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

Project Period: 06/01/2016-05/31/2019
UNAVCO 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 with the Borah Peak Idaho earthquake scarp in the background. The short course on GPS surveying methods was held August 2018 at Idaho State University campus and field camp. Twenty geoscience field instructors were participants. (Photo by Colin Shaw, University of Montana)
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 (Science Education Resource Center), 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 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 grant we have:

- Completed and published two teaching modules related to field geodesy
  - High Precision Positioning with Static and Kinematic GPS/GNSS
    [https://serc.carleton.edu/getsi/teaching_materials/high-precision/index.html](https://serc.carleton.edu/getsi/teaching_materials/high-precision/index.html)
  - Analyzing High Resolution Topography with TLS and SfM
    [https://serc.carleton.edu/getsi/teaching_materials/high-rez-topo/index.html](https://serc.carleton.edu/getsi/teaching_materials/high-rez-topo/index.html)

- Conducted three* 2.5-day in-person professional development short courses for a total of 66 participants
  - 2016 – Using TLS and Structure from Motion (SfM) Photogrammetry in Undergraduate Field Education
  - 2017 – Using high resolution topography, UAVs, and GPS in undergraduate field education
  - 2018 - Using high resolution topography, UAVs, and GPS in undergraduate field education

- Led a webinar on the field education modules in collaboration with SERC’s InTeGrate Project—Integrating GPS, SfM, and TLS into Geoscience Field Courses

- Analyzing High Resolution Topography module was included in AGU short course Hooking undergraduates into geophysics data and methods (GPS, Lidar, InSAR, SfM photogrammetry) through societal important issues. (26 participants)

- Analyzing High Resolution Topography module was included in six UNAVCO/GAGE-sponsored GSA and AGU short courses related to TLS and SfM. More than 100 participants were at these courses. The short course emphases were on the technical aspects of the methods, but the educational module was also introduced.

- Sessions related to field education geodetic methods were proposed and executed by participants in the 2016 Geodesy Field Education short course at both GSA and AGU annual meetings in 2017.
  - GSA: T123. Pedagogical Applications of Point Cloud Collection and Manipulation
  - AGU: Field Geodesy in Undergraduate Education: Using Photogrammetry, Lidar, Sonar, and GPS to Promote Spatial Learning

- Gathered feedback from thirteen module users in “Share Your Experience” surveys in order to better understand adaption and adoption practices of instructors.

- Gathered feedback from short course participants on continuing challenges in
geodesy field education implementation

*Note: the original proposal only included two professional development short courses but through collaboration with UNAVCO, NSF GAGE, and Septentrio (GPS manufacturer) we are able to do three courses.

**Specific Objectives**

We concur with the assessment by the Science Education Resource Center external evaluator that this project has had significant accomplishments related to the Project Goals (see SERC report in Appendix B).

**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, throughout the grant we have conducted professional development short courses and other training activities as detailed above in "Major Activities". Overall, participant satisfaction has been very high as shown in the report by the Science Education Resource Center external evaluator (see SERC report in Appendix B). Participants also show good gains in confidence about teaching field geodesy methods.

Based on feedback from 28 of the 43 participants in the 2016 and 2017 short courses, a total of >450 undergraduate students learned elements of the geodetic field methods through the modules developed by this project. Approximately 200 students learned one or more of the geodetic field methods directly from the project PIs. Another 135 undergraduate students used prepared data from GETSI Field and >50 graduate students were taught with the module materials. Feedback surveys from 13 module adopters gave the modules an overall quality rating of 8.75 out of 10 and offered suggestions for further improvement. When asked if they planned to use the module again (4=very likely, 3=somewhat likely), instructors averaged a response of 3.9.

