# A FIELD-BASED DIRECT ACTIVE LEARNING METHOD FOR TEACHING UNIFORMITARIAN PRINCIPLES IN INTRODUCTORY GEOLOGY COURSES USING RECONSTRUCTIONS OF EARLY HOMINID AND DINOSAUR TRACKWAYS

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**Abstract**

Numerous studies have demonstrated that students have increased learning outcomes in courses that promote learning by means of both direct and active activities and research experiences. One complication for subjects such as geology is that central theoretical tenants and primary data collection within 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. An important concept within the historical sciences, such as geology, is the principle of uniformitarianism. Uniformitarianism states that we can use our understanding of modern processes to understand events of the Earth's past. This is a process-driven concept and thus is difficult for students to grasp within a lecture format because they are separated from the actual processes. I propose to construct on the UNCC campus a model of world famous hominid and dinosaur trackways that can be used in numerous courses as a field oriented active learning lab. Courses that could use this model, GEOL 1200, GEOL 1210, and LBST 2213, satisfy two general education requirements and would impact a broad section of our student body. These models will serve to bring the 'field' to UNCC and provide an opportunity for direct active learning activities unavailable on a typical university campus. I have data from three previous semesters when this lab was taught as an indirect learning active and will compare the student learning outcomes of the direct and indirect methodologies.

## Aims

A fundamental geologic concept that students often struggle to understand is the principle of uniformitarianism. This philosophy states that we can understand past geologic processes by studying modern geologic processes and extrapolating those modern processes into the past. This concept is difficult for students to understand without witnessing examples of modern processes in action, something that we generally need to be in the real world to do. For example, students might watch waves on a beach sorting and orienting sediment grains and then compare that orientation to similar patterns in rocks deposited millions of years ago. From this they would conclude that those rocks were deposited in a beach environment because the orientation of the grains was the same as on a modern beach. This concept is difficult to grasp without a directly observed example.

For many of the natural sciences, such as geology, physical geography, and ecology, true direct learning experiences require students to actively participate in fieldwork where much of data collection in these disciplines is conducted. Consensus among both geology and biology instructors is that teaching outside of the classroom, field-work, is an essential component in the training of future biologists and geologists (Barker et al., 2002; Dillon et al., 2006; Gibson et al., 1999; Petcovic et al., 2014). However, many university-level biology and geology courses do not contain field-based work, particularly at the introductory-level. Since most students in these introductory courses are non-majors, these courses may be the only science courses they take as college students and thus they are deprived of a fundamental aspect of these disciplines by not being involved in fieldwork.

One specific difficulty with developing active, direct learning experiences in field-based disciplines such as geology is that many high school and university campuses are urban environments lacking appropriate natural space within which to conduct field studies, or are located a considerable distance from appropriate locations for conducting fieldwork. However, I believe that some of the characteristics of urban campuses can be modified to provide powerful analogies for field-based rich-learning experiences for students. The design of field-based learning activities in higher education is greatly facilitated by the use of one's campus as a laboratory, students benefit from a strong sense of place and ownership when their own campus is part of the lesson.

Herein I propose to construct an outdoor model of two well-known fossil trackways, the Paluxy River track site in Texas (Figs. 1 and 2) and the Laetoli track site in Tanzania (Fig. 3), that can be used to provide field-based direct-learning experiences for students in a variety of introductory Geology and Liberal Studies courses. This type of model can be constructed on nearly any university campus providing an accurate model of real field locations around the world. In this way I hope to provide a way for students to better understand a fundamental earth science concept, the principle of uniformitarianism, by transforming an indirect learning activity into a more direct and field-based activity. By doing so I hope to provide a blueprint for other urban universities to provide similar opportunities to students.

This model and the field-based direct learning activities associated with it could be used in a broad range of classes at UNCC. I intend to use it in my LBST 2213 and Geology 1210 courses, both of which satisfy general education requirements. In conversations with Dr. Scott Hippensteel he has expressed an interest in using the model in his LBST 2213 and Geology 3140 courses. The model could also be incorporated into Geology 1200, another general education course, as a tool to teach the principle of uniformitarianism.

