Inquiry-based Introductory Earth Science Laboratory Using Survey Equipment

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Recommended Citation
DOI: 10.20429/ger.2009.070106
Available at: https://digitalcommons.georgiasouthern.edu/gerjournal/vol7/iss1/6
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Abstract
A laboratory assignment entitled was developed to give high-school students an opportunity to collect, analyze, and interpret data after they have been introduced to topographic maps and associated terminology. Survey equipment (automatic level, graduated staff, and tripod) is used to collect data with the goal of creating a topographic profile along a linear transect on campus. This assignment sets itself apart from traditional introductory earth science labs because the students are using instrumentation to collect data, rather than having a data set provided for them. The benefits of this assignment include: 1) further understanding of topographic maps, 2) practice with the conversion of English units to metric, 3) familiarity with the concepts of precision and accuracy of data collection, 4) practice in evaluating mathematical formulas, 5) collaboration with peers. This lab is designed to be completed in four laboratory hours: two hours for data collection and two hours for analyses and lab report writing.

Keywords
Introductory, Earth science, Laboratory, Inquiry-based, Survey equipment

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Inquiry-based Introductory Earth Science Laboratory
Using Survey Equipment

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Abstract: A laboratory assignment entitled Continued Exploration of Topographic Maps: Determining Elevation laboratory was developed to give high-school students an opportunity to collect, analyze, and interpret data after they have been introduced to topographic maps and associated terminology. Survey equipment (automatic level, graduated staff, and tripod) is used to collect data with the goal of creating a topographic profile along a linear transect on campus. This assignment sets itself apart from traditional introductory earth science labs because the students are using instrumentation to collect data, rather than having a data set provided for them. The benefits of this assignment include: 1) further understanding of topographic maps, 2) practice with the conversion of English units to metric, 3) familiarity with the concepts of precision and accuracy of data collection, 4) practice in evaluating mathematical formulas, 5) collaboration with peers. This lab is designed to be completed in four laboratory hours: two hours for data collection and two hours for analyses and lab report writing.

The earth sciences are an exciting and dynamic field that has practical application needed by students who foresee themselves pursuing careers in science or non-science. Students enrolled in an earth science laboratory should not only leave the course with the ability to interpret the beauty of the natural environment around them, but also the material covered in the laboratory should prepare them to be thoughtful citizens who can comprehend the processes behind geologic hazards. With that stated, a major tool used by earth scientist’s to first interprets the natural environment and to locate areas of potential hazard (geologic or otherwise) often starts with a topographic map of the area of interest. The ability to locate and interpret areas on topographic maps is an essential skill that will serve students beyond the completion of an introductory earth science course. However, exercises using topographic maps often do not stimulate thought and inquiry. In addition, as mentioned by Rapp, Culpepper, Kirby, and Morin (2007) novice earth science students often have difficulty visualizing three-dimensional interpretations of flat, two-dimensional displays.

Students who are actively engaged in the learning process will grasp concepts more completely than in situations where they are not asked to gather or process information (Apedoe, Walker, & Reeves, 2006). Although content is undoubtedly a necessary foundation for learning, content-oriented lectures and laboratories provide little stimulation beyond memorization and have little significant value when compared to hands-on activity (Abrams, 1998; Jones, 2000; Kubicek, 2005). An inquiry-based earth science laboratory provides the same hands-on analytical opportunities as those experienced by other laboratory sciences, such as biology, chemistry, and physics. Moreover, it has been shown that courses that involve field exercises boost student interest and attitude toward the subject material being taught (Kern & Carpenter, 1984; Spencer, 1990).
I have developed an introductory earth science laboratory for non-science majors that incorporate the use of survey equipment, global positioning system (GPS) receivers, and topographic maps. It is essential to the success of this laboratory that students are introduced to topographic maps prior to starting this exercise. For this reason, this laboratory is taught the week following exercises that introduce topographic map concepts such as contour lines, scale, topographic profiles, and latitude and longitude.

The initial focus of this assignment is to give students the opportunity to have a hands-on experience with field equipment—a concept not typical in introductory earth science courses. The opportunity to set up, calibrate, and operate a piece of equipment completely unfamiliar to the students provides a learning situation in and of itself. Fuller, Gaskin, and Scott (2003) suggested an enhanced understanding of the subject and skills when learning to use specific equipment in field situations. As part of the laboratory introduction I have put together step-by-step instructions on how to properly set up the automatic level. These instructions are meant to do the following: a) ensure student success at the start of the laboratory, which increases morale, b) limit the amount of time the instructor needs to spend with each group during the set up phase, c) emphasize the proper use and calibration of the instrument, and d) promote quality data collection. The instrument set-up activity is a drill in problem-solving, and therefore a crucial phase of the learning experience. Students work through their questions within the group before consulting the instructor.

The secondary focus of the exercise is to collect, analyze, and present data gathered using the survey equipment and the GPS receiver. The students are provided field sheets that clearly outline the data they will need to collect in the field. The students also have the understanding that the quality of the data collected in the field determines the overall quality of the final laboratory report. This makes for a good platform to discuss cumulative error, and the differences between accuracy and precision.