One MS Geology graduate student, Ian Lauer from Idaho State University, was an active contributor to this project. He participated in the design and implementation of the 2017 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 include the teaching modules and the professional development short courses and webinar. Both modules were published online as part of the GEodesy Tools for Societal Issues (GETSI; [http://serc.carleton.edu/getsi](http://serc.carleton.edu/getsi)) Field Collection, which is hosted by the very well known SERC website (5 million visitors per year). 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

**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, Denver CO
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, San Francisco CA
Authors: Beth Pratt-Sitaula, Katherine Shervais, Christopher Crosby, Bruce Douglas, Benjamin Crosby, Donna Charlevoix

Title: Teaching Resources and Instructor Professional Development for Integrating Laser Scanning, Structure from Motion, and GPS Surveying into Undergraduate Field Courses
Conference: American Geophysical Union Annual Meeting 2017, New Orleans LA
Authors: Donna Charlevoix, Beth Pratt-Sitaula, Bruce Douglas, Benjamin Crosby, Christopher Crosby, Ian Lauer, Katherine Shervais

Title: Data-rich societally-situated undergraduate teaching resources and instructor professional development for geoscience classrooms and field courses
Conference: Earth Educators Rendezvous 2018, Lawrence KS
Authors: Beth Pratt-Sitaula, Donna Charlevoix, Becca Walker, Bruce Douglas, Benjamin Crosby, Meghan Miller

Title: Integrating High Resolution Topography Methods into Undergraduate Field Courses
Conference: American Geophysical Union Annual Meeting 2018, Washington DC
Authors: Beth Pratt-Sitaula, Bruce Douglas, Christopher Crosby, Katherine Shervais, Yonathan Admassu

Title: Context matters: Designing data-rich geodesy teaching materials that get used
Conference: Earth Educators Rendezvous 2019, Nashville TN
Authors: Kristin O’Connell, Beth Pratt-Sitaula, Becca Walker, Bruce James 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 was covered through the NSF GAGE Facility Cooperative Agreement.

Beth Pratt-Sitaula  UNAVCO  Co-PI  4 Months
A UNAVCO Educational Specialist, Pratt-Sitaula served as the GETSI facilitator in charge of project logistics and communication. She coordinated between UNAVCO, the authors, technical experts, pilot-testers, SERC, NAGT, and related organizations. She led dissemination (meeting presentations, journal papers, articles, website content, webinars). Pratt-Sitaula’s funding to work on GETSI Field is entirely from this NSF IUSE award.

Christopher Crosby  UNAVCO  Professional  1 Month
C. Crosby served as a co-instructor on two of the short courses in which TLS materials were presented. He also provides regular technical and structural advice for the project. His salary was covered through the NSF GAGE Facility Cooperative Agreement.

Marianne Okal  UNAVCO  Professional  1 Month
Okal served as short course co-instructor for the August 2016 and 2017 short courses. Her salary was covered through the NSF GAGE Facility Cooperative Agreement.

Ian Lauer  UNAVCO and ISU  Grad Student  4 Months
Lauer was a UNAVCO Summer Internship Program (USIP) intern in summers 2016 and 2017. He continued work on the GPS module and supported the August 2017 and 2018 short courses. He also worked 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. Ian was jointly funded through the UNAVCO and ISU portions of this NSF IUSE award.

Ellen Iverson  SERC  Professional  0 month
Iverson was the lead assessment consultant and external evaluator for the GETSI project. She was paid by SERC (Science Education Resources Center) via a service agreement with this NSF IUSE project.

Monica Bruckner  SERC  Professional  1 months
Bruckner was the webmaster for the GETSI project. She supported any team needs related to the SERC-hosted GETSI website and surveys. She was paid by SERC (Science Education Resources Center) via a service agreement with this NSF IUSE project.
Kristin O’Connell  SERC  Professional  1 months
O’Connell supports Iverson on assessment and evaluation for the GETSI project. She was 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, SERC Director of Evaluation, and Kristin O’Connell, SERC Evaluation Specialist, are providing external evaluation of the GETSI project (see SERC report in Appendix B).

