Teaching the Theory of Island Biogeography as an on-campus field laboratory

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Abstract: Numerous studies have demonstrated that students perform better and have increased learning outcomes in courses that promote active learning by means of inquiry-based activities and research experiences. One complication for subjects such as the Earth Sciences and Ecology is that central theoretical tenants of these disciplines are field-based. Typical educational inquiries into these concepts use existing or simulated data to illustrate patterns and processes. As a result, students acquire a superficial understanding of the systems being taught. We propose to test whether student learning outcomes are improved if an inquiry-based field exercise and research project are used to teach the Theory of Island Biogeography compared to the use of simulated data in class. This project will be implemented in two courses in the Department of Geography and Earth Sciences: Biogeography and Landscape Ecology. We will compare student learning outcomes using our new methodology to student learning outcomes from a previous semester of Biogeography to assess whether our field-based inquiry method outperforms a traditional lecture and the use of simulated data. Student learning outcomes will be assessed through course pre- and post-tests, multiple-choice and essay questions on traditional exams, and a research paper. An increase in learning outcomes due to our new methodology would provide valuable data for field-based disciplines being taught at UNC Charlotte and elsewhere on how to best design exercises in upper division courses.

Budget Request for SOTL Grant

Year 2013

Joint Proposal?	____ Yes X No
Title of Project	Teaching the Theory of Island Biogeography as an on-campus field laboratory
Duration of Project	1 year
Primary Investigator(s)	Mr. William Garcia, Dr. Sara A. Gagné
Email Address(es)	wjgarcia@uncc.edu; sgagne@uncc.edu
UNC Charlotte SOTL Grants Previously Received (please names of project, PIs, and dates)	None
Allocate operating budget to Department of	Geography and Earth Sciences

		Year One
Account #	**Award**	**January to June**
Faculty Stipend	Transferred directly from Academic Affairs to Grantee on May 15	$ 3,598
911250	Graduate Student Salaries	$7,000
911300	Special Pay (Faculty on UNCC payroll other than Grantee)	
915000	Student Temporary Wages	$1,400
915900	Non-student Temporary Wages	
920000	Honorarium (Individual(s) not with UNCC)	
921150	Participant Stipends	

925000	Travel - Domestic	
926000	Travel - Foreign	
928000	Communication and/or Printing	
930000	Supplies	$1,050
942000	Computing Equipment	
944000	Educational Equipment	
951000	Other Current Services	
	GRAND TOTAL	$13, 048

Attachments:

1. Attach/provide a narrative that explains how the funds requested will be used.

2. Has funding for the project been requested from other sources? ___ Yes _X_ No. If yes, list sources.

BUDGET NARRATIVE

Faculty Stipend: The amount shown represents two weeks of salary for Sara Gagné. Dr. Gagné will be supervising the summer graduate student assistant during preliminary data collection and the creation of visual identification keys.

Graduate Student Salaries: A half-time teaching assistant is required to assist with the project in GEOG 3190: Biogeography and GEOG 4216/5216: Landscape Ecology during the Fall 2013 and Spring 2014 semesters, respectively.

Student Temporary Wages: The amount shown represents the pay for a graduate student assistant who will carry out preliminary data collection and prepare visual identification keys. We plan to hire a student for four weeks in May 2013. The student will work 20 hours the first week and 40 hours during each of the remaining weeks. The student will be paid ten dollars per hour (standard rate for the Department of Geography and Earth Sciences).

Supplies: The table below lists the supplies needed for the collection and identification of ground beetles and ground spiders.