## Literature Review

Over the last several decades there has been an increasing demand for reform in undergraduate science education, and in particular, amplification of undergraduate research experiences (National Research Council, 2003; 2002; 1996; National Science Foundation, 1996; Volpe, 1984). Each of these critiques emphasized the importance of actively involving students in the learning process to facilitate deeper, more long lasting learning. Active learning can take a variety of forms (Michael and Modell 2003), but can be summarized as a process by which students engage in activities that require them to reflect on ideas and how they are using them. Central to active learning is that students are attaining knowledge by participating or contributing, keeping students mentally and often physically active through gathering information, thinking, and problem solving (Collins and O'Brien, 2003). Active learning is often a student-centered type of learning in which students influence the content, activities and pace of learning (Collins and O'Brien, 2003). Critics have pointed out that traditional, teacher-centered, university lecture courses are at odds with current understanding of human cognition (Halpern and Hakel, 2002) as they are fundamentally models of passive learning, and thus are limited as classroom strategies.

Significant research has demonstrated the benefits of active learning (Michael, 2006). This research has come from a variety of different disciplines including Physics (Hake, 1999), Chemistry (Niaz et al, 2002; Towns and Grant, 1997), and Biology (Burrowes, 2003; McNeal and D'Avanzo, 1997; Wilke and Straits, 2001) and incorporates a variety of student-centered, active learning techniques. These techniques include, but are not limited to case-based learning, collaborative learning, peer instruction, conceptual change strategies, inquiry-based learning, discovery learning, and technology-enhanced learning (Michael and Modell, 2003).

Implementation of learning experiences through inquiry-based learning, or community of inquiry pedagogy, has been successful in numerous 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). Studies of impacts of inquiry-based learning have shown success in broad aspects of learning (Hmelo-Silver, 2004; Hmelo-Silver et al., 2007), although some research indicates that only particular types of inquiry-based learning have been successful (Mayer, 2004).

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.

Much of a geologist's work, the work that we would like to duplicate with direct learning experiences, involves conducting fieldwork, either to collect data or to solve geologic problems that are encountered in the field. Numerous reasons have been cited for the lack of field work in both high school and university earth science classes; large class sizes, lack of sufficient time, availability of transport, interest of faculty, cost, lack of sufficient field localities, risk of accidents, lack of student interest, and lack of credit toward career advancement for faculty (Fido and Gaylord, 1982; Kinchin, 1993; Fisher, 2001); even though research has demonstrated that field-work has a positive effect on student learning outcomes (Ballantyne et al., 2010; DeHaan, R. L., 2005; Dillon et al., 2006). As a result, the amount of direct learning activities that students experience in the natural sciences is limited, and some evidence indicates that it is declining, particularly in the U.K (citations).

**Methods**

I have taught a Dinosaurs course in various forms on three prior occasions at UNCC. During each of these courses students completed an assignment in which they measured dinosaur 'trackways' that I created on rolls of butcher paper using paper cutouts of dinosaur 'footprints'. In this assignment students recorded their straight line walking and jogging speeds along a measured course using a stopwatch. They then calculated their walking speed using a formula developed by R. McNeill Alexander (1976) for analyzing fossil trackways. Students then compare their recordings of their speeds with their calculations of speed to determine that the formula properly determines walking velocity. Students then use the formula to determine the speed of locomotion for 3 different dinosaur 'trackways' laid out for them on butcher's paper, measuring stride length directly from the distance between footprints and using foot length as a proxy for hip height, a relationship that seems to hold for many modern animals (Alexander, 2003). This assignment is a good example of an indirect active learning activity. It is active in that students are engaged in both physical and mental work to solve problems, however, it is an indirect activity in that students are not involved in a real-world situation. While a trackway can be mimicked on paper, certain aspects of dinosaur behavior that can be analyzed through trackways are not discernable with this model and complications with using uniformitarian principles cannot be demonstrated largely due to the two-dimensionality of the paper trackway.