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 lowering these barriers considerably by providing comprehensive teaching resources and instructor professional development for using field geodetic methods in undergraduate courses. With the development of modular curricular material, the barrier for incorporating geodetic methods into field curriculum is lowered and as a result we are increasing the number of faculty who will use these materials and thereby increasing the number of students who will learn about geodesy and geodetic methods.
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

Nothing to report
Appendix A – Outcomes report for general public

This project aimed to improve undergraduate student learning in geoscience field education through development of teaching modules that combine geoscience content and geodetic technologies, as well as provide the needed professional development for field instructors to use the materials. Geodesy is the study of the size, shape, and mass of the Earth and they change with time; recent developments have revolutionized our understanding of Earth processes and produced discoveries of major societal impact. Geodetic field techniques are particularly valuable for hazard assessment, stratigraphic analyses, and understanding plate tectonic and geomorphic processes. The particular methods included in this project were terrestrial laser scanning (TLS), structure from motion photogrammetry (SfM), and global positioning system (GPS) surveying. Fieldwork is an integral part of Earth sciences and there is a longstanding tradition of teaching field methods as part of the undergraduate curriculum; but it can be challenging to integrate more recent methods into traditional courses. The project was conceived in response to years of community requests for more geodesy field education support and shaped by community recommendations from a workshop and survey.

This grant initiated the Field Collection within the larger GEodetic Tools for Societal Issues project (GETSI; http://serc.carleton.edu/getsi). The entire GETSI project (funded through other grants) includes teaching modules and professional development for classroom courses as well. GETSI Field collaborating institutions were UNAVCO, Idaho State University, and Indiana University. Science Education Resource Center (SERC) and National Association of Geoscience Teaching (NAGT) were also critical partners. The curriculum development model was adapted from SERC’s InTeGrate project and used evidence-based best practices for STEM education and rigorous review process. The project produced and disseminated two teaching modules for majors-level undergraduate courses with field components:

- **Analyzing High Resolution Topography with TLS and SfM**
- **High Precision Positioning with Static and Kinematic GPS/GNSS**

The project also held three 2.5-day short courses for undergraduate instructors – one more than originally proposed. A total of 66 people participated and rated the workshops at an average of 9.1 out of 10 for satisfaction. Forty people also attended a webinar on the teaching modules and another >100 people were introduced to the modules in brief during other 1-day short courses run by UNAVCO.

Based on feedback from 28 of the 43 participants in the 2016 and 2017 short courses, a total of >450 undergraduate students learned elements of the geodetic field methods through the modules developed by this project. Approximately 200 students learned one or more of the geodetic field methods directly from the project PIs. Another 135 undergraduate students used prepared data sets from GETSI Field and >50 graduate students were taught with the module materials. Feedback surveys from 13 module adopters gave the modules an overall quality rating of 8.75 out of 10 and offered
suggestions for further improvement. When asked if they planned to use the module again (4=very likely, 3=somewhat likely), instructors averaged a response of 3.9.

Undergraduate instructors learn to conduct a GPS survey during a project short course.
Appendix B – SERC Final Evaluation Report
GETSI: A Field-Based Curriculum for Quantifying Deformation of the Earth's Surface with Lasers, GPS and Cameras

FINAL EVALUATION REPORT

May, 2019

SERC EVALUATION TEAM

Ellen Iverson, Ph.D., Evaluation Director
Ellen Altermatt, Ph.D.
Kristin O’Connell, M.S.
Kathryn Sheriff, M.L.I.S.

LEAD AUTHOR

Kristin O’Connell, M.S.
EXECUTIVE SUMMARY

The following report of GETSI: A Field-Based Curriculum includes findings from Year 3 and provides a summative look at success of the project overall. Major accomplishments during year three include second pilot test of the second module, High Precision Positioning with Static and Kinematic GPS/GNSS (https://serc.carleton.edu/getsiteaching_materials/high-precision/index.html), a third positively received August short course, and additional “share your experience” reflections.

PROGRESS ON PROJECT GOALS

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

Success of Goal 1 has two lines of evidence, 1) student work collected and analyzed in 2017 evaluation report, and 2) faculty perception data through multiple mechanisms including end of workshop surveys (prior to teaching with GETSI materials), and structured reflections on instructor stories (after teaching with GETSI materials).