Project use	Supplier	Item	Unit cost	Quantity	Total
To construct traps	Wal-mart	Hefty Cups Easy Grip Party Cups 18 oz, 50 ct (need 118 for 59 traps)	3	9	27
Killing agent in traps	Lowes	Winter-EEZ 1 Gallon RV & Marine Anti-freeze	5.93	21	124.53
To store invertebrates	Amazon	Whirl-pak Sample Bags Stand-up Bags With White Write-on Strip, Nasco - Model B01364wa, pack of 500	56.59	2	113.18
To store invertebrates	Fisher	Ethanol, lined steel drum 20L, A407-20	133.60	1	133.60
To sort invertebrates	Wal-mart	Pyrex baking dish	8	10	80
To construct trap roofs	Lowes	Grip-Rite 1 Lb. 1-1/4" Hot Galvanized Joist Hanger Nails, Item #: 69220 | Model #: 114HGJST1	4.97	1	4.97
To construct trap roofs	Home-Depot	OPTIX 24 in. x 18 in. x 4 mm. Corrugated Plastic Sheet in White (15-Pack), Model # COR-2418-15 Internet # 202038093	39.96	1	39.96
To identify invertebrates	Ward's Natural Science	Dissection kit (Item # 14 V 0794)	34.75	10	347.5
To measure habitat quality of islands	Amazon	4 in1 Plant Soil Survey Instrument PH Temperature Moisture Sunlight Tester Meter	26.81	2	53.62
To write on sample bags	Home Depot	Grease pen	5	2	10
To dispense ethanol	Ward's Natural Science	Wide-Mouth Wash Bottles, 500 mL (Item # 18 V 4116)	5.25	10	52.5
To use in traps	Wal-Mart	Ajax Antibacterial Orange Hand Soap Dish Liquid, 34oz, 2pk	3.84	1	3.84
To identify invertebrates	Barnes and Noble	Ubick et al. (2005)	58.5	1	58.5
TOTAL					**1049.20**

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November 6, 2012

SOTL Grants Committee

Center for Teaching & Learning

ctl@uncc.edu

Dear Committee Members:

I write in support of Dr. Sara Gagné's and Mr. Bill Garcia's application for a 2013 Scholarship of Teaching and Learning Award. The proposed research, *Teaching the equilibrium theory of island biogeography as a field laboratory: do field based-experiments provide better learning outcomes than simulated data?,* addresses both fundamental requirements of the SOTL program: to fund instructional research projects that will benefit the UNC Charlotte teaching and learning community; and that the results of the proposed research will be shared among the UNC Charlotte teaching Community.

The proposed project will assess the benefits of inquiry-based learning through the implementation of a novel based experiential course project that will be shared between two courses: GEOG 3000 Biogeography and GEOG 4216/5216 Landscape Ecology. These two courses are an important component of Department's newly revised undergraduate curriculum which stresses Human-Environmental Interactions in the Earth Sciences. The measurement of the biodiversity of invertebrate species associated with different-sized parking lot medians, located at varying distances from a "mainland" forest strikes me as an extremely novel way to present a fundamental theorem of Biodiversity and Ecology: The Island Theory of Biogeography to our students.

The implementation of this innovative experiential field and laboratory activity has the potential to significantly impact how students learn fundamental concepts in environmental science, learn to apply the scientific method, learn and practice field and laboratory techniques and critically evaluate the scientific literature. General areas of pedagogical focus include: increasing student engagement through curricular innovation; increasing faculty-student interaction; increasing cooperation among students; encouraging active learning; enhancing student professional development; and improving learning outcomes. Beyond the two instructors applying the results of the research to their own courses, they plan to present the class results at the UNC Charlotte Undergraduate Research Conference and the 4th Annual Campus Conversations: Students Discuss Sustainability conference. Finally, this project has the potential to impact instruction well beyond UNC Charlotte with the co-Pi's proposing to disseminate their educational results at conferences, such as the annual conference of the Association for the Study of Higher Education, and by means of articles in journals, such as *BioScience* and the *Journal of Geography in Higher Education*.

It is my pleasure to recommend this project for your consideration. Please let me know if you require further information.

Sincerely yours,

Nancy A. Gutierrez

Nancy A. Gutierrez, Dean
College of Liberal Arts and Sciences

A. SPECIFIC AIMS

Numerous studies have demonstrated that students perform better and have increased learning outcomes in courses that promote active learning by means of inquiry-based activities and research experiences (Cummins et al., 2004; Geier et al., 2008; Hmelo-Silver, 2004; Hmelo-Silver et al., 2007; Marx et al., 2004; Oliver, 2007). Active learning strategies such as these may be of various kinds, both direct and indirect (Fink 2003). A direct learning experience involves students engaging in real actions in an authentic setting. For example, an environmental sciences student that participates in a real-world community discussion of environmental issues is engaging in a direct learning experience. Indirect learning experiences occur when students are unable to participate in real-word situations. In-class role-playing exercises are examples of indirect learning experiences.