The goal of the assignment is for students to understand how the application of uniformitarianism allows them to make inferences about the behavior of an extinct animal without having witnessed the behavior in question. This philosophy is fundamental to not just geology, but all of the historical sciences including evolutionary biology, cosmology and archeology and is a basic concept that students should understand from introductory science courses. Students use formulae to calculate their walking and jogging velocity to prove that the mathematics work. They then apply this technique to calculate tracks of known speed. Once they have demonstrated that the calculations work in the present world they apply them to the fossil record by calculating walking velocities for dinosaurs.

Student achievement of this learning outcome has been assessed in two ways. First, a series of questions is contained within the trackway assignment and is designed to connect the concept of uniformitarianism to the experiment they have just conducted. Second, students are asked an essay question on their the exam after the exercise relating to the process of how paleontologists study the past and are asked to use trackways as an example.

**Evaluation**

I propose to test whether student achievement on these learning outcomes, as measured by these two assessment tools, increases when students are taught these topics through a more direct, field-based learning activity rather than the currently used indirect learning activity. I believe that construction of models of real trackways, both early hominid and dinosaurian, will provide more direct learning experiences and will thus result in an increase in the number of students who achieve passing results on these assessments and an increase in the overall mean score on these assessments. The assignment and assessment methods used will be the same as those used when the activity was previously taught as an indirect activity allowing for a controlled experiment in which the only variable is whether the activity is an indirect or more direct experience.

The proposed trackway site will have three sections. The first section will be 25 feet long and 5 feet wide and will have two sets of my tracks, one while walking and one while jogging on drying cement. These tracks will provide an example for which the track maker's speed is known so that students can test the accuracy of the formula they will use throughout the activity. The second portion would be approximately the same width as first portion, but 100 feet long. It would contain a recreation of the hominid tracks present at Laetoli, Tanzania (Fig. 3) and would be used as an example of uniformitarianism applied to an organism similar to our modern example. The final section of the trackway site would be approximately 75 feet long and 10 feet wide. This section would be a replication of part of the Main Trackway at the Paluxy River, Texas trackway locality (Fig. 1 and 2). In this section of the model students would be able to apply techniques of estimating organism speed to the tracks of extinct animals, a full application of the principle of uniformitarianism.

## Dissemination

I plan to disseminate the results of this research in three avenues. First, I plan to submit a journal article on the pedagogy of the project and learning outcome changes from the previous indirect to direct methods in the Journal of Geoscience Education. This journal is the primary outlet for educational research in the geosciences across high school and university curricula and the readership is the appropriate audience for this research. Second, I plan to present a talk at the October, 2015 Geological Society of America conference in

Baltimore, MD on the construction of the model and how it is used in our various courses. The Education Division of GSA is the fastest growing group in the society and the annual meeting attracts both high school and university earth science instructors providing an excellent venue to present this research. Lastly, I would like to present the results of the comparison of learning outcomes at the $35^{th}$ International Geologic Convention in Cape Town, SA in September of 2016. This international conference meets every 3-4 years and has a series of earth science education sessions.

**Human Subjects**

I believe this research falls under the category of exempt from the need for approval. Student scores on assessment questions will be used to measure achievement toward learning outcomes, but student scores will be used in aggregate and individuals will not be identifiable.

**Extramural Funding**

The only additional funding source that I anticipate using is the yearly travel stipend that the Department of Geography and Earth Sciences provides its faculty. This typically amounts to $1,000 and I plan to use it for the 2015 Geological Society of America conference in Baltimore, MD in order to present the results of this research.

**Timeline**

If this proposal is funded and money is dispersed by the beginning of the Spring semester in 2015, I anticipate that the trackway model can be constructed during the later half of Spring 2015 or Summer of 2015 depending upon availability of Facilities personnel.

Construction during the Summer of 2015 may be preferable to reduce the likelihood of vandalism while the concrete is drying. I am currently in conversations with Facilities Management personnel to find a location on campus for the model.