1. Student work collected and analyzed from two pilot tests of Module 1: Analyzing High Resolution Topography with TLS and SfM demonstrated students ability to meet the three module learning goals for the units covered (see 2017 evaluation report). Additional student work from three pilot tests of Module 2: High Precision Positioning with Static and Kinematic GPS/GNSS was scored and analyzed to inform revisions.

2. Survey responses on end of workshop reflections indicate that faculty anticipated that the materials would influence student learning related to the specific module objectives (see Figures 7 & 8). Reflection responses on the InstructorSstory pages underscore that after enacting either of the GETSI field modules, student learning outcomes were largely realized, including understanding and working with geodetic data, and recognizing the limitations of geodetic data collection and uses (see instructor stories section).
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

Success of Goal 2 has three lines of evidence, 1) materials meeting rigorous standards encoded in the development rubric, 2) structured faculty reflections (“share your experience” and instructor stories) after teaching with the materials, and 3) short course survey questions related to faculty efficacy.

1. Both modules have met a rigorous materials development rubric that ensured the module was of high quality and that the student work demonstrated learning related to the module goals. This process included iterative feedback from the assessment consultant as well as informing revisions based on pilot student data. The 2017 and 2018 evaluation reports detail this process.
2. Structured faculty reflections were collected after materials were tested in author and non-author courses to better understand the flexibility of the materials and the experience teaching with the materials. The materials were successfully adapted to field and classroom settings, different sets of module units incorporated to fit with different contexts (see “Share Your Experience” and Instructor Story sections).
3. Short course end of event surveys showed that most faculty perceived an increase in their efficacy related to teaching geodetic techniques in the field, indicating confidence to facilitate the module learning goals, despite varied prior experience (see Figure 6).

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

Success of Goal 3 has two lines of evidence, 1) structured faculty reflections after teaching with the materials, and 2) Share Your Experience reflections that included questions about faculty motivation to incorporate geodetic technologies and knowledge of pedagogical practices.

1. After teaching with GETSI field modules, structured faculty reflections are gathered through two mechanisms. Instructor stories document the official project pilot tests and are using materials in their preliminary format. “Share Your Experience” forms ask faculty to reflect on their experience teaching with the final published materials. Seven instructor stories (from six instructors) and thirteen “Share Your Experience” reflections
have been submitted to date. The reflections characterize the types of successes and challenges faculty experienced when implementing the module materials and the ways the materials are adapted to fit each unique setting.

2. In addition to course context, pedagogical style, and formative module feedback, “Share Your Experience” structured reflection surveys also probe the importance that each faculty attributes to each module learning goal as well as the importance of incorporating geodetic data sets and methods, quantitative skill development, and focus on societal issues. The importance attributed to each of these items suggests an indirect measure of aspects that may inspire faculty motivation for incorporating geodetic techniques into their teaching.

**MODULE DEVELOPMENT AND TESTING**

During the third year of the project, the second module (High Precision Positioning with Static and Kinematic GPS/GNSS) was piloted in a second classroom, including the summative assessment questions and associated rubrics. A purposive sample of student assessment data drawn from two of the course enactments was scored by the project lead and external evaluator. The scoring evaluated the student work against the module learning goals and the GETSI guiding principles. Informed by this score analysis, potential module revisions may include additional teaching tips for facilitating more complete student responses such as including the rubric as part of the instruction, tips for student assessment that allow students to demonstrate how the field work connects to Geodesy Grand Challenges, and providing an answer key (specifically for Unit 3) that includes a range of possible answers that is more realistic for graphing determinations.

Data reported in the 2017 and 2018 evaluation report analyzed student data, showing that overall the students did accomplish the intended learning goals and module guiding principles.

**Instructor stories**

Faculty perceptions collected through structured reflections following pilot tests by authors and non-authors are published with the module materials as Instructor Stories (https://serc.carleton.edu/163712 and https://serc.carleton.edu/203796). These reflections highlight the various contexts in which the modules were taught, successes and challenges teaching with the materials in each specific context, and discusses outcomes. The current set of seven instructor stories (from six instructors) describe the span of settings in which the GETSI materials were piloted, from a compact field setting over 2 full days, to a course setting spread out over 10 weeks (4 hours a week). Modules were adapted and adopted to fit the context of the course and varied access to field time, including omitting module units that did not fit with the allotted schedule or field setting. Success described by faculty adopting materials in different
contexts are an indication that faculty are finding the modules flexible enough to use in various settings.

