Collaborative Research: A Field-Based Curriculum for Quantifying Deformation of the Earth's Surface with Lasers, GPS and Cameras

**Project Period:** 06/01/2016-05/31/2018

**Reporting Period:** 06/01/2016-05/31/2017

**Principal Investigators:** Donna Charlevoix (PI), Beth Pratt-Sitaula (Co-PI)

**Sponsor:** NSF DUE-IUSE

**Award ID:** 1612248

**Collaborators:** Bruce Douglas (Indiana University), Benjamin Crosby (Idaho State University)

*Geodesy field education short course group photo generated by Structure from Motion (SfM). Blue squares show camera positions. 3D point cloud is colored by an orthophoto overlay. Short course on TLS and SfM methods was held August 2016 at the Indiana University Geology Field Station and included 21 field instructors as participants.*
Accomplishments

What are the major goals of the project?

The primary program goal is to improve students’ Earth science understanding and workforce-ready capabilities through field education experiences that incorporate geodetic technologies and applications. Resources (inputs) for this project include NSF funding, the UNAVCO GAGE Facility, faculty collaborators, SERC, NAGT (National Association of Geoscience Teachers), and the geodesy community. The three goals are student-focused either directly or toward improving instruction through faculty development.

Goal 1. Build student understanding of geodetic instrumentation, techniques, and applications

Objective 1.1: Increase student understanding of geodetic instrumentation, methods, and applications, specifically Terrestrial Laser Scanning (TLS), Structure from Motion (SfM), and Static and Real-time Kinematic (RTK) Global Positioning Systems (GPS)

Objective 1.2: Increase student ability to collect, analyze, manipulate and interpret geodetic field data

Objective 1.3: Increase student knowledge of the array of scientific challenges and problems that can be studied using geodetic tools

Goal 2. Increase faculty efficacy in teaching geodetic techniques in geology field courses

Objective 2.1: Develop robust learning modules for field or classroom use that are flexible enough for instructors to integrate into field camps and classes

Objective 2.2: Increase faculty knowledge of best practices for instruction in field courses

Goal 3. Obtain baseline data from faculty to better understand successes and challenges of implementing pre-developed curricular materials in field education experience

Objective 3.1: Document faculty experience in field instruction, motivation for incorporating geodetic technologies, and working knowledge of best pedagogical practices

Project activities will result in (outputs): two modules (up to six units each) for incorporating geodetic technologies in field education, multi-day professional development workshops for geoscience faculty, one-day short courses for faculty training, baseline data on how faculty adopt curricular materials into their field instruction, and student data contributed to the GLE (Geosciences Literacy Exam) national database. The student and faculty outcomes are articulated in the project objectives.

What was accomplished under these goals?

Major Activities

During this first year of the grant we have:

● Completed and published the first of two teaching modules – Analyzing High
Resolution Topography with TLS and SfM
(http://serc.carleton.edu/getsi/teaching_materials/high-rez-topo/index.html)

- Held a 2.5-day in-person professional development short course for 21 field instructors to support their understanding of the geodetic methods and implementation into their courses (Analyzing High Resolution module) – “Using TLS and Structure from Motion (SfM) Photogrammetry in Undergraduate Field Education” (http://www.unavco.org/education/professional-development/short-courses/2016/field-education/field-education.html)
- Included the Analyzing High Resolution module in three 1-day short courses (along with two other modules). It was featured most prominently in “Hooking undergraduates into geophysics data and methods (GPS, Lidar, InSAR, SfM photogrammetry) through societally important issues”, which was held in conjunction with American Geophysical Union (AGU) annual meeting 2016. Twenty-six people participated. (http://www.unavco.org/education/professional-development/short-courses/2016/agu-education/agu-education.html). It was also included in two UNAVCO-sponsored 2016 GSA short courses related to TLS and SfM. More than fifty participants were at these two courses.
- Written and revised a draft of the second teaching module – High Precision Positioning with Static and Kinematic GPS/GNSS. Testing in a field course is scheduled to occur in June 2017.
- Nearly completed the writing of an additional unit for Analyzing High Resolution module that will allow a road engineering application
- Recruited for and filled a second short course that will be held in August 2017. Over 40 applicants for the 22 spots available. – “Using High Resolution Topography, UAVs, and GPS in Undergraduate Field Education” (http://www.unavco.org/education/professional-development/short-courses/2017/field-education/field-education.html)