Despite the consensus on the benefits of active learning strategies in higher education, little is known about the efficacy of different types of active learning experiences. The purpose of our project is to test the effect of learning experience type on learning outcomes. We aim to answer the question: **Do students learn more about a concept if they engage in a direct learning experience rather than an indirect learning experience?**

We plan to answer this question using two relatively new courses taught in the Department of Geography and Earth Sciences: GEOG 3190 Biogeography and GEOG 4216/5216 Landscape Ecology. Both courses teach the Theory of Island Biogeography (TIB), which predicts the number of species on oceanic islands based on their size and distance from the mainland (MacArthur and Wilson, 1967). The Theory of Island

Biogeography was posited on the basis of empirical observations and has been tested extensively using empirical data. In our view, such theories are best taught using direct learning experiences that involve the elaboration of hypotheses, predictions, and field data collection. Due to practical limitations, the Theory of Island Biogeography is traditionally taught using simulated data, i.e., an indirect learning experience. In our experience, the use of simulated data results in students acquiring a superficial understanding of the processes and systems being taught.

The UNC Charlotte campus provides us with an opportunity to engage students in a hands-on empirical test of the TIB using invertebrate species and parking lot islands. We predict that a direct learning experience such as this will improve students' understanding of the concepts inherent in the TIB. The design of field-based learning activities in higher education is greatly facilitated by the use of one's campus as a laboratory. In addition, students benefit from a strong sense of place and ownership when their own campus is part of the lesson.

The objectives of our project are to:

1. Design an inquiry-based learning activity that makes use of the UNC Charlotte campus as a study area to test the Theory of Island Biogeography.
2. Compare the learning outcomes from the new inquiry-based learning activity with those from traditional, indirect activities used to teach the Theory of Island Biogeography.

This project supports themes within the Department of Geography and Earth Sciences, particularly the themes of Global Change and Human Environment Interactions, by providing students with a deeper and more nuanced understanding of the factors that determine biodiversity at both regional and global scales. With this understanding they may better realize how human activities can alter biodiversity. This project addresses two of the College of Liberal Arts and Science's goals, namely "to support all students' academic success by maintaining a student climate of enriched educational experiences, opportunities for leadership, and exposure to the application of disciplinary knowledge and skills" and "to foster a self-reflective community of educators who continuously examine their processes and assess practices in all aspects of teaching and research to insure effective outcomes". The improved learning outcomes and opportunity to engage in actual field research provide greatly enhanced student experiences, while the data generated on indirect vs. direct learning will allow the instructors to examine and improve our teaching practices.

Further, the development of this exercise will provide a template that instructors at other universities can use to teach TIB using a direct learning experience. Islands have long had a great influence on the science of biology in general, and biogeography specifically. The study of island biotas has influenced central theories of biology such as natural selection (Darwin, 1859), evolution and ecology (Lack 1947, 1976), speciation concepts (Mayr 1942, 1953), and geographic variation of species (Hutchinson 1958, 1959, and 1967). Aside from Darwin's use of the Galápagos Islands in his formulation of the theory of natural selection, the most significant influence of the study of islands for biology is the TIB (MacArthur and Wilson, 1967), which has become one of the most fundamental ideas in biology for understanding the diversity and ecologic structure of areas. The influence of the Theory of Island Biogeography is pervasive within biology. As a result, proper understanding of the Theory of Island

Biogeography provides a deeper and richer understanding of mechanisms controlling biodiversity.

B. LITERATURE REVIEW

Over the last decade there has been an increasing demand for reform in undergraduate earth science education, and in particular, amplification of undergraduate research experiences (National Research Council, 1996; National Science Foundation, 1996). Implementation of learning experiences through community of inquiry pedagogy has been successful in numerous earth science departments at different types and sizes of universities across the United States (Bunley et al., 2002; Jarrett and Burnley, 2003; Beane, 2004; Nicolaysen and Ritterbush, 2005) and internationally (e.g. Edwards, 2003; James, 2006; King, 2006).

Inquiry-based education and research experiences benefit both students and faculty. Students can better test their interest in a career involving research (Herrick, 1991; National Science Foundation, 1996; Jarrett and Burnley, 2003). They may be more marketable as a new graduate with demonstrated skills on advanced tools, technology and manipulation of data and they may be more capable of communicating technical material to the scientific community (Stukus and Lennox, 1995). Finally, students engaged in experiential learning may gain a sense of scientific ownership (Gawel and Greengrove, 2005).

Undergraduate research experiences are equally important for science and non-science majors. According to the National Science Foundation (1996): "Integrating research and education is a powerful means by which to provide students with the skills in problem solving and critical thinking that will be necessary for their successful navigation of the workplace in the 21st century". Further, experiential learning has been demonstrated to be an effective method of retaining nontraditional students in the sciences (Kern and Carpenter, 1984; Gawel and Greengrove, 2005).

