

Enhancing Learning in Construction Surveying Courses

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This article describes teaching strategies used in a Construction Surveying course to improve students' performances, increase their interest in the subject and, ultimately, catalyze their learning. These outcomes are pursued by introducing several structured competitions and by exposing students to the powerful capabilities of state-of-the-art surveying instruments. In the competitions, students collaborate within their assigned groups and are motivated by the possibility of obtaining passing grades. The collected and processed student feedback indicates that the proposed competition-based strategies are welcome by most students and the vast majority of them strongly agree that those competitions help them learn. The article also includes a strategy to expose undergraduate students to the capabilities and complex work-flows of two surveying instruments: an accurate global navigation satellite system device with real-time-kinematic surveying capabilities, using the American (GPS) and Russian (GLONASS) constellation of satellites, and a long-range, laser-based, three-dimensional scanning system or terrestrial light detection and ranging (LiDAR) instrument. Most of the students exposed to these devices quickly expressed their enthusiasm to further learn their operations and uses.

Key Words: Construction Surveying, student competitions, GPS, laser scanners, LiDAR

Introduction

Facilitating, enhancing and catalyzing student learning is the major goal of most educators. The authors have designed and implemented a few strategies that seem to positively assist in the attainment of such goal within the context of a Construction Surveying course. These proposed strategies are to focus on two components of the motivational spectrum. One of them is the use of cooperative learning via team competitions. For this, seven team-based competitions were designed, are currently being successfully used, and are herein proposed to enhance student learning. One individual-based competition is implemented as well. It serves to compare student perceptions on different type of competitions. Student feedback on this first strategy is also presented in this article. Even though this is a single cross-sectional study, the collected feedback is positive and encouraging. The employed team learning approach, based on games and tournaments, is a recognized cooperative learning method (Johnson, 2000) and is already a well-developed technique (DeVries, 1980). The other strategy is based on motivating students by empowering them with minimal, but sufficient knowledge on the operational aspects of two powerful, state-of-the-art surveying instruments, including a survey-grade, 3D laser-based scanner (or terrestrial LiDAR instrument).

Problem Statement

The problem addressed herein is two-fold. First, field competitions were introduced in the Construction Surveying course several years ago. After learning about their initial weaknesses and strengths, adjustments were made over several academic terms. Therefore, the instructor's views and perceptions are incorporated in the current version of the competitions. The acquired pedagogical experiences are presented in this article to potentially benefit other instructors. On the other hand, student opinions and perceptions on these contests were unknown. Only some verbal feedback has been provided by students. Furthermore, the official student evaluations of instruction showed none or minimal comments about the competitions. Therefore, there were unanswered questions on the appropriateness of the competitions; on the grading scale used; on the perceived stresses felt by students; and on the amount of assistance that the competitions offered to the learning process.

The second component of the problem addressed by this article is associated with the difficulty in transmitting to undergraduate students the considerable amount of information needed to properly instruct them on the operation of modern, and complex, surveying instruments. Because it is not possible to devote a substantial portion of the class time to overcoming the learning curve of these instruments, a shortcut strategy is proposed herein to quickly empower students with some basic operational knowledge and helping them to understand the extent of instrument capability.

Enhancing Learning via Student Competitions

The competitions described herein were developed over several semesters of instruction. They where designed for similar Construction and Plane Surveying courses. The original versions of the competitions were completed by students who were not graded on their performances. This approach did not properly motivate all students. It was observed that only those with a natural appetite for learning and knowledge performed at expectation. In order to engage more students and motivate them to learn, grades were incorporated in these competitions. Grades are now assigned according to the rank that individual students, or their teams, attain in these contests. This adjustment improved student participation increasing their learning and performance. This can be seen in figure 1 below.