Specific Objectives

We concur with the assessment by the Science Education Resource Center external evaluator (Appendix) that this project has made strong progress on Goals 1 and 2 but that more data is needed before accomplishment of Goal 3 can be properly evaluated. Goal 3 depends on collection of feedback from modules users, which has only just begun but will continue to increase as the materials have more users.

Opportunities for training and professional development?

A key component of this project is professional development for geoscience field instructors to better implement the prepared modules. As such, we have held one extended short course on project topics, collaborated in a shorter one, and have scheduled another extended one (more details above). Overall participant satisfaction has been very high as shown in the report by the Science Education Resource Center external evaluator (Appendix). She reported that overall participants were highly satisfied.

One MS Geology graduate student, Ian Lauer, has been an active contributor to this project. He participated in the design and implementation of the 2016 short course and helped author materials for activities within the High Precision Positioning module. Ian served as
a UNAVCO student intern in the summers of 2016 and 2017, interacting with numerous other undergraduate and graduate students as well as UNAVCO staff.

How have results been disseminated to communities of interest?

Results of this project so far include the teaching modules and the professional development short courses. The first module has already been published online as the first part of the GEdespy Tools for Societal Issues (GETSI; http://serc.carleton.edu/gets) Field Collection, which is hosted by the very well known SERC website (5 million visitors per year). The second module will also be published on this prominent venue. The short courses are another way to disseminate knowledge of the teaching modules. Project PIs have presented at Earth Educators Rendezvous (EER), AGU, and GSA. In addition we use available avenues for news, listservs, and social media through UNAVCO and other partner organizations such as NAGT and AGU. These include dissemination of products as well as opportunities to apply to short courses. Examples:

- EOS Meeting Report “Integrating Topographic Imaging into Geoscience Field Courses” https://eos.org/meeting-reports/integrating-topographic-imaging-into-geoscience-field-courses
- UNAVCO Highlight on the Field Learning Resources http://www.unavco.org/highlights/2016/fieldeducation.html

Plan for next reporting period?

During the next reporting period

- The remaining module (High Precision Positioning) will be tested, revised, and published online. Demonstration datasets will be gathered and vetted.
- We will conduct two more extended short courses and possibly include the field modules in other short courses run by UNAVCO and/or the larger GETSI project. Originally we only proposed doing two short courses total as part of this project, but with additional funds from UNAVCO and the GPS company Septentrio, we are now expecting to do three ~2.5-day short courses total. The remaining ones are:
  - August 2017 (already scheduled see above)
  - May 2018 (dedicated solely to GPS topics)
- We will accelerate seeking feedback from module users, to obtain more baseline data on how field instructors use these teaching materials (Project Goal 3).
- Sessions related to field education geodetic methods have been proposed for both GSA and AGU annual meetings for 2017. The GSA session has been approved and recruitment for submissions is underway.
- We will carry out the analysis necessary to underpin a peer-reviewed publication about the project findings.

Products

Conference Papers and Presentations

Title: Data-rich societally-relevant undergraduate teaching resources for geoscience
classrooms and field courses
Conference: Geological Society of America Annual Meeting 2016
Authors: Beth Pratt-Sitaula, Bruce Douglas, Becca Walker, Benjamin Crosby, Donna Charlevoix, Christopher Crosby, Katherine Shervais

Title: Teaching Structure from Motion Photogrammetry Methods to Undergraduates: New Learning Module for Field Geoscience Courses
Conference: American Geophysical Union Annual Meeting 2016
Authors: Beth Pratt-Sitaula, Katherine Shervais, Christopher Crosby, Bruce Douglas, Benjamin Crosby, Donna Charlevoix

Websites
GETSI Project Site: http://serc.carleton.edu/getsi/index.html
This is the GETSI project website. It gives background information on the project and is the primary publication site of the teaching modules when they are complete. Development workspaces allow for internal project notes and draft module text. The modules from this IUSE award are published alongside the classroom modules but are listed as the GETSI Field Collection.