Faculty members perceive that their students performed well in relation to their own vision and goals for teaching with the materials. For example:

_ I have found that the majority of students accomplish the learning goals and gain significant confidence on using a method that initially appears daunting and complicated._

_ At the end of the exercise, the students have learned both the technical skills necessary to operate the hardware as well as the geomorphic skills necessary to interpret the results. These were the two primary goals for using the module._

One faculty described challenges with time and computer access, and despite the challenges perceived benefits for their students:

_ My goals to test most units within the module were overly ambitious. Students felt rushed through analysis. Some of the exercises were too computer and indoor-analysis intensive. Regardless, most students responded favorably to the units, some suggesting that they would pursue further experience and training in GNSS because they were so inspired by the course. Student performed very well, given the time limitations._

Another faculty addressed the progress students made on understanding limitations to geodetic data:

_ My main goal was for the students to understand the limitations of data and how to design a survey to best address a geologic problem. They all became very aware of the limitations of the system as they tried to measure topographic steps. In the end all were comfortable operating the equipment and aware of the necessity of good survey design._

**Share Your Experience**

To date, 12 complete Share Your Experience surveys have been collected, 9 from Module 1 (Analyzing High Resolution Topography with TLS and SfM Feedback), and 3 from Module 2 (High Precision Positioning with Static and Kinematic GPS/GNSS). Eleven of the twelve institutions were MS or PhD granting, with one baccalaureate institution represented.

The instructors reported a variety of types of course formats and foci, including:

- Class sizes ranging from 3 to 80 students, with an average of 27 (n=10).
- Percent of the “lecture” portion of class spent on active learning (activities, questions, discussions) varied from 5% to 90%, with an average of 43% (n=10).
Various primary course audiences from early stage earth science majors (n=4), late stage earth science majors (n=6), graduate students (n=4), and one described as “combined geoscience majors”.

The instructors reported having a wide range of prior experience with geodetic methods and applications (Figure 1).

Prior knowledge: topical methods and application
Before learning about and using this module I already knew a lot about [TLS, SfM, GPS]

Disagree (strongly, moderately, slightly) (slightly, moderately, strongly) Agree

<table>
<thead>
<tr>
<th>Method</th>
<th>9%</th>
<th>9%</th>
<th>9%</th>
<th>18%</th>
<th>27%</th>
<th>9%</th>
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<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>SfM</td>
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<td>GPS</td>
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</table>

Figure 1: Instructor self-reported prior knowledge from "share your experience" surveys

As predicted by the project, the reported implementation of the modules varied widely, with some instructors using as little as one unit, and others using as many as five units. Of the units used, some were adopted mostly as written (with little modification), while others were adapted significantly to fit course or reduce the scope (see Tables 1 & 2).

<table>
<thead>
<tr>
<th>Module 1 Modifications (n=9)</th>
<th>Unit 1- TLS</th>
<th>Unit 1- SfM</th>
<th>Unit 2</th>
<th>Unit 2.1</th>
<th>Unit 3</th>
<th>Unit 4</th>
<th>Unit 5</th>
</tr>
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<tbody>
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<td>Used the unit with little modification</td>
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<td>2</td>
<td></td>
<td></td>
<td>3</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Used elements of the unit but with significant modification to fit course</td>
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<td>4</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Used elements of the unit but greatly reduced in scope</td>
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<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Did Not Use</td>
<td>4</td>
<td>1</td>
<td>8</td>
<td>5</td>
<td>7</td>
<td>1</td>
<td>3</td>
</tr>
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</table>

Table 1: Number of instructors that selected the different levels of modification of units in Module 1