I anticipate teaching my Dinosaurs course as an LBST 2213 offering in the Fall of 2015, pending its approval by the college curriculum committee, or in the Spring of 2016 at the latest. During this course I will use the trackway model with the exercise I have previously used and compare the learning outcomes with and without the model. If the course is taught in Fall of 2015 I can present at GSA in October of 2015, in Cape Town in September of 2016 and should have a manuscript submitted to JGSE in the summer of 2016.

Figure 1. Photograph of a portion of the Paluxy River track site near Glen Rose, Texas. Photograph by Greg Kuban.

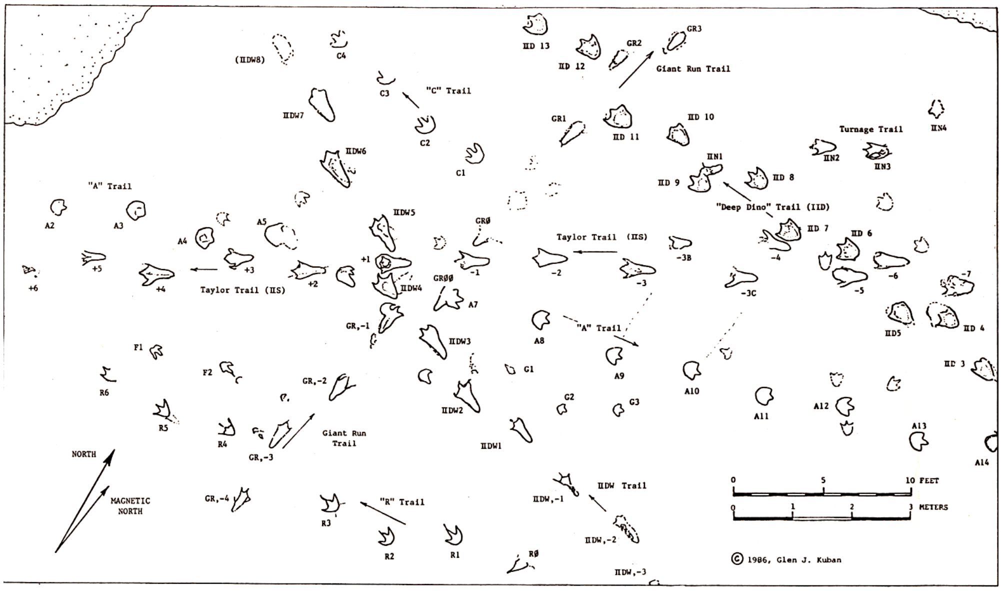


Figure 2. Map of the Main Track layer of the Paluxy River track site. Map by Greg Kuban.

Figure 3. Photograph of the Laetoli track site in northern Tanzania. Photograph by Mary Leakey.

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# Budget Request for SOTL Grant

## Year 2014

| | |
|---|---|
| Joint Proposal? | _____ Yes X No |
| Title of Project | **A FIELD-BASED DIRECT ACTIVE LEARNING METHOD FOR TEACHING UNIFORMITARIAN PRINCIPLES IN INTRODUCTORY GEOLOGY COURSES USING RECONSTRUCTIONS OF EARLY HOMINID AND DINOSAUR TRACKWAYS** |
| Duration of Project | Spring 2015 – Fall 2016 |
| Primary Investigator(s) | William Garcia |
| Email Address(es) | wjgarcia@uncc.edu |
| UNC Charlotte SOTL Grants Previously Received (please names of project, PIs, and dates) | Teaching the equilibrium theory of island biogeography as an on campus field laboratory, William Garcia and Sara Gagne, Spring 2013-Spring 2014 |