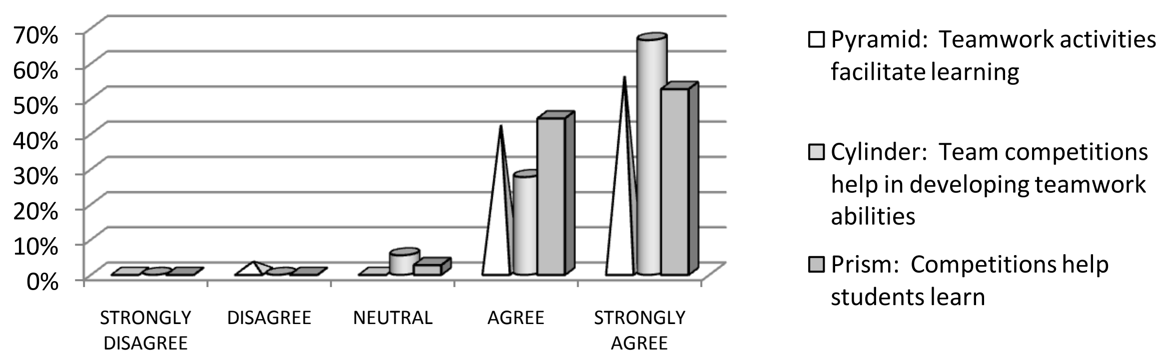


Figure 1: Student feedback on teamwork, competitions and learning

Nonetheless, in several occasions, all competing teams performed adequately, including those who ranked low, but still within tolerances. After considering informal feedback from students, it was clear that in such cases failing grades were not a fair option. Proper motivation could still be attained if students and teams competed for A, B and C grades only. Therefore, all competitions presented in the following paragraphs are currently graded in the A-C range only. However, there is a caveat: At the instructor's discretion, students or teams not achieving certain minimum accuracy standards may still receive failing grades. This passing-grade-only policy does not preclude students from failing the course. This is because competitions only represent a fraction of the total grade (10%-20%) for the course. Other components of the grade include exams, homework, attendance and peer evaluations among members of the same teams. Exams represent 60% of the total grade. The contribution of peer evaluations is selected in the 5%-10% range. These peer evaluations were incorporated to motivate all team members to properly participate in the efforts of their respective groups.

Suggested Competitions

Competition 1: Estimating Distances by Pacing

This is an individual competition where students attempt to accurately determine the length of their own personal pace and stride (1 stride = 2 paces). Afterwards, they estimate the length of an unknown distance by pacing it. To determine the length of their own pace, they walk several times, back and forth, over a given known distance. The distance chosen is 400 feet long. It is marked with an initial and a final line along a straight, and approximately horizontal, sidewalk on our campus. After walking this distance several times, and counting their paces each time, students discard counts that could be wrong or atypical (i.e., those that differ by 1 or more paces in 100 feet). Then, the retained counts are averaged to obtain the student's average number of paces in 400 feet. The length of one pace is calculated as follows: *length of one pace = (400* *ft)/(average number of paces)*. Once students know the length of their own paces, they estimate, by pacing it, the length of an unknown distance marked by the instructor in the same sidewalk. After all students have reported their estimates, the unknown distance is measured using the electronic distance measuring (EDM) device of a laser-based total station, or a regular fiberglass surveyors' tape. This unknown distance usually ranges from 150 to 250 feet. The students reporting the most accurate estimates receive higher grades. In courses with 24-30 students, grades are evenly distributed in the 70%-100% interval (i.e., C-A letter grades). This competition may be completed in less than 45 minutes.

Competition 2: Trilateration

This is a team completion. Its purpose is to teach/learn a simple land surveying procedure, trilateration. It is employed to determine/estimate the total area of a closed, polygonal region by subdividing it into triangles. For this purpose, each team is assigned a five-sided, closed, polygonal traverse on the grounds of the university. The competition consists of four main steps: (i) Subdivide the total polygonal area into simpler triangular regions. (ii) Measure the three sides (a, b, and c) of each triangle. (iii) Calculate the area of each triangle via Heron's expression, $Area = \sqrt{s\,(s-a)\,(s-b)\,(s-c)}$, where s is the semi perimeter, $s = (a+b+c)/2$. (iv) Add the areas of each triangle to obtain the total area of the complete polygonal region. Students may be required to measure the sides by pacing them or by using a regular fiberglass 100-footer tape. In order to perform the measurements, students need a clear path to walk along the sides of all triangles. Also, in order to avoid the need to project all measurements into a horizontal plane, the selected area has to be approximately horizontal. Winners are determined by comparing total calculated area against a more accurately determined area. This control area is measured via an EDM device. If students are required to measure by pacing, each student of a group may obtain their own estimated area and the group may report the averaged result. For half-acre or smaller polygons, the data collection component of this competition may be completed in less than an hour.