Participants

Individuals
Donna Charlevoix UNAVCO Co-PI 0 Months
As the Director of UNAVCO's Education and Community Engagement, Charlevoix is responsible for coordination with the science community and the successful accomplishment of the work. Her salary is covered through the NSF GAGE Facility Cooperative Agreement.

Beth Pratt-Sitaula UNAVCO Co-PI 2 Months
A UNAVCO Educational Specialist, Pratt-Sitaula serves as the GETSI facilitator in charge of project logistics and communication. She coordinates between UNAVCO, the authors, technical experts, beta-testers, SERC, NAGT, and related organizations. She leads dissemination (meeting presentations, journal papers, articles, website content, webinars) and will ultimately write the geodesy curriculum developer’s manual. Pratt-Sitaula’s funding to work on GETSI Field Collection is entirely from this NSF IUSE award.

Christopher Crosby UNAVCO Professional 0 Months
C. Crosby served as a co-instructor on all the short courses in which project materials were presented. He also provides regular technical and structural advice for the project. His salary is covered through the NSF GAGE Facility Cooperative Agreement.

Marianne Okal UNAVCO Professional 0 Months
Okal served as short co-instructor for the August 2016 short course. Her salary is covered through the NSF GAGE Facility Cooperative Agreement.
Ian Lauer  UNAVCO and ISU  Student  2 Months
Lauer was a UNAVCO Summer Internship Program (USIP) intern in summer 2016. He began work on the GPS module and supported the August 2016 short course. He also continued work on the project under the Idaho State University part of the grant during the remainder of the reporting period. That work is captured in the ISU report.

Ellen Iverson  SERC  1 month
Iverson is the lead assessment consultant and external evaluator for the GETSI project. She is paid by SERC (Science Education Resources Center) via a service agreement with this NSF IUSE project.

Monica Bruckner  SERC  0 month
Bruckner is the webmaster for the GETSI project. She supports any team needs related to the SERC-hosted GETSI website and all issues related to submission of student data for assessment review. She is paid by SERC (Science Education Resources Center) via a service agreement with this NSF IUSE project.

Organizations
Type: Academic Institution
Name: SERC (Science Education Resource Center)
Location: Northfield, MN
Contribution: Assessment and evaluation; dissemination; web hosting
Details: SERC is providing assessment design, external evaluation, project dissemination, and webhosting through a service agreement. GETSI module design and assessment are following the model of SERC’s InTeGrate project. Expert assessment consultants are reviewing modules and student data is collected using the InTeGrate collection system. SERC is also hosting the GETSI website and providing content management assistance for the site and webinars. As needed, GETSI announcements go out through SERC channels to the wider geoscience community. Ellen Iverson, a SERC assessment specialist, is providing external evaluation of the GETSI project (Appendix).

Type: Other Nonprofits
Name: National Association of Geoscience Teachers (NAGT)
Location: Northfield, MN
Contribution: Collaborative Research
Details: NAGT is collaborating with GETSI Field Collection on dissemination. For example, as part of publicizing short courses, announcements went out on NAGT listservs.

Impacts
What is the impact on the principal discipline?
Geodesy encompasses an increasingly important set of geoscience methods for better understanding earth processes. Its scope has greatly increased from early applications of surveying and tectonic plate motions to include critical insights into natural hazards, climate change, and water resources. Researchers now use a variety of very valuable field geodetic methods (TLS, SfM, GPS), but the barriers to use in undergraduate field courses
remain high. This project is considerably lowering these barriers by providing comprehensive teaching resources for using field geodetic methods in undergraduate courses.