Introducing this laboratory early in the semester has several benefits. First, it allows students the opportunity to interact in a field setting that is deemed more informal than the classroom. This allows students to quickly form bonds with peers that often evolve into study groups. Second, from grading the laboratory reports the instructor gains a firm understanding of the overall strengths and weaknesses of each student. It is especially important to determine the mathematical aptitude of non-science students early on; students who do poorly on the lab may be referred to tutoring. Third, a solid foundation in understanding topographic maps and the intricacies of GPS will set the stage for success in sequential physical geology laboratories.

Description of Activity

The purpose of this inquiry-based laboratory exercise is to provide an opportunity for students to apply knowledge gained from lectures to a field situation. The success of this laboratory relies heavily on the students having been previously introduced to terms relating to topographic maps and GPS. In a sequence of laboratories that I have taught, this particular exercise fell in the third week following a laboratory introducing maps, and then a laboratory introducing the use of GPS and topographic maps. The recommended class size is 25 students; these are divided into five groups of five students each with its own set survey equipment (automatic level, graduated staff, and tripod), GPS receiver
and United States Geological Society (USGS) topographic map of the campus. Because a primary goal of this laboratory is to create a topographic profile, the location that the instructor chooses is essential to the success of the assignment. I often choose transect locations that reflect a sharp decline or incline in elevation that dramatically illustrates topography for the students.

Prior to the beginning of the exercise a written introduction to the laboratory, provides a refresher on topographic maps, GPS, as well as background information on the purpose of surveying, the surveying instrumentation, the surveying terms (e.g. benchmark, foresight, backsight, turningpoint) and the needed surveying calculations. Students are also given a summary of the goals of the laboratory, guidelines on the time requirements for completing the exercise, suggestions about dressing appropriately for the weather, reminders to use the equipment appropriately, and an example of what their end-product (topographic profile) should resemble (Figure 1).

*Figure 1.* Example of a topographic profile and the associated field data.

<table>
<thead>
<tr>
<th>BS</th>
<th>HI</th>
<th>FS</th>
<th>Elevation</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.32'</td>
<td>90.55'</td>
<td>0.86'</td>
<td>83.23'</td>
<td>BM</td>
</tr>
<tr>
<td>8.11'</td>
<td>97.80'</td>
<td>1.54'</td>
<td>89.69'</td>
<td>2</td>
</tr>
<tr>
<td>5.36'</td>
<td>101.62'</td>
<td>1.62'</td>
<td>96.26'</td>
<td>TP</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>100'</td>
<td>4</td>
</tr>
</tbody>
</table>

**Definitions:** BS - Back Sight, HI - Height of Instrument, FS - Fore Sight, BM - Bench Mark, TP - Turning Point

**Note:** In the field you will only collect BS and FS. Keep track of your units! You will need to do calculations to solve for HI and Elevation. The shaded boxes will be left empty.
The purpose of this schematic is to show students what the end product of their lab should resemble. As part of the laboratory assignment they will use the data they collected in the field to make their own topographic profile.

The next section of the exercise guides students through the instrument set-up procedure. The basic set-up includes one step: the attachment of the level to the tripod. Following this step, the students will be asked to level the instrument. It has been my experience that leveling the instrument is the largest source of frustration in this laboratory and proves to be difficult for students. Because leveling the instrument is crucial to data accuracy and because it needs to be done every time the instrument is moved, it is worthwhile for the instructor to touch base with each group before they proceed to the next section of the assignment.

The next step will be for students to determine what role they will have within their group. The position titles and descriptions are as follows: runner-- the person who ‘runs’ the level, and therefore looks through the sight toward the staff to get the measurement; data collector-- the person who writes down the information relayed by the runner; staff-- the person holding the graduated staff in position; measurers- two people who measure out the transect in 50-ft sections prior to moving the instrument. Positions could be rotated during the course of the experiment, although for accuracy, I recommend that the runner remains the same person throughout.

With the roles assigned, the students can begin to collect data by taking measurements. Steps 1-4 are listed below and appear just as I have written them for the student laboratory.

Figure 2. Photo depicts student positions and may help readers to visualize steps 1-4.

NOTE: Photograph of one group of physical geology laboratory students working through the topographic map laboratory. The person in the foreground holds the position referred to as staff; he is facing the runner (at the level) and the data collector (right). The two other students hold the positions referred to as measurers.
Step 1. Set up and level the instrument 50 ft away from your bench mark (BM). Thus, the person with the graduated staff should be at the starting point of the transect (labeled BM) and the level should be 50ft in front of that position. Be sure to mark the BM with a flag and write down the GPS coordinates from the receiver. After you have centered the bubble on the level, you can read your measurement by looking through the sight. Record this measurement as a backsight (BS) on the sheet labeled “Field Copy” (Figure 3).

Figure 3. Data sheet referred to as field copy.