Competition 3: Centering and Leveling a Total-Station Instrument

This is a team competition where individual students play an important role in setting up total-station instruments with laser or optical plummets. Since each team may consist of four or five students, this competition may present four or five rounds, or legs, respectively. In each leg, one student per group attempts to set up the assigned instrument on a given iron, or stake, in the shortest possible time. In each round, students representing their groups start at the same time with their instruments detached from the tripods and the tripods resting on the floor, near their respective irons. After a student has leveled and centered the instrument within the required tolerances, they inform the instructor. In turn, the instructor checks the stationing and accepts it, or not. Those students who complete the proper procedure in the shortest times receive the highest scores. After completing all rounds, each group adds the points attained by each of its members to obtain their final score. This determines the overall performance, rank and grades (A-C) of each team. For teams with four members this competition may be completed in less than an hour (15 minutes per round).

Competitions 4 (and 5): Profile-Leveling using Auto-Levels (and Total-Stations)

During this activity, teams compete to perform a closed-loop profile leveling procedure around the building that houses the authors' academic unit. This loop is approximately 1300 feet long (≈ quarter mile) and follows the longitudinal center line of a brick sidewalk. This line is a closed seven-sided polygon with vertices marked by painted points on the sidewalk. Also, additional progression points are marked (painted) every 50 feet. Students start at a nearby official benchmark and use differential leveling techniques to obtain the elevations of all vertices and progression points. The difference in elevations between the lowest and highest point in the loop is approximately 10 feet. In this competition, students use an automatic-level or a total-station instrument. Each group is ranked based on its error of closure and on the accuracy attained in the calculated elevations for selected points (usually 7 or 8 points) along the path of the closed loop. This additional control is incorporated to detect numeric fabrication (fraud) in reportedly attained zero or quasi zero error of closures. Letter grades range from A to C. All required control elevations are previously obtained by the instructor. This is accomplished by using a seven-second total-station instrument and averaging results from repeated measurements. Alternatively, the elevations of the control points may be determined by more precise instruments (such as sub-centimeter GPS devices and/or two- or one-second total-station instruments). Students complete this competition in less than two hours.

Competition 6: Angular Error of Closure

This team competition consists in the measurement of several horizontal angles with a total-station instrument (±7 seconds precision). Each team is assigned a different closed, five-sided, polygonal traverse and is required to measure all internal angles of that traverse, which can be the same traverse used in Competition 3. At each vertex, students have to measure the corresponding internal angle in direct and reverse mode. Then, those two values are averaged to obtain the internal angle that will be reported at that particular vertex. Also, each team reports the total sum of all five internal angles. This is done to compare that figure against the actual theoretical value, $(n-2)*180°$, where n is the number of sides, or number of vertices, of the polygon. It is preferable that students are not informed a-priori about the equation that generates the corresponding theoretical value of the total sum of the internal angles. After all teams report their total sum of internal angles, the $(n-2)*180°$ expression is presented to the students and they use it to report their attained total angular error of closure. Groups with the lowest errors attain the highest grades (A-C). By performing only two measurements per vertex of a five-sided polygon, students may complete this competition in less than 1 hour and 15 minutes.

Competition 7: Linear Precision of Closed-Traverse Calculations

The purpose of this competition is to collect required data (lengths of sides and internal angles) and perform all necessary calculations to determine the area of the corresponding closed traverse. These calculations are presented in class. However, their details are also fully described in the textbook used in this course (Crawford, 2003). This contest is a team-based one and can be related to the previously described competition at the discretion of the instructor. That is, the same five-sided, closed, polygonal traverses employed in Competition 6 (and 3) may be used in this new contest. To measure the perimetral sides of their traverses, each team employs the EDM capabilities of their assigned total-station instrument. The same instruments are used to also measure the corresponding horizontal internal angles. Alternatively, if teams work on the same traverses used in Competition 6, they may decide to use the angular values obtained in that previous contest, as long as they were accurately measured. After processing the data, the linear precision attained by each group determines its final ranking in this competition. This linear precision involves the total perimetral length, P, of the traverse and the attained linear error of closure.

Competition 8: Field Book Quality

The purpose of this competition is to motivate students to properly collect field data (including graphical sketches) and adequately annotate it in their field books. This is a team competition. Even though each individual student needs to have and keep their own updated field book, only a few books (usually 2) per team are collected for this competition. The collected ones are randomly selected and ranked according to their relative completeness and neatness. Then, teams receive the accumulated scores of their representative field books and are ranked accordingly. All team members receive the same grade attained by their team (in the A-C range). This competition occurs twice per semester. The first one is near mid term and the other near the end of the semester.

