

<u>Survey Administration Tasks</u>

Gain permission from each residential college to use its e-mail distribution list (C)
Write all e-mail correspondences with our potential respondents: pre-notice e-mail; cover letter e-mail; first follow-up e-mail; second follow-up e-mail (C)
Identify ways to advertise our survey to increase our response rate: mailbox flyers; word of mouth; Facebook; classroom visits; student groups; etc. (C)

<u>Data Analysis Tasks</u>

Become familiar with some basis statistical analyses and our SPSS software (I, C)
Identify what survey questions your team will be working with for your research question (I, T)
Determine the expected relationships between your team's variables (I, T)
Run the appropriate statistical analyses to examine these relationships (I, T)
Work on interpreting the results of these statistical analyses (I, T)
Write a draft of your team's research poster (I, T)
Peer review another team's research poster (I, T)
Finalize your team's research poster (I, T)
Present your team's research poster at the Lyman Briggs College Research Symposium (T)

Table 3. The Research Questions of the Six Collaborative Teams.

Are men or women more likely to take climate change actions? Are there gender differences in the type of action, public or private, taken regarding climate change?
Does the amount of university-level science training influence knowledge of climate change health effects?
How does one's residential college influence one's view on climate change and health-related behaviors?
How does academic major influence perception of climate change?
Does one's preferred media source for climate change information influence one's understanding of and concern for climate change?
How do students' political views, both party affiliation and ideology, affect their perceptions of the economic and environmental risks associated with climate change?

four items correctly before the semester to answering slightly more than six items correctly about three-quarters of the way through the semester. The students seemed to be on the verge of becoming proficient in their statistical analyses at that point of the semester, so later administration of the posttest survey likely would have revealed an even greater increase in their knowledge scores.

The middle section of Table 4 shows that students in the experimental group assessed their interdisciplinary research skills and their general scientific and statistical skills as significantly stronger in the twelfth week of the semester than just prior to the start of the semester. Yet, their self-reported confidence in their scientific and statistical skills did not change over time. The lack of change in the latter is at least partially due to a ceiling effect whereby experimental group students rated their confidence in their scientific and statistical skills as quite high on the pretest survey. The bottom section of Table 4 shows that students in the experimental group developed more favorable attitudes toward sociology and social science more generally, but participating in the sociological inquiry-based learning project did not affect their belief about the importance of knowing statistics for understanding science. Again, the average pretest response on the latter item suggests that there is a ceiling effect in play.

On their own, the results in Table 4 suggest that participation in the sociological inquiry-based learning project had a positive effect on students' scientific and statistical knowledge, skills, and attitudes (see, e.g., Burdette & McLoughlin, 2010; Himes & Caffrey, 2003). Yet, it might be that students' scores on these knowledge, skills, and attitudes measures generally increase over the course of the semester regardless of what class they are in and/or whether or not they participated in the sociological inquiry-based learning project. After all, this could occur as a result of maturation or general education outside of the classroom. Comparing the posttest survey responses of the students in the experimental group to those of similar students in similar courses (the control group) will allow us to determine with greater confidence if the significant changes in knowledge, skills, and attitudes in Table 4 are due to participation in the sociological inquiry-based learning project.

Table 5 reports the results of seven multivariate OLS regression models that examine variation in posttest values for students in either the experimental group (N=27) or in the control group (N=130). The entries are standardized coefficients to more easily compare the effects of the predictor and control variables. The key predictor variable is the dummy variable for experimental group membership. Each of the seven models displayed in Table 5 examine the effect of participating in the sociological inquiry-based learning project while controlling for the effects of gender, class standing, cumulative GPA, completion of a college-level statistics course, and Honors College membership.

According to the first model in Table 5, students in the experimental group had higher scores on the science and statistical knowledge index than did students in the control group. Combining this with the results in Table 4, it is reasonable to conclude that participation in the sociological inquiry-based learning project improved students' knowledge of scientific and

Table 4. Results of Paired-Sample T-Tests for Pretest/Posttest Differences on Knowledge, Skills, and Attitudes Indicators (N=27).