**What is the impact on society beyond science and technology?**

As our global population continues to increase, living in ever more marginal lands with ever-increasing temperatures and decreasing water resources, our ability to mitigate effectively for natural hazards, respond to climate changes, and manage our common resources becomes ever more critical. The GETSI project and the GETSI Field Collection are framing the study of earth science through the lens of societally important questions. The aim is to increase students’ (future geoscience workforce’s) ability to analyze and address these challenges with tangible skills.

**Changes/Problems**

**Actual or Anticipated problems or delays and actions or plans to resolve them**

So far the project is proceeding on schedule.
Appendix – Report from External Evaluator

Year One Evaluation Report
Prepared for GETSI Field by
Ellen Iverson, Director of Evaluation
Science Education Resource Center (SERC) at Carleton College

Summary
The first year of the GETSI: Field-Based Curriculum project focused on module development and holding the first field short course. During this period, the first module Analyzing High Resolution Topography with TLS and SfM (http://serc.carleton.edu/getsi/teaching_materials/high-rez-topo/index.html) was completed. In addition, the accompanying short course was positively received by participants with 16 of the 21 participants indicating a willingness to be part of a pilot test. The second module High Precision Positioning with Static and Kinematic GPS/GNSS was under development during this grant-reporting period. This module is on track to be publicly available during the next academic year. Of the three goals for the project, strong progress has been demonstrated on the first two goals with some indication that the third goal could be met with further data collection.

Progress on Project Goals
The GETSI: Field-Based Curriculum project proposed to meet three goals for the project:

Goal 1. Build student understanding of geodetic instrumentation, techniques, and applications

Objective 1.1: Increase student understanding of geodetic instrumentation, methods, and applications, specifically Terrestrial Laser Scanning (TLS), Structure from Motion (SfM), and Static and Real-time Kinematic (RTK) Global Positioning Systems (GPS)

Objective 1.2: Increase student ability to collect, analyze, manipulate and interpret geodetic field data

Objective 1.3: Increase students’ knowledge of the array of scientific challenges and problems that can be studied using geodetic tools

Evidence of progress for Goal 1: The project has two lines of evidence for progress on the student understanding goal:

1. Student work collected from two pilots prior to the summer field short course. As described under Module 1: Analyzing High Resolution Topography with TLS and SfM, the collected unit assessments of the student work demonstrated student achievement of learning outcomes that were in line with the three learning goals of the module. The student work showed outcomes related to student understanding of Objective 1.1 and outcomes related to student abilities related to Objective 1.2. The unit assessments collected from faculty did not include a pre-test so it was not possible to determine whether the student outcomes were an increase. Student work for Pilot test B characterized students perceptions about how geodetic tools could address scientific problems which relates to Objective 1.3.

2. Faculty perception data collected through end of workshop surveys. These survey responses underscored how faculty anticipated that the materials would influence student learning and related to the specific objectives.
As the second module moves past Checkpoint 4, it will be important to collect additional evidence of student understanding.

**Goal 2. Increase faculty efficacy in teaching geodetic techniques in geology field courses**

  **Objective 2.1:** Develop robust learning modules for field or classroom use that are flexible enough for instructors to integrate into field camps and classes

  **Objective 2.2:** Increase faculty knowledge of best practices for instruction in field courses

**Evidence of progress for Goal 2:** The project has two lines of evidence for the faculty efficacy goal:

1. The piloting and publishing of *Module 1: Analyzing High Resolution Topography with TLS and SfM* included meeting a rigorous materials development rubric which ensured that the module was of high quality and that the student work demonstrated learning related to the module goals. In addition, each pilot used different sets of units thus demonstrating that the module could meet learning outcomes with flexibility in types of field integration.

2. The end of survey for the field course showed that faculty perceived that they left the short course with higher faculty efficacy related to teaching geodetic techniques in the field (see Table 1).

The project is on track to strengthen the claims of this goal through data collected at the additional short course and testing on the remaining module.