Student Feedback

Recently, students taking two sections of the Construction Surveying course in our Construction Management program provided feedback on most of the above competitions and their perceived effects. Those students had participated in competitions 1, 3, 4, 5, and 8 only. This is because not all above competitions are presented to students during a given academic semester. One of the responding sections had 15 students, but only 13 were present when the feedback was requested. The other section had 27 students with only 23 being present. That is, a total of 36 students (out of 42) responded. The employed feedback instrument was an anonymous, 16-question survey. Questions 1-12 were on the competitions themselves and are briefly indicated on the right-hand side of figures 1-4. The remaining 4 questions were not used in this study. They were related to the instructor and course.

Figure 1 shows that most students agree or strongly agree that teamwork activities facilitate learning (97%); that team competitions help in developing teamwork abilities (94%); and that these competitions help students learn (97%). Only a relatively low percent of the students demonstrated indifference (selected the neutral option) in those three statements. This confirms the benefits of the adopted competitions, as perceived by students' point of view.

An example of the actual learning catalyzed by competitions is clearly observed in Competition 3, where all participating students learn how to setup a total-station instrument. In the past, before we started using this particular contest, several students were unable to setup that instrument, even as we approached the end of the course. This disappointing fact existed despite the multiple in-class reminders of the need of each student to practice and perform this setup during several field work activities. However, this was difficult to monitor in the field, especially when 6 or 7 teams were working simultaneously over a large area. Informal verbal feedback from the students indicated that this behavior was due to the fact that other team members learned the procedure and performed it whenever it was necessary. Those who did not learn it, or felt more insecure about using the instrument, presented a more passive participation in their groups. That is, they did not contribute as instrument persons, but as rod persons, reflector holders, numeric data collectors, etc. After implementing this competition, there is no doubt that all participating students learned how to setup this instrument. They all had to do it.

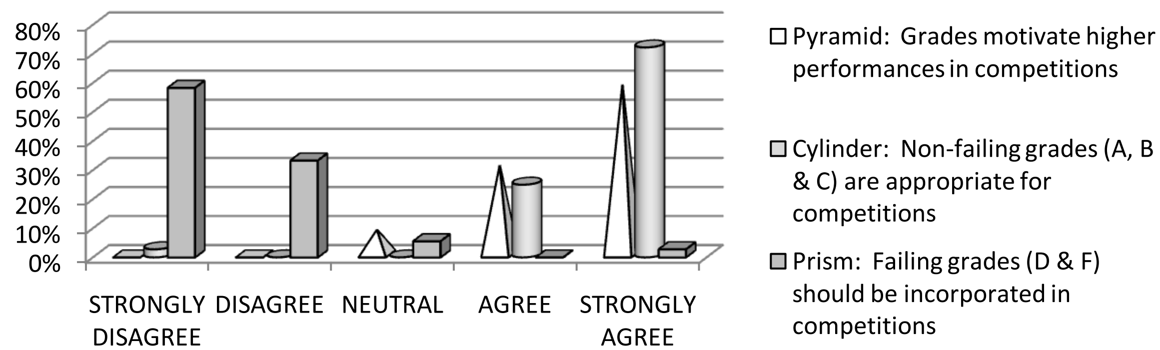


Figure 2: Student feedback on grade motivation, non-failing grades and failing grades.

Figure 2 shows that most students (31%+58%=89%) agree or strongly agree that grades motivate higher performances in competitions. In this regard, 8% were neutral and 3% did not respond. A vast majority of them (25%+72%=97%) prefer the current policy of using non-failing grades only (A, B and C) in the contests, as opposed to incorporating failing ones (D and F). This confirms the verbal feedback received from numerous students when implementing the early versions of these contests several years ago.