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 | $0 |
| 911250 | Graduate Student Salaries | $0 |
| 911300 | Special Pay (Faculty on UNCC payroll other than Grantee) | $0 |
| 915000 | Student Temporary Wages | $0 |
| 915900 | Non-student Temporary Wages | $0 |
| 920000 | Honorarium (Individual(s) not with UNCC) | $0 |
| 921150 | Participant Stipends | $0 |
| 925000 | Travel - Domestic | $0 |
| 926000 | Travel - Foreign | $0 |
| 928000 | Communication and/or Printing | $0 |
| 930000 | Supplies | $10,500 |
| 942000 | Computing Equipment | $0 |
| 944000 | Educational Equipment | $0 |
| 951000 | Other Current Services | $0 |
| | | |
| | **GRAND TOTAL** | $10,500 |

| | | Year Two |
|---|---|---|
| Account # | Award | July to June |
| Faculty Stipend | Transferred directly from Academic Affairs to Grantee on May 15 | $0 |
| 911250 | Graduate Student Salaries | $0 |
| 911300 | Special Pay (Faculty on UNCC payroll other than Grantee) | $0 |
| 915000 | Student Temporary Wages | $0 |
| 915900 | Non-student Temporary Wages | $0 |
| 920000 | Honorarium (Individual(s) not with UNCC) | $0 |
| 921150 | Participant Stipends | $0 |
| 925000 | Travel - Domestic | $0 |
| 926000 | Travel - Foreign | ~~$3,700~~ $2500 |
| 928000 | Communication and/or Printing | $0 |
| 930000 | Supplies | $0 |
| 942000 | Computing Equipment | $0 |
| 944000 | Educational Equipment | $0 |
| 951000 | Other Current Services | $0 |
| | | |
| | GRAND TOTAL | ~~$3,700~~ $2500 |

**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 Justification**

I am requesting funding primarily to fund the construction of the trackway model on the UNCC campus. I am in discussions with Mac Fake in Design Services about finding a location on campus for the model and an estimate of what Facilities would charge to build the model. Facilities has yet to locate a site on campus for the model, but are in the process of finding one, and have yet to give me an estimate for the cost to build. However, online contracting calculators indicate a price of approximately $10,500 for the cost of a 15 foot by 100 foot concrete sidewalk including cost of materials and labor.

My other request for funding is for travel to the 35th International Geology Congress in Cape Town August 27th through September 4th of 2016. Conference registration and hotel rates for the conference have yet to be announced, but rates for the 34th Congress in Brisbane were between $850 and $1,300 depending on the type of registration. Eight nights of hotel expenses in Cape Town at a location within ¼ mile of the convention center would cost approximately $800 at current rates. Current airfare for late August to early September of 2015 from Charlotte to Cape Town is approximately $1,600. Fares for 2016 are not currently available.

Total estimated costs for construction of the trackway model and travel expenses to Cape Town are $14,200.

UNC CHARLOTTE
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November 4, 2014

SOTL Grants Committee
Center for Teaching & Learning
ctl@uncc.edu

Dear Committee Members:

I am writing in support of the SOTL proposal submitted by William Garcia of our Department of Geography and Earth Sciences, "A field-based direct active learning method for teaching uniformitarian principles in introductory geology courses using reconstructions of early hominid and dinosaur trackways." Garcia proposes to construct on campus a model of famous hominid and dinosaur trackways that are preserved in the geologic record. These trackways would be used in a number of different courses to provide a field-based active learning lab.

While fieldwork is a common experience for many majors in the natural sciences, something exciting about this project is that it creates an opportunity for field-based work in lower-level general education courses. Thus, even non-science majors will have an opportunity for this type of valuable learning experience.

Garcia will be able to compare student performance on select learning outcomes using the direct field-based learning activity proposed to the results obtained when the course was previously taught and an indirect activity was used for the same material. It provides a strong basis for comparing the two methods and he plans to disseminate the results through two presentations and an article to be submitted to the Journal of Geoscience Education. I believe the construction of the trackways will be a valuable addition to our campus and to the instruction and learning in the Geology and general education courses that are able to make use of them. I am pleased to recommend the proposal for your consideration.

Please let me know if you require further information.  Thank you.

Sincerely yours,

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