Indicators	Pretest		Posttest		T Statistic
	Mean	**SD**	**Mean**	**SD**	
Knowledge					
Variables and Statistical Knowledge Index	3.96	1.48	6.37	1.82	6.24***
Skills					
Interdisciplinary Research Skills Self-Assessment	3.89	.75	4.37	.63	3.32**
Scientific/Statistical Skills Self-Assessment Index	20.67	3.58	22.30	3.58	2.36*
Confidence in Scientific/Statistical Skills Index	8.81	1.08	8.70	1.20	-.41
Attitudes					
Perception of How Scientific Sociology Is	2.93	.96	3.59	.69	3.34**
Favorable Attitudes Toward Social Science Index	10.59	2.14	12.30	1.56	3.82**
Knowing Statistics Helps to Understand Science	4.15	.77	4.26	.66	.68

* p<.05 ** p<.01 *** p<.001

statistical principles and processes. That is, the increase in this knowledge within the experimental group between the pretest before the semester started and the posttest in the twelfth week of the semester led these students' posttest knowledge scores to be significantly greater than those for the control group students. As one might expect, students in the Honors College also scored higher on scientific and statistical knowledge than did their non-Honors College counterparts, but there was no correlation between this knowledge and students' class standing, cumulative GPA, or experience with a college statistics course. Also, male students had slightly higher knowledge scores than did female students.

The next three columns in Table 5 deal with the three skills indicators. Students in the experimental group had higher posttest values on these three indicators than did students in the control group. Recall that the results in Table 4 showed that participation in the inquiry-based learning project seemed to have a positive effect on the experimental group students' assessment of their interdisciplinary research skills and of their scientific and statistical skills but no effect on their confidence in their scientific and statistical skills. The results in Table 5 mean that it is reasonable to conclude that participation in the sociological inquiry-based learning project improved the experimental group students' assessment of their interdisciplinary research, scientific, and statistical skills. The statistically significant positive coefficient on experimental group membership in the fourth model in Table 5 merely reflects the fact that experimental group students were more confident in their scientific and statistical skills in general than were control group students.

Class standing, cumulative GPA, and Honors College membership had no effect on any of the skills indicators. Those students who had completed a college-level statistics course assessed their scientific and statistical skills as weaker than those of other LBC students and expressed lower confidence in these same skills as compared to those students who had not completed a college-level statistics course. Also, male students assessed their scientific and statistical skills as stronger than those of other LBC students and expressed greater confidence in these same skills as compared to female students. This latter finding is consistent with much sociology of science scholarship on the gendered pattern of skills self-assessment and confidence among university students (e.g., Committee on Science, Engineering, and Public Policy, 2007; Etkowitz, Kemelgor, & Uzzi, 2000).

Finally, the last three columns in Table 5 deal with the three attitudes indicators. Students in the experimental group had higher posttest values on these three indicators than did students in the control group. The results in Table 4 suggest that participation in the inquiry-based learning project had a positive effect on experimental group students' perception of how scientific sociology is and their favorable attitudes toward social science but no effect on their belief that knowing statistics helps them to understand science. The results in Table 5 mean that it is reasonable to conclude that participation in the sociological inquiry-based learning project improved students' attitudes toward sociology specifically and social science in general. The statistically significant positive coefficient on experimental group membership in the fourth model in Table 5 merely reflects the fact that experimental group students were slightly more likely to believe that knowing statistics helps them to understand science than were control group students.

As with the skills indicators, class standing, cumulative GPA, and Honors College membership had no effect on any of the attitudes indicators. Those students who had completed a college-level statistics course had less favorable attitudes toward social science and were less likely to believe that knowing statistics helps them to understand science compared to those students who had not completed a college-level statistics course. Also, male students perceived sociology to be more scientific than did female students, and the former were more likely to believe that knowing statistics helps them to understand science than were the latter.

Table 5. Standardized Coefficients from OLS Regression Models Predicting Knowledge, Skills, and Attitudes Indicators (N=157).