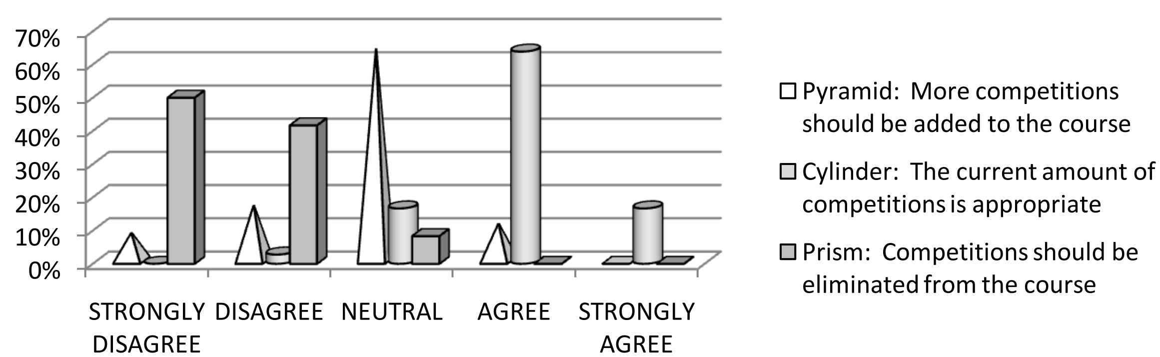


Figure 3: Student feedback on the amount of competitions.

The feedback results shown in Figure 3 indicate that 92% of students moderately or strongly prefer that competitions remain as a vital part of the course requirements (they disagree or strongly disagree on eliminating them). Also, the same figure shows that almost 81% of students agree or strongly agree that the number of competitions they performed (5) was appropriate. In this regard, 17% of the students were neutral and almost 3% disagreed. So the immediate question is: Should more competitions be added? Many students, 64%, selected to be neutral in this regard; 11% preferred more competitions; and 25% did not support such an increase. Therefore, it can be inferred that 64%+11%=75% of students would not mind increasing the number of competitions.

In Figure 4 it can be observed that nearly 20% of students agree or strongly agree that competitions are stressful. Almost 39% were neutral in this regard and near 41% agreed or strongly agreed that competitions are not stressful. These are encouraging results. It can be interpreted that almost 80% of the students are not affected by stress when these competitions are used as tools to catalyze the learning process. The authors understand that this conclusion is strongly related to the fact that only passing grades are employed in these competitions. From the remaining data plotted in this figure, it is seen that only 3% of the students agree or strongly agree that more individual-based competitions (rather than team-based ones) are needed in this course. Most of the students, 61%, disagree or strongly disagree with such statement, and 36% remained neutral. Also, it is observed that almost 28% of students agreed that individual competitions are better than team-based ones. Almost 39% disagree or strongly disagree with this statement and 33% remained neutral. So, it is clear that the majority of students prefer team-based competitions rather than individual-based ones. However, a strong minority still prefer the individual-based competitions.

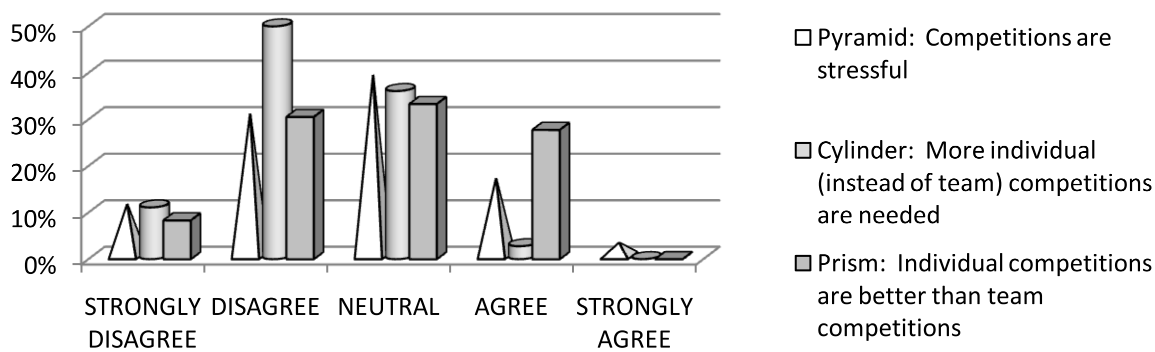


Figure 4: Student feedback on competition-induced stress and on their preference regarding team- or individual-based competitions.