**Goal 3. Obtain baseline data from faculty to better understand successes and challenges of implementing pre-developed curricular materials in field education experience**

  **Objective 3.1:** Document faculty experience in field instruction, motivation for incorporating geodetic technologies, and working knowledge of best pedagogical practices

**Evidence of progress for Goal 3:** The project aims to collect instructor stories and structured reflection from faculty who piloted the field materials. To date, one instructor story and two structured feedback reflections (from field course participants) have been collected. The two feedback surveys characterized the types of successes and challenges faculty experienced when implementing the module materials and the ways the materials are used and adapted. The feedback survey instrument appears to collect useful data about faculty prior knowledge and faculty perceptions related to adopting and adapting the materials. Responses to the instrument fail to collect specific information about faculty motivation or their working knowledge of pedagogical practices. Explicit items related to these aspects may be useful additions to the survey in order to meet objective 3.1. In general, more data is needed to evaluate Goal 3.

**Module 1: Analyzing High Resolution Topography with TLS and SfM**

As described in the proposal, the TLS units for *Analyzing High Resolution Topography module* were developed and piloted in 2015. During the grant period, the module was revised to include SfM units and a fuller Unit 5 summative final student project. The full module was
reviewed by both the Project Lead (Pratt-Sitaula) and the External Evaluator (Iverson) using a modified GETSI materials development rubric adapted for field course materials. In response to feedback from the full review, the module was modified to give more explicit instructions on how to give early formative feedback on unit activities. The unit assessment tips promote greater flexibility of the curriculum in the field. In addition, all provenance and copyright was updated for the publicly available module.

As part of the review of the module, student work from two pilots was also reviewed. In Pilot test A, students completed Units 1, 4, and 5. Student work of the Unit 5 project report was included for the review. In Pilot test B, students completed Units 1, 2, and 3. Because of inclement weather during the field course, students were not able to complete the Unit 5 summative as planned. Earlier unit assessments from pilot B were available for review (e.g., responses to the question, “What is the societal impetus to study this feature and why is TLS a good method to use?” and “What other geological research questions would you like to apply TLS survey to and why?”) While each of the pilots covered different units, the student work demonstrated students’ ability to meet the three module learning goals for the units covered, namely:

1. Students will be able to design and conduct a complex TLS and/or SfM survey to address a geologic research question.
2. Students will be able to articulate the societal impetus for answering a given geodetic research question.
3. Students will be able to justify why TLS and/or SfM is the appropriate method in some circumstances.

Thus, the pilots demonstrated the flexibility and adaptability of the field curriculum with demonstrated student learning outcomes. The module is currently being tested by Dr. David Schmidt at the University of Washington-Seattle Campus in order to gain more direct feedback on the SfM portion of the resources.

**GETSI Field-Based Materials Development Rubric.** The materials development rubric used for this project is based on the InTeGrate materials development rubric but aligned to the guiding principles of the Field-Based curriculum project. The main differences with the guiding principles is that the “Module develops student ability to address interdisciplinary problems” is removed. Students are still required to articulate how/why the research method might be applied to societally important topics/challenges, but they do not engage in an interdisciplinary analysis as this level of analysis is beyond the scope of what is feasible for a typical field course. As is true of other GETSI modules, the systems thinking aspect that is part of the InTeGrate rubric is replaced by Learning strategies and activities support quantitative problem solving.

The module is publicly available and one instructor story (by Dr. Bruce Douglas) is available. The module is on track for collecting additional faculty reflections as it is currently being tested by Dr. David Schmidt at the University of Washington-Seattle Campus.