	Knowledge	**Skills**			**Attitudes**		
Independent Variables	**Variables and Statistical Knowledge Index**	**Interdisciplinary Research Skills Self-Assessment**	**Scientific and Statistical Skills Self-Assessment Index**	**Confidence in Scientific and Statistical Skills Index**	**Perception of How Scientific Sociology Is**	**Favorable Attitudes Toward Social Science Index**	**Knowing Statistics Helps to Understand Science**
experimental group	.51***	.34***	.33***	.22**	.34***	.22**	.17*
gender (female)	-.16*	-.10	-.35***	-.28***	-.22**	.01	-.18*
class standing	.02	-.03	.01	-.09	.06	.05	.01
cumulative GPA	.06	.04	.15	.17	-.13	.02	-.01
completed college statistics course	-.13	-.07	-.15*	-.17*	.13	-.16*	-.17*
Honors College membership	.21***	.06	-.01	-.05	-.01	.07	.12
adjusted R^2	.26	.08	.19	.11	.18	.04	.04

* p<.05 ** p<.01 *** p<.001

V. Discussion.

To briefly recap, the results presented above suggest that participation in a sociological inquiry-based learning project helped STEM students to (a) improve their knowledge of scientific and statistical principles and processes, (b) hone their scientific research skills (if we assume that their self-assessment of these skills correlates with an objective assessment of these skills), and (c) gain respect for sociology specifically and social science more generally. More studies of this nature should be conducted to determine the robustness of these findings. The results of such studies may find that participation in such a sociological inquiry-based learning project may help students improve their scientific knowledge and quantitative skills and shift their attitudes to (a) get more out of interdisciplinary undergraduate majors and minors; (b) secure a position in an interdisciplinary internship or research team; or (c) get into an interdisciplinary graduate or professional program.

Several limitations of this current study demand attention, suggest that these results should be treated with caution, and provide avenues for future research. First, this study employed a quasi-experimental design largely because of the structural impediments to randomly sorting students into different courses and the logistical difficulties of gathering data from students in other instructors' courses at multiple points in a semester. Yet, significant planning in certain curricular settings may allow for a truly randomized experimental design to more effectively determine the influence of participation in such an inquiry-based learning project. Second, this study utilized imperfect measures of scientific process skills and quantitative literacy. Better measures do exist in the literature and, with revision and shortening, may be employed in future studies of this type. Third, this study only examined the immediate impacts of participating in an inquiry-based learning project. While significant short-term impacts on scientific and quantitative literacy were found, such impacts may not endure over a longer time frame. Thus, future research should aim to follow up with participants in the weeks and months after the semester.

Despite these limitations, this study does suggest that such an inquiry-based learning project may be fruitful for cultivating the scientific and quantitative literacies and social science skills necessary for STEM students to effectively deal with complex environmental problems and solutions. Thus, other educators may utilize projects similar to one described here to help their students gain hands-on experience doing research on a wide range of environmental topics. Further, this study provides an effective model for integrating sociology (and social science more generally) into a STEM curriculum. This is important for two reasons: the increasing workforce demands for university graduates with STEM degrees and the shifting priorities within the country's federal scientific funding bodies. This paper concludes by elaborating on these two reasons.

University officials, prospective employers, and public policy-makers expect that university graduates with STEM degrees have a wide range of personal and social skills and interdisciplinary and international experiences upon graduation to compete effectively in the increasingly global 21st century workforce (U.S. National Research Council, 2009). Interdisciplinary undergraduate programs are emerging across the nation, but far too many undergraduates seeking interdisciplinary experiences still struggle to find them. Many students seek out such experiences on an individualized, ad hoc basis—through a specific internship or a specific research opportunity, such as an NSF-funded Research Experience for Undergraduates. Systematizing or formalizing our interdisciplinary research opportunities—with one example being the inquiry-based learning project described here—may allow groups of students to share common experiences and thus further benefit through collaborative learning.