<table>
<thead>
<tr>
<th>Module 2 Modifications (n=3)</th>
<th>Unit 1</th>
<th>Unit 2</th>
<th>Unit 2.1</th>
<th>Unit 2.2</th>
<th>Unit 3</th>
</tr>
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<tbody>
<tr>
<td>Used the unit with little modification</td>
<td>1</td>
<td>2</td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Used elements of the unit but with significant modification to fit course</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
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<tr>
<td>Used elements of the unit but greatly reduced in scope</td>
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<td>1</td>
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</tr>
<tr>
<td>Did Not Use</td>
<td>1</td>
<td></td>
<td>2</td>
<td></td>
<td></td>
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</tbody>
</table>

Table 2: Number of instructors that selected the different levels of modification of units in Module 2
Instructors were also asked to attribute a level of importance to the various aspects of the module learning goals (see Figures 2 & 3), with the highest level of agreement on the importance of an “emphasis on geodetic data sets or methods”.

**Figure 2: Reported level of importance of Module 1 & 2 elements**

<table>
<thead>
<tr>
<th>Module Element</th>
<th>Somewhat Important</th>
<th>Important</th>
<th>Very Important</th>
</tr>
</thead>
<tbody>
<tr>
<td>Focus on societal issues addressed by Earth science</td>
<td>33%</td>
<td>58%</td>
<td>8%</td>
</tr>
<tr>
<td>Opportunities for student quantitative skill development</td>
<td>8%</td>
<td>50%</td>
<td>42%</td>
</tr>
<tr>
<td>Emphasis on geodetic data sets and/or methods</td>
<td>25%</td>
<td>75%</td>
<td>0%</td>
</tr>
</tbody>
</table>

**Figure 3: Reported level of importance of Module 1 specific learning goals**

<table>
<thead>
<tr>
<th>Learning Goal</th>
<th>Not Important</th>
<th>Somewhat Important</th>
<th>Important</th>
<th>Very Important</th>
</tr>
</thead>
<tbody>
<tr>
<td>Justify why TLS and/or SfM is the appropriate method in some circumstances. (n=9)</td>
<td>11%</td>
<td>33%</td>
<td>44%</td>
<td>3%</td>
</tr>
<tr>
<td>Articulate the societal impetus for answering a given research question. (n=8)</td>
<td>38%</td>
<td>38%</td>
<td>25%</td>
<td>5%</td>
</tr>
<tr>
<td>Design and conduct a complex TLS and/or SfM survey to address a geologic research question....</td>
<td>11%</td>
<td>33%</td>
<td>56%</td>
<td>0%</td>
</tr>
</tbody>
</table>

**Faculty Development and Dissemination**

The goal of the short courses and webinar was to equip geoscience field instructors with the knowledge, skill, and confidence to incorporate geodetic data into their teaching. Overall, the events were positively received and perceived to reach their goals (see Summary Table 3).
The GETSI field project hosted short courses in August of 2016, 2017, and 2018 to disseminate the two field modules. Along with formative feedback about the events, faculty were asked to reflect on their 1) prior knowledge, 2) teaching priorities, 3) confidence to teach the materials, and 4) perceived likelihood that students would accomplish the stated learning goals. Overall, participants were highly satisfied with the content and facilitation of the short courses, and 94% to 100% agreed that:

- there was a good mix of lecture and hands-on components,
- the design facilitated exchange of expertise among participants,
- the course was neither too complex nor too simple, and
- the course was well facilitated

It is notable that despite a very wide range in prior knowledge (see Figures 4 & 5), by the end of the short course faculty report confidence in their ability to teach with the relevant GETSI module (see Figure 6). Survey responses also indicate that two-thirds of all faculty think that teaching with GETSI materials will benefit students as intended (see Figures 7 & 8).