<table>
<thead>
<tr>
<th>BS +</th>
<th>HI</th>
<th>FS -</th>
<th>ELEVATION</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>640</td>
<td>BM</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td></td>
<td></td>
<td>TP</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td></td>
<td></td>
<td>TP</td>
</tr>
<tr>
<td></td>
<td>4</td>
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<td>5</td>
<td></td>
<td></td>
<td>TP</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td></td>
<td></td>
<td>TP</td>
</tr>
</tbody>
</table>

DEFINITIONS: BS- Back Sight  HI- Height of Instrument FS- Fore Sight BM- Bench Mark TP- Turning Point
NOTE: In the field you will only collect BS and FS. Keep track of your units! You will need to do calculations to solve for HI and ELEVATION. The shaded boxes will be left empty.

NOTE: Notice that the acronyms are listed underneath the chart for reference. The grey boxes are areas where data does not need to be collected. When students process their data they will be solving for the height of the instrument (HI), the foresight (FS), and the elevation. The students’ final lab copy should resemble that in Figure 1.

Step 2. The person with the staff will now move 50-ft IN FRONT of the level. This station will be marked with a flag and called station 2. Remember to write down the GPS coordinates for this station. The person “running” the level does not move. The person running the level will rotate the instrument so that it points to station 2. The instrument is already leveled, so it is not necessary to repeat the procedure at this spot (since you have
not moved the tripod). The person running the level will now read the staff and record this as a foresight (FS) on the sheet labeled “Field Copy”.

**Step 3.** The person holding the staff will STAY PUT at location 2. The person with the level will move 50 ft IN FRONT of the person with the staff. Calibrate the level and adjust it to eye-level again. The person running the level will now read the measurement. This will be recorded as a BS.

**Step 4.** The person with the staff will now move 50-ft IN FRONT of the level. This will be marked with a flag and called station 3. Use the GPS receiver to gather the coordinates. The person “running” the level will not move. The person running the level will rotate the instrument so that it points to station 3. The instrument is already leveled, so it is not necessary to repeat leveling at this spot (since you have not moved the tripod). The person running the level will now read the staff and record this as a FS on the sheet labeled “Field Copy”.

These steps will repeat themselves until the transect is complete. Typically, I have students complete a transect that is 400 ft long.

Once the field work is complete (I allot 2 hours), the data collector will need to ensure that everyone in the group has the information that s/he wrote down. Each student will then, independently, complete the laboratory report. The students will need to prepare the survey data first by making conversions from English units to metric. They will then complete topographic profiles from the data they collected that are similar to that seen in Figure 1. After these two steps are completed, there is a series of questions that make relationships between the data they gathered to the USGS topographic map of the area. Questions include: What is the scale of the map? Using your GPS coordinates, find the starting location of your transect on the topographic map. What is the elevation at this location? What is the change in elevation from the start to the end of your transect? What types of error may have been introduced during your field survey?

**Recommendations**

Using groups of five students has worked well for this field exercise as there is ample work for each position. I would not recommend a group smaller than three, unless you shortened the overall transect length or had more time to allocate to the field work portion of the assignment. Although the person deemed the ‘runner’ will be in charge of the level, I would encourage the instructor to make sure all students have taken the opportunity to calibrate the instrument and to look through the sight to take a reading from the staff. Also, the instructor needs to emphasize that the data collector needs to write legibly and listen closely to the information given by the runner.

I spend time at the beginning of the lab discussing how to read the graduated staff. Depending on the type purchased by your department, the units can be either in English units (e.g. inches, inches and feet, or in tenths of a foot) or metric (e.g. millimeters, millimeters and meters). I recommend purchasing the graduated staffs in English units and having the students convert their data into units of metric to learn to convert between systems.
The principal drawback to this assignment is would be the cost of initial set-up. If the class does have 25 students, I would recommend the purchase and use of five sets of equipment. Survey equipment can be sold as a set (automatic level, graduated staff, and tripod) or individually from a local forestry supply or survey store. The sets I purchased were around $400 each. To cut costs, instructors could attempt to contact local surveyors who may be willing to donate old survey equipment because they have upgraded to computerized technology. As far as GPS receivers are concerned, the cost of units has come down considerably in the past few years. Cost can range from upwards of $100. Although it will be more expensive, I would encourage instructors to purchase units that have Wide Area Augmentation System (WAAS) capability. An instrument with WAAS capability can improve accuracy up to 3 m on average.

Conclusions

The laboratory Continued Exploration of Topographic Maps: Determining Elevation laboratory allows students to better understand how a flat, two-dimensional image can represent a three-dimensional landscape. Likewise, this laboratory experience provides an opportunity for students to apply knowledge previously gained in lecture. The exercise is adaptable to most landscapes. If an instructor is teaching in a flat region of the country, they may want to have student’s survey mock landscapes, such as an outdoor staircase. There is other flexibility built into the laboratory such as transect length and overall time of data collection. It has been my experience that a two-hour block of time for data collection is necessary. Lastly, I have stressed that the concept and terminology associated with topographic maps are introduced prior to the start of the lab.

Acknowledgements

I would like to thank my mentor, Mary Ann Holmes, University of Nebraska-Lincoln, Department of Geosciences, for her comments/edits and continual enthusiasm. Also, I extend my gratitude to the Berry College Center for Teaching Excellence who provided me with a Summer Teaching Development Grant that supported this project.
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