Within the U.S. scientific community, there is an increasing premium on interdisciplinary scholarship in recent years. For instance, the NSF includes several interdisciplinary programs (e.g., Cyber-enabled Discovery and Innovation; Dynamics of Coupled Natural Human Systems), competitions for centers that formalize interdisciplinary research teams (e.g., Science of Learning Centers; Science and Technology Centers), and programs that support students (e.g., Integrative Graduate Education and Research Traineeship Program). Many of these initiatives and opportunities at the NSF and beyond (e.g., National Institutes of Health; National Oceanic and Atmospheric Administration; National Aeronautics and Space Administration) not only support scholarship that spans multiple disciplines in the natural sciences but also scholarship that spans the much wider cultural divide between the natural sciences and the social sciences. Indeed, compared to decades past, the future of scientific opportunities for interdisciplinary scholarship looks quite bright, with increased funding opportunities, publication outlets, conferences, and graduate programs. Thus, we also should be improving the quality and quantity of our interdisciplinary educational opportunities for undergraduate STEM and social science majors. The type of inquiry-based learning project described in this study may be one fruitful avenue in this regard.

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References

Albers, C. (2008). Improving pedagogy through action learning and scholarship of teaching and learning. *Teaching Sociology*, *36*, 79-86.

Alper, J. (1993). The pipeline is leaking women all the way along. *Science, 260*, 409-411.

American Association of University Women. (1992). *How Schools Shortchange Girls*. Washington, DC: AAUW.

Arum, R., & Roksa, J. (2011). *Academically Adrift*. Chicago: University of Chicago Press.

Atkinson, M.P., & Hunt, A.N. (2008). Inquiry-guided learning in sociology. *Teaching Sociology, 36*, 1-7.

Brickman, P., Gormally, C., Armstrong, N., & Hallar, B. (2011). Effects of inquiry-based learning on students' science literacy skills and confidence. *International Journal for the Scholarship of Teaching and Learning*, *3*(2), 1-22.

Burdette, A.M., & McLoughlin, K. (2010). Using census data in the classroom to increase quantitative literacy and promote critical sociological thinking. *Teaching Sociology*, *38,* 247-257.

Chandramohan, B., & Fallows, S.J. (Eds.). (2009). *Interdisciplinary Learning and Teaching in Higher Education*. London: Routledge.

Committee on Science, Engineering, and Public Policy. (2007). *Beyond Bias and Barriers*. Washington, DC: National Academy Press.

Cook, T.D., & Campbell, D.T. (1979). *Quasi-experimentation*. Chicago: Rand McNally.

Derting, T.L., & Ebert-May, D. (2010). Learner-centered inquiry in undergraduate biology. *CBE Life Science Education*, *9,* 462-472.

Etkowitz, H., Kemelgor, C., & Uzzi, B. (2000). *Athena Unbound*. New York: Cambridge University Press.

Garkovich, L. (1982). A proposal for building interdisciplinary bridges. *Teaching Sociology*, 9, 151-168.

Grawe, N.D. (2011). The potential for teaching quantitative reasoning across the curriculum. *International Journal for the Scholarship of Teaching and Learning*, *5*(1), 1-12.

Handelsman, J., Ebert-May, D., Beichner, R., Burns, P., Chang, A., DeHaan, R., Gentile, J., Lauffer, S., Stewart, J., Tilghman, S.M., & Wood, W.B. (2004). Scientific teaching. *Science*, *304*, 521-522.

Himes, C.L., & Caffrey, C. (2003). Linking social gerontology with quantitative skills. *Teaching Sociology*, *31*, 85-94.

Johansen, D., Scaff, C., & Hargis, J. (2009). Interdisciplinary project-based model for enhanced instruction of courses. *International Journal for the Scholarship of Teaching and Learning*, *3*(1), 1-14.

Klein, J.T. (2010). *Creating Interdisciplinary Campus Cultures: A Model for Strength and Sustainability*. San Francisco: Jossey-Bass.