**Module 2: High Precision Positioning with Static and Kinematic GPS/GNSS**

During this grant period, the second module was reviewed at Checkpoint 2 (Checkpoint 2 includes Breadth, Depth, and Assessment: The purpose of this checkpoint is to provide
comprehensive feedback on the structure of the materials, the pedagogic design of the materials and assessments, and the alignment of assessments, materials and goals). At the time of that review, sufficient materials were available to meet the first two module learning goals: 1) Students will be able to design and conduct static and/or kinematic GNSS surveys to address a geologic research question. 2) Students will be able to justify why different high precision positioning techniques are appropriate in different situations. More of the module materials was needed to evaluate the third learning goal: Students will be able to justify the benefit to society of answering a given research question. In addition, more work on the summative assessment questions was suggested. The module was reviewed at Checkpoint 3 by Pratt-Sitaula where the review found that Unit 3 and 3.1 were complete and recommended changes to Units 1 & 2. Unit 3 had additional proto testing completed. The module appears nearly ready for Checkpoint 4, at which point it is ready for course testing. It is on schedule for being publicly available during the next academic year.

Short Course: Using TLS and Structure from Motion (SfM) Photogrammetry in Undergraduate Field Education held on August 16-19, 2016 at Indiana University Geologic Field Station in Cardwell, MT

The goal of this workshop was to equip instructors of geoscience courses with field components with the knowledge and skills needed to integrate terrestrial laser scanning (TLS) and structure from motion (SfM) photogrammetry methods and applications into their courses. The type of teaching resources that were featured can be previewed in the published module. The evaluation of the short course was accomplished through two roadchecks and a final end of workshop survey. All 21 participants completed the end of workshop survey. All participants reported value from their field workshop experience and described either how the workshop deepened their understanding of the material or reported on the value of gaining additional tips and tricks for teaching in the field.

In the end of workshop survey, participants reported that all of the learning goals of the modules were important. The overwhelming majority (90%) of the participants reported that students were likely to accomplish the learning goals from using module materials. Without regard to the prior knowledge, the faculty participants left the workshop with high confidence in using the materials (see Table1). The participants reported their perceptions for how students would learn from the materials and these quotes exemplify some of their comments:

- "These materials provide a clear workflow that we can follow. We can apply these methods to data we already have and organize them, for students who have no idea about TLS or SfM, they could definitely master how to implement a project to build their own model according to materials here."
- "It is great to have pre-vetted materials for the instructor. Especially the step-by-step software materials because they are really tedious to create (Thanks!). The materials also do a good job of emphasizing the need to identify the research question before starting the surveys. I also appreciate the "social impact" pieces because a lot of times this is left out (or minimized) of education in general"
"The module would help build enthusiasm for new technology and understand technologies advantages over alternative techniques."

Table 1 Knowledge and readiness to incorporate TLS and/or SfM in field courses

<table>
<thead>
<tr>
<th>Statement</th>
<th>Disagree (slightly, moderately, or strongly)</th>
<th>Agree (slightly, moderately, or strongly)</th>
<th>Statement</th>
<th>Disagree (slightly, moderately, or strongly)</th>
<th>Agree (slightly, moderately, or strongly)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before the short course I already knew a lot about TLS survey methods and applications (n=21)</td>
<td>57.5%</td>
<td>42.5%</td>
<td>I am confident in my ability to explain TLS methods and applications to students (n=21)</td>
<td>0%</td>
<td>100%</td>
</tr>
<tr>
<td>Before the short course I already knew a lot about teaching TLS survey methods and applications to students (n=21)</td>
<td>90%</td>
<td>10%</td>
<td>I am confident in my ability to facilitate student accomplishment of Analyzing High Resolution Topography module learning goals using TLS (n=21)</td>
<td>0%</td>
<td>100%</td>
</tr>
<tr>
<td>Before the short course I already knew a lot about SfM survey methods and applications (n=21)</td>
<td>52%</td>
<td>48%</td>
<td>I am confident in my ability to explain SfM methods and applications to students (n=21)</td>
<td>4%</td>
<td>96%</td>
</tr>
<tr>
<td>Before the short course I already knew a lot about teaching SfM survey methods and applications to students (n=20)</td>
<td>80%</td>
<td>20%</td>
<td>I am confident in my ability to facilitate student accomplishment of Analyzing High Resolution Topography module learning goals using SfM (n=21)</td>
<td>5%</td>
<td>95%</td>
</tr>
</tbody>
</table>