C. METHODS

Previous Teaching Methodology: During the Fall of 2010 Biogeography was taught as a cross-listed ESCI/GEOG 4000 Topics course. One of the key concepts was the Theory of Island Biogeography and the significant impacts it has had on the overall science of ecological biogeography. Two weeks (4 classes), a laboratory, and a paper were devoted to the theory. The first class involved a lecture on the basic formulation of the theory and its significant predictions using data from various historical publications cited in the textbook of the course. The second and third classes involved an in-class assignment in which students collected data using in-class simulations of island colonizations and extinction. This data was then compared to the predictions of MacArthur and Wilson's model.

Student learning outcomes concerning the Theory of Island Biogeography were measured in three ways. First, students were asked multiple-choice questions and completed an essay related to island biogeography on an exam. These questions were designed to assess the students' understanding of the predictions of the theory and its importance to regional and global biodiversity. Second, students submitted a short analysis of the simulation data created in class during lab and compared this data to the predictions of the Theory of Island Biogeography. This assignment was designed to assess students' ability to apply the theory to actual data and critically analyze whether the data matched the predictions of the theory. Third, students chose an island from a prepared list and researched the biodiversity and geographic features of their choice. They were required to use their knowledge of the TIB to explain the modern species richness of the island they chose.

Proposed Methodology: We propose to use the vegetated islands in parking lots 6, 6A, and 13 on the UNC Charlotte (Fig. 1) campus as a model system with which to test the Theory of Island Biogeography using ground invertebrates (ground beetles and ground spiders). We assume that the asphalt surface of the parking lots represents a hostile environment that severely constrains invertebrate dispersal and that vegetated islands are habitat for ground invertebrates. Invertebrate richness will be compared among islands of different sizes and located at different distances from 'mainland' source areas (Fig. 1).

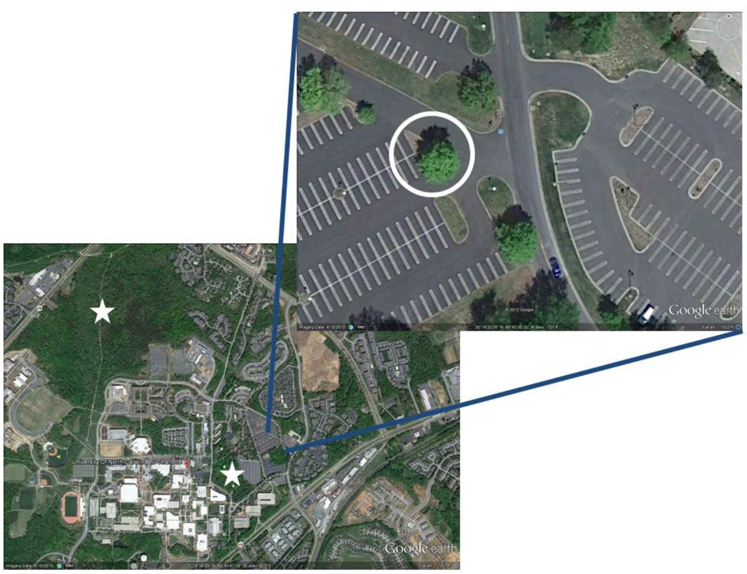

Figure 1. Aerial view of the UNC Charlotte campus. White stars indicate potential mainlands from which invertebrate species disperse to parking lot islands (inset).

We plan to collect preliminary data on ground invertebrate richness in May 2013 (see Timeline). Preliminary data will be used to create visual identification keys for use by GEOG 3190: Biogeography and GEOG 4216/5216: Landscape Ecology students. A field assistant will install pitfall traps in the vegetated island in lots 6, 6A, and 13 (total number of islands is 46). The number of traps per island will be proportional to island size, with the smallest islands hosting a single trap. A pitfall trap consists of two plastic cups embedded in the ground with the inner cup flush with the ground surface. Traps will be filled with 100 mL of propylene glycol and a drop of dish soap and covered with small roofs to prevent rain and debris from entering the trap. Trap contents will be collected once a week for three weeks and collected invertebrates will be identified to species or the lowest taxonomic level possible using Ciegler (2000) and Ubick et al. (2005). Model specimens of each species or taxonomic group will be photographed using the camera attached to a stereomicroscope in Dr. Gagné's laboratory. We will use these photographs as well as photographs found online (e.g., from bugguide.net) to create visual identification keys.