*I think the detail and sequencing of the module is going to be very successful in accomplishing all of the learning objectives (2018 participant)*

### Table 3: Professional development events highlighting the two GETSI field modules

<table>
<thead>
<tr>
<th>Short course: Using TLS and Structure from Motion (SfM) Photogrammetry in Undergraduate Field Education, Aug 16-19, 2016</th>
<th>21 participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>21 completed end of event survey</td>
<td></td>
</tr>
<tr>
<td>95-100% reported that they tended to agree or agreed that the event was well facilitated, had a good balance of lecture to hands on activities, facilitated exchange of ideas between participants, and was a good pace.</td>
<td></td>
</tr>
<tr>
<td>Short course: Using high resolution topography, UAVs, and GPS in undergraduate field education, Aug 15-18, 2017</td>
<td>25 participants</td>
</tr>
<tr>
<td>22 completed end of event survey reporting high satisfaction (9.5 out of 10)</td>
<td></td>
</tr>
<tr>
<td>Webinar: Integrating GPS, SfM, and TLS into Geoscience Field Courses, April 24, 2018</td>
<td>122 registered participants</td>
</tr>
<tr>
<td>40 participated in schedule discussion hour</td>
<td></td>
</tr>
<tr>
<td>4 completed end of event survey reporting high satisfaction (9.25 out of 10)</td>
<td></td>
</tr>
<tr>
<td>442 visitors (to date) viewed the webinar page</td>
<td></td>
</tr>
<tr>
<td>Short course: Using kinematic and static GPS in undergraduate field courses, August 14-17, 2018</td>
<td>20 participants</td>
</tr>
<tr>
<td>19 completed end of event survey reporting high satisfaction (8.7 out of 10)</td>
<td></td>
</tr>
</tbody>
</table>

2016-2018 August Field Short Course Summary

The GETSI field project hosted short courses in August of 2016, 2017, and 2018 to disseminate the two field modules. Along with formative feedback about the events, faculty were asked to reflect on their 1) prior knowledge, 2) teaching priorities, 3) confidence to teach the materials, and 4) perceived likelihood that students would accomplish the stated learning goals. Overall, participants were highly satisfied with the content and facilitation of the short courses, and 94% to 100% agreed that:

- there was a good mix of lecture and hands-on components,
- the design facilitated exchange of expertise among participants,
- the course was neither too complex nor too simple, and
- the course was well facilitated

It is notable that despite a very wide range in prior knowledge (see Figures 4 & 5), by the end of the short course faculty report confidence in their ability to teach with the relevant GETSI module (see Figure 6). Survey responses also indicate that two-thirds of all faculty think that teaching with GETSI materials will benefit students as intended (see Figures 7 & 8).
It will allow the students a likely first opportunity to learn about uncertainty and different types of measurement techniques. After completion of the module, the students would have successfully worked with many different types of instruments and datasets, providing them with a great set of tools for future work (2018 participant)

**Prior knowledge** Faculty attending the short courses reported a wide range of prior knowledge of topical methods and application of the relevant survey instruments, with a slightly higher knowledge of GPS as compared to SfM and TLS (see Figure 4). The majority of 2016 and 2017 participants indicated that they did not know a lot about teaching SfM and TLS methods and applications to students, while over half of 2018 participants had knowledge of teaching GPS methods and applications to students (see Figure 5).

### Prior knowledge: topical methods and application

*Before the short course I already knew a lot about [TLS, SfM, GPS] methods and applications:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Agree</td>
<td>23%</td>
<td>24%</td>
<td>32%</td>
<td>25%</td>
<td>5%</td>
</tr>
<tr>
<td>Disagree (strongly, moderately, slightly) (slightly, moderately, strongly)</td>
<td>14%</td>
<td>14%</td>
<td>14%</td>
<td>16%</td>
<td>16%</td>
</tr>
<tr>
<td>Agree</td>
<td>18%</td>
<td>10%</td>
<td>9%</td>
<td>5%</td>
<td>11%</td>
</tr>
<tr>
<td>Disagree (strongly, moderately, slightly) (slightly, moderately, strongly)</td>
<td>32%</td>
<td>30%</td>
<td>23%</td>
<td>30%</td>
<td>26%</td>
</tr>
<tr>
<td>Agree</td>
<td>14%</td>
<td>10%</td>
<td>9%</td>
<td>15%</td>
<td>5%</td>
</tr>
<tr>
<td>Disagree (strongly, moderately, slightly) (slightly, moderately, strongly)</td>
<td>10%</td>
<td>9%</td>
<td>18%</td>
<td>15%</td>
<td>16%</td>
</tr>
</tbody>
</table>