Learning the Operation of Modern Surveying Instruments

Today, a wide variety of powerful surveying instruments are available. A short list of them includes highly precise robotic total stations, sub-centimeter Global Navigation Satellite Systems (GNSS) for global positioning operations (known as GPS devices) and fast short- and long-range laser-based scanners, which are also known as terrestrial light detection and ranging (LIDAR) devices. Even though their commercial prices are still high in the affordability spectrum of educational units, more and more engineering, surveying and construction companies are now acquiring them to increase or maintain their competitiveness. Therefore, today CM students should know about the capabilities of these new instruments and how to employ them in several specialized construction activities, such as the accurate determination of required bench marks on construction sites, the highly accurate layout of foundation anchor rods, embeds, and leveling plates, the rapid determination of site topography, the virtual three dimensional modeling of as-built conditions, etc.

Exposing Undergraduate Students to Modern Instruments

CM programs at several universities and colleges, unfortunately, may not be able to afford the above mentioned modern instruments (their approximate total commercial price is about $500,000). This is especially true, when the classical or typical delivery of construction surveying courses requires dividing students into surveying parties or groups (with 3-5 members each), and the assigning of one instrument per group. Fortunately, last year, both authors and other professors from their institution joined efforts and obtained a federally supported grant to acquire one each of the instruments mentioned above for research and teaching purposes. During last spring and summer, these professors received training from the instrument manufacturers to operate them. The training was intensive and covered near three weeks with eight or more instructional hours per day. Consequently, it was evident that it was not possible to incorporate this training into our undergraduate construction courses, especially when only one instrument of each type was acquired and they all needed to be available not only for teaching purposes, but also for various research activities planned by the authors and grant co-PIs from the Anthropology and Geology disciplines. To properly expose undergraduate students to the capabilities of these instruments, the authors decided to complete the following tasks:

(1) After a careful consideration of the operation requirements of the instruments, two were selected to be presented to undergraduate students attending the Construction Surveying course. They both required the incorporation of some enhanced features to facilitate and simplify their operation. These two instruments, their capabilities, and their added features are:

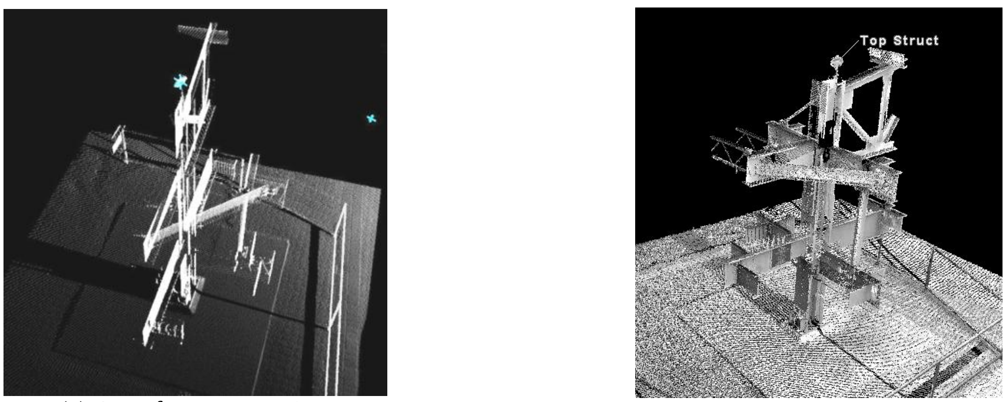
- The *Leica ATX1230GG SmartAntenna* capable of real-time kinematic (RTK) GPS surveying at 1-cm accuracy. It uses both the American (GPS) and the Russian (GLONASS) constellation of satellites dedicated to global positioning tasks. This instrument was enhanced by the addition of a data-only cellular telephone to allow it to directly communicate with the bases of the largest privately owned GNSS GPS network of the USA, eGPS. Since the university allowed this company to place an antenna on top of one of its buildings, the company has allowed faculty free access to their network for educational purposes. The cellular phone enhancement permits the instrument to simply operate as a rover inside the eGPS network. This avoids the need to setup and use our own base and communicate with it via a battery operated radio (which is a more complex operation). This instrument can be used to accurately place benchmarks, layout points, lines, areas, and collect topographic information in real time as long as it has adequate sky access to communicate with enough satellites. The fact that it uses American and Russian satellites improves its chances of properly working in areas with limited sky access.