Levine-Rasky, C. (2009). The public poster session. *Teaching Sociology*, *37*, 309-316.

Lindner, A.M. (2012). Teaching quantitative literacy through a regression analysis of exam performance. *Teaching Sociology*, *40,* 50-59.

Longmore, M.A., Dunn, D., & Jarboe, G.R. (1996). Learning by doing. *Teaching Sociology*, *24,* 84-91.

McKinney, K. (2008). Correlates of success in the sociology major. *International Journal for the Scholarship of Teaching and Learning*, *2*(1), 1-14.

McKinney, K., & Busher, M. (2011). The sociology research experience capstone course at three institutions. *Teaching Sociology*, *39*, 290-302.

Mohamed, A.R. (2008). Effects of active learning variants on student performance and learning perceptions. *International Journal for the Scholarship of Teaching and Learning*, *2*(2), 1-15.

Nguyen, T., & Trimarchi, A. (2010). Active learning in introductory economics: do MyEconLab and Aplia make any difference? *International Journal for the Scholarship of Teaching and Learning*, 4.1, 1-18.

Parrott, H.M., & Cherry, E. (2011). Using structured reading groups to facilitate deep learning. *Teaching Sociology*, *39*, 354-370.

Pedersen, D.E. (2010). Active and collaborative learning in an undergraduate sociological theory course. *Teaching Sociology*, *38*, 197-206.

Raddon, M., Nault, C., & Scott, A. (2008). Integrating the complete research project into a large qualitative methods course. *Teaching Sociology*, *36*, 141-149.

Ross, S.M., & Hurlbert, J.M. (2004). Problem-based learning. *Teaching Sociology*, *32*, 79-93.

Rusche, S.N., & Jason, K. (2011). You have to absorb yourself in it. *Teaching Sociology*, *39,* 338-353.

Steck, L.W., Engler, J.N., Ligon, M., Druen, P.B., & Cosgrove, E. (2011). Doing poverty. *Teaching Sociology*, *39,* 259-273.

Svinicki, M.D. (1999). New directions in learning and motivation. *New Directions for Teaching and Learning*, *80,* 5-27.

Teixeira-Poit, S.M., Cameron, A.E., & Schulman, M.D. (2011). Experiential learning and research ethics. *Teaching Sociology, 39,* 244-258.

U.S. Department of Education. (2006). *A test of leadership: A report of the Commission appointed by Secretary of Education Margaret Spellings*. Washington, DC: U.S. Department of Education.

U.S. National Research Council. (2003). *BIO2010*. Washington, DC: National Academies Press.

U.S. National Research Council. (2007). *Rising above the gathering storm*. Washington, DC: National Academies Press.

U.S. National Research Council. (2009). *Transforming agricultural education for a changing world*. Committee on a Leadership Summit to Effect Change in Teaching and Learning; Board on Agriculture and Natural Resources. Washington, DC: National Academies Press.

Uriarte, M., Ewing, H.A., Eviner, V.T., & Weathers, K.C. (2007). Constructing a broader and more inclusive value system in science. *BioScience, 57,* 71-78.

Vajoczki, S., Watt, S., Vine, M.M., & Liao, X. (2011). Inquiry learning: Level, discipline, class size, what matters? *International Journal for the Scholarship of Teaching and Learning, 5*(1), 1-11.

Whitman, P.D., Richlin, L., Arboleda, A., Garrett, N.D., Robinson, E., Viale, D., Seward, E., Biseda, M., Alexander, J., Andrade-Lopez, E., Brooks, A., Carter, L., Ha, A.O., Owens, R., Thompson-Eggersten, K.A., & Vercoe, M.J.H. (2007). The status of the scholarship of teaching and learning in the disciplines. *International Journal for the Scholarship of Teaching and Learning*, 1.1, 1-17.

Wilder, E.I. (2009). Responding to the quantitative literacy gap among students in sociology courses. *Teaching Sociology*, *37,* 151-170.

Yamane, D. (2006). Course preparation assignments. *Teaching Sociology, 34,* 236-248.