*Figure 4: Faculty perceived prior knowledge as reported on 2016, 2017, 2018 short course surveys*

### Prior knowledge: teaching methods

*2016, 2017, 2018 short course surveys

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Agree</td>
<td>36%</td>
<td>33%</td>
<td>50%</td>
<td>35%</td>
<td>26%</td>
</tr>
<tr>
<td>Disagree (strongly, moderately, slightly) (slightly, moderately, strongly)</td>
<td>36%</td>
<td>43%</td>
<td>32%</td>
<td>20%</td>
<td>11%</td>
</tr>
<tr>
<td>Agree</td>
<td>18%</td>
<td>14%</td>
<td>5%</td>
<td>25%</td>
<td>32%</td>
</tr>
<tr>
<td>Disagree (strongly, moderately, slightly) (slightly, moderately, strongly)</td>
<td>5%</td>
<td>10%</td>
<td>14%</td>
<td>10%</td>
<td>11%</td>
</tr>
<tr>
<td>Agree</td>
<td>5%</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
<td>5%</td>
</tr>
<tr>
<td>Disagree (strongly, moderately, slightly) (slightly, moderately, strongly)</td>
<td>14%</td>
<td>23%</td>
<td>32%</td>
<td>36%</td>
<td>16%</td>
</tr>
</tbody>
</table>

*Figure 5: Faculty perceived prior teaching method knowledge as reported on 2016, 2017, 2018 short course surveys*
Confidence to teach with GETSI modules and accomplish learning goals

I am confident in my ability to:

<table>
<thead>
<tr>
<th>Disagree (strongly, moderately, slightly)</th>
<th>(slightly, moderately, strongly) Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Facilitate student accomplishment of &quot;High Precision Positioning&quot; module learning goals using GPS (2018, n=19)</td>
<td></td>
</tr>
<tr>
<td>Explain GPS methods and applications to students (2018, n=19)</td>
<td></td>
</tr>
<tr>
<td>Facilitate student accomplishment of Analyzing High Resolution Topography module learning goals using...</td>
<td></td>
</tr>
<tr>
<td>Explain SfM methods and applications to students (2016 &amp; 2017, n=43)</td>
<td></td>
</tr>
<tr>
<td>Facilitate student accomplishment of Analyzing High Resolution Topography module learning goals using...</td>
<td></td>
</tr>
<tr>
<td>Explain TLS methods and applications to students. (2016 &amp; 2017, n=42)</td>
<td></td>
</tr>
</tbody>
</table>

Perceived benefits of the TLS and SfM materials for students (2016 & 2017, n=43)

Students will be able to:

<table>
<thead>
<tr>
<th>Unlikely (very, somewhat)</th>
<th>(somewhat, very) Likely</th>
</tr>
</thead>
<tbody>
<tr>
<td>Justify why TLS and/or SfM is the appropriate method in some circumstances</td>
<td></td>
</tr>
<tr>
<td>Articulate the societal impetus for answering a given research question</td>
<td></td>
</tr>
<tr>
<td>Apply a TLS and/or SfM survey findings to address a geologic research question</td>
<td></td>
</tr>
<tr>
<td>Design and conduct a complex TLS and/or SfM survey</td>
<td></td>
</tr>
</tbody>
</table>
Perceived benefits of the GPS materials for students (2018, n=19)

*Students will be able to:*

- Justify why different high-precision positioning techniques are appropriate in different situations: 5% unlikely, 37% somewhat likely, 58% very likely.
- Apply the findings of GPS/GNSS surveys to issues important to society: 5% unlikely, 58% somewhat likely, 37% very likely.
- Apply GPS survey findings to address a geologic research question: 16% unlikely, 37% somewhat likely, 47% very likely.
- Design and conduct a GPS survey: 16% unlikely, 37% somewhat likely, 47% very likely.

*Figure 8: Overall, faculty indicate that the GPS materials are likely to help students*