- The *Leica ScanStation C10*. This is a high definition, long-range, laser-based scanning instrument (or terrestrial Lidar instrument). This new instrument works attached to a tripod and has a 300 m scanning range at 90% albedo (134 m at 18% albedo). It captures spatial XYZ coordinates at a maximum rate of 50,000 points per second. The set of points collected by this instrument are usually designated as a point cloud. The instrument presents an ample field of view with a full 360° horizontal coverage and a vertical-angle range of 270°. That is, only its tripod is outside its angular scanning range. This scanner is also characterized by its ultra-fine scanning capabilities and its survey-grade accuracy. According to the manufacturer, its measuring accuracies, within a 50 m range, are ≤ 6 mm and ≤ 4 mm for positions and distances, respectively. Its horizontal and vertical angular resolution, at one standard deviation, is 60 μrad (12 seconds). It presents dual axis compensators for precise automatic leveling of its vertical axis within 1-second resolution from zenith. This feature considerably reduces angular errors due to tilting of the vertical axis. This scanner also contains an integrated, auto-adjusting, high-resolution digital camera. A USB-based router was added to this instrument to permit its wireless operation from a controlling laptop computer. The point cloud data is directly transferred to this computer. This wireless operation allows us to bring the instrument to the classroom, connect the controlling laptop to the projection system, and present the operational details to all attending students. This instrument can be used to obtain three dimensional virtual models of any constructed facility (including as-built models) as well as any topographic and geologic features, such as earthwork on construction sites. Today it is also commonly used for many other different purposes, such as the reconstruction of crime scenes for forensic purposes.

(2) Preparation of draft short protocols to facilitate the operation of these two instruments by undergraduate students while performing simple, but common field tasks. Undergraduate students were recruited to assist with the instrument demonstrations to other students attending the Construction Surveying course. Two Honors students were invited to use the initial draft protocols and improve them as part of their Honors contract with the Construction Surveying course or as part of other Honors required activities. Also, other motivated undergraduate students were invited to attend informal training sessions arranged by the authors.

(3) The ubiquitous steel sculpture (present on many university campuses) was selected to demonstrate the main aspects of the scanning process, including the need to perform several scans from different points of view (different stations) to fully cover all necessary geometric features. For this purpose, both authors worked together and scanned the steel sculpture from four different stations. Then, the point clouds resulting from each station were all registered. That is, they were properly "stitched" and converted into a common reference coordinate system. This process requires the use of several fixed circular target points (at least four) properly placed in locations that will be scanned from the stations whose point clouds will be later registered together. This registration can be performed using the mentioned targets or it can be attempted by using the cloud-to-cloud approach where some common points are scanned from two stations and are made to coincide to register the point clouds produced by those two stations.

(4) The GPS instrument is explained to undergraduate students and many of them are invited to follow the provided written protocol to collect field data with coordinates expressed in the Plane State Coordinate System. Similarly, the use of the scanning instruments is demonstrated in the classroom to collect data from only one station as seen in part (a) of figure 5. The registration process is explained to students by using the data already collected for the steel sculpture from four different stations as seen in part (b) of figure 5.



(a) Scan from one station (b) Scans from four stations

Figure 5: Comparison of the sculpture scanned from just 1 station and after registering the scans from 4 stations.

Closing Remarks, Lessons Learned and Acknowledgement

Student feedback indicated that competitions were strongly supported by the vast majority of them and are considered an effective learning tool. It showed that most students (97%) agree or strongly agree that these competitions help them learn. Near 89% of students agree or strongly agree that grades motivate better performances in the proposed competitions. Near 97% of students prefer the current policy of using non-failing grades (A, B and C) only in these contests. Almost 92% of students disagree or strongly disagree on eliminating the current competitions. Also, near 81% of students agree or strongly agree that the number of competitions they performed (5) was appropriate. Only 20% of students consider the competitions to be stressful and almost 39% of them were neutral in this regard. Regarding individual-based competitions, only 3% of the students agree or strongly agree that more of these competitions (rather than team-based ones) are needed in this course. However, almost 28% of students considered that individual competitions are better than team-based ones.

The generated protocols proved to be an effective shortcut strategy to empower undergraduate students with minimum, but sufficient knowledge to understand the main aspects and operational steps of the GPS and laser scanning instruments. The protocols also allowed students to collect data with these powerful devices. It was observed that most students were very motivated to increase their operational knowledge of these instruments and offered to assist the instructors in future scanning projects. These instruments were acquired via a Major Research Instrumentation grant from the National Science Foundation (CMMI-0959311), under Program Director Lawrence C. Bank. The authors are very grateful for this support.

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