In Fall 2013 and Spring 2014, students in GEOG 3190 Biogeography and GEOG 4216/5216 Landscape Ecology, respectively, will identify invertebrates collected using the method described above. A teaching assistant in each course will help students install traps and prepare trap contents for identification by students during weekly class periods. Students will identify collected invertebrates in the laboratory using the visual identification keys provided, reference books, and basic stereomicroscopes. GEOG 3190 Biogeography students will also use GIS to estimate island size and island distance from several different potential 'mainlands' (Fig. 1). GEOG 4216/5216

Landscape Ecology will additionally calculate island shape using GIS and estimate the habitat quality of each island in the field. Habitat quality will be estimated from variables that describe ground cover, litter depth, tree presence, soil water content, and soil temperature. In each course, students will plot the collected data to determine if the predictions of TIB are supported and will use statistical analyses (e.g., linear regressions) to test for effects of island size and isolation on invertebrate richness. In addition, the students in GEOG 4216/5216 Landscape Ecology will test for the mediating influences of habitat quality and island shape on the predictions of TIB.

D. EVALUATION

Experimental Design to Measure Student Learning Outcomes: We expect students who successfully complete the proposed classes to demonstrate a greater understanding of island biogeography in the following ways:

- Improved scores on a similar test that is given at both the start (pre-test) and the end (post-test) of the semester.
- Improved scores on exams given during the semester compared to previous semesters with different teaching methodologies
- Demonstrated ability to discuss the strengths and weaknesses of models for the geologic evolution of islands based upon present flora and fauna
- Demonstrated ability to effectively synthesize and critique scientific articles and media reports addressing biodiversity.

Evaluation of each of these expectations will be conducted as follows:

a. Students will be given a pre-test on the first day of class in GEOG 3190 consisting of questions concerning various aspects of biogeography and the same exam on the last day of class. Improvement, measured as the average number of correct answers, on questions related to the Theory of Island Biogeography will be compared from the pre- to the post-test. This will serve as a first pass examination of student understanding.

b. Quantitative comparison of student performance using the two teaching methods will be achieved by comparing the number of correct student responses to the multiple choice questions asked the previous semester the course was taught. These questions were previously asked on the GEOG 3190: Biogeography final exam using the previous teaching methodology, and will be asked again on the final exam for that course during the Fall of 2013. We will compare the average number of correct answers based upon each teaching method.

c. Student learning will be qualitatively assessed by comparison of student answers to the essay and through comparison of student papers on Island Biogeography. These assessments will examine student ability to analyze new data (Bloom, 2003).

d. Student learning in GEOG 4216/5216 will be qualitatively assessed by means of a final 'journal article' that contains all the elements of a professional scientific journal article (IMRAD format) and describes the student research carried out to the test the TIB using parking lot islands on the UNC Charlotte campus.

E. KNOWLEDGE DISSEMINATION

We plan to have students in GEOG 3190: Biogeography and GEOG 4216/5216: Landscape Ecology present the class results (i.e., the results of the test of the Theory of Island Biogeography) at the UNC Charlotte Undergraduate Research Conference and the 4th Annual Campus Conversations: Students Discuss Sustainability conference. We also plan to disseminate our educational results at UNC Charlotte's Center for Teaching & Learning's workshops, at conferences, such as the annual conference of the Association for the Study of Higher Education, and by means of articles in journals, such as BioScience, the Journal of Geography in Higher Education, and the Journal of Geoscience Education

F. HUMAN SUBJECTS

We have completed the Human Subjects Protocol Form and will be submitting it for approval. We believe our proposal should be considered exempt research under provisions described on the University website on human subjects.

G. EXTRAMURAL FUNDING

We do not plan to seek extramural funding at this time.

H. TIMELINE

Date	Activity
May 6 2013	Pitfall traps installed in islands
May 13 2013	Pitfall trap contents collected & traps re-set
May 14 - 17 2013	Taxa collected identified
May 20 2013	Pitfall trap contents collected & traps re-set
May 21-24 2013	Taxa collected identified
May 28 2013	Pitfall trap contents collected & traps re-set
May 29-31 2013	Taxa collected identified
June 4-18 2013	Identification keys created
Fall 2013	Data collection and analysis in GEOG 3190 Biogeography
Spring 2014	Data collection and analysis in GEOG 4216 Landscape Ecology
Summer 2014	Project evaluation
Fall 2014	Results disseminated

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