Integrating Faculty Led Service Learning Training to Quantify Height of Natural Resources from a Spatial Science Perspective

Daniel R. Unger[1], David L. Kulhavy[1], Kai Busch-Petersen[1] & I-Kuai Hung[1]

[1] Arthur Temple College of Forestry and Agriculture, Stephen F. Austin State University, Nacogdoches, Texas, U.S.A.

Correspondence: Daniel R. Unger, Arthur Temple College of Forestry and Agriculture, Stephen F. Austin State University, Nacogdoches, Texas, U.S.A. Tel: 1-936-468-3301.

Received: June 23, 2016 Accepted: July 12, 2016 Online Published: July 18, 2016

doi:10.5430/ijhe.v5n3p104 URL: http://dx.doi.org/10.5430/ijhe.v5n3p104

Abstract

Arthur Temple College of Forestry and Agriculture (ATCOFA) faculty members were trained how to integrate service learning activities within senior level classes at Stephen F. Austin State University (SFASU) in Nacogdoches, Texas. The service learning training, taught under the acronym Mentored Undergraduate Scholarship (MUGS), involved meeting with fellow faculty members over the course of an academic year during the fall semester to first learn how to incorporate service learning activities in a senior level class followed by its incorporation into a class the following spring semester. The service learning model was applied to students in GIS 420, a senior level Landscape Modeling, Spatial Analysis, and Quantitative Assessment course within ATCOFA. The students were instructed within a hands-on interactive environment on how to use geospatial analysis to quantify natural resources. The overall goal was for a student to demonstrate proficiency in understanding how to apply aerial photo interpretation, satellite remote sensing, global positioning system and geographic information systems technology to quantify, qualify, map, monitor and manage natural and environmental resources at the local and landscape scales. Students applied this concept within a quantitative resource assessment, whereby students compared the conventional methodology of measuring height of vertical features within a landscape using a clinometer with the newer ways of measuring height using Pictometry hyperspatial imagery and drone acquired digital imagery. Conventional results were compared to newer technological methodologies to determine the most efficient and accurate way to quantify vertical resources from a spatial perspective.

Keywords: Service learning, Faculty training, Spatial science, Capstone course

1. Introduction

Within the Arthur Temple College of Forestry and Agriculture (ATCOFA) at Stephen F. Austin State University (SFASU) we want our students asking interesting questions that are relevant to their daily lives and future work expectations. This conceptual training will provide them with new knowledge about our natural resources and the field in which they will participate. Natural resource undergraduates are tasked with solving complex problems, working in interdisciplinary teams to develop and implement spatial science research plans as they prepare for their profession (Thompson, Jungst, Colletti, Licklider, & Benna, 2003; Newman, Bruyere, & Beh 2007; Bullard et al., 2014); their education must be relevant, rigorous and build relationships (Bullard, 2015). Collaborative learning problem-solving and written and oral communication skills are identified by natural resource employers as desirable traits for solving societal, employer and environmental needs (Sample, Ringgold, Block, & Giltmier, 1999).

We applied this concept within an undergraduate quantitative resource assessment course whereby the students compared the conventional methodology of measuring height of vertical features within a landscape using a clinometer compared with newer ways of measuring height with Pictometry and drone acquired digital imagery. Driving questions of concern were: Is a clinometer the best way to measure height? Do we really need to spend time and money in the field to obtain accurate measurements? Can Pictometry online data achieve the same level of results as *in situ* clinometer measurements? Are quantitative measurements, obtained from drone imagery, better than conventional assessments and Pictometry measurements?

In order to answer the aforementioned research questions, we instructed the students to conduct a height assessment on the same object by using different measurement approaches including a clinometer, Pictometry imagery, and a drone. At the same time, the actual height of the object was attained by using a measurement height pole. Then, the accuracy of each height measurement approach was assessed and compared in order to achieve the objective of determining if any of the three height measurement approaches is better than others.

1.1 Mentored Undergraduate Scholarship Program

ATCOFA undergraduate students at SFASU focus on applying the use of spatial science for the purpose of natural resources management (Kulhavy, Unger, Hung, & Douglass, 2015) and forest land cover classification (Henley, Unger, Kulhavy, & Hung 2016). The mission statement of ATCOFA is to maintain excellence in teaching, research and outreach to enhance the health and vitality of the environment through sustainable management, conservation, and protection of natural resources. The college is devoted to comprehensive education at undergraduate and graduate levels, basic and applied research programs, and service (Bullard et al., 2014). In order to effectively attain the mission statement, undergraduate remote sensing coursework within ATCOFA focuses on traditional classroom and laboratory instruction combined with a heavy emphasis on integrating hands-on instruction in a rigorous setting via one-on-one faculty collaboration, to produce a more accomplished and competent graduate (McBroom, Bullard, Kulhavy, & Unger, 2015). Students studying and learning spatial science at ATCOFA focus on hands-on instruction and real-world applications using the most current geospatial science technology (Unger, Kulhavy, Hung, & Zhang, 2014; Kulhavy, Unger, Hung, & Zhang, 2016).

ATCOFA faculty members were trained how to integrate service learning activities within senior level classes at SFASU. The service learning training, taught under the acronym Mentored Undergraduate Scholarship (MUGS), involved meeting with fellow faculty members over the course of a year during the fall semester 2015 to first learn how to incorporate service learning activities in a senior level class followed by its incorporation into a class the following spring 2016 semester. MUGS promotes higher order thinking skills through collaborative learning, field based education and mentored scholarship to understand, connect and synthesize facts and develop student competencies (Lobry de Bruyn, & Pryor, 2001). The MUGS program places an emphasis on critical inquiry, frequent writing and collaborative learning that develop intellectual and practical competencies (Kuh, Cruce, Shoup, Kinzie, & Gonyea, 2008). The interactive hands-on instruction methodology employed by ATCOFA was well suited to the MUGS program as its objective is to involve the students directly in mentored instruction, often in a one-on-one environment (Figure 1). Student progress can then be measured in their ability to integrate the data and make informed decisions comparing the three height measurements of using a clinometer, Pictometry imagery and the DJI Phantom 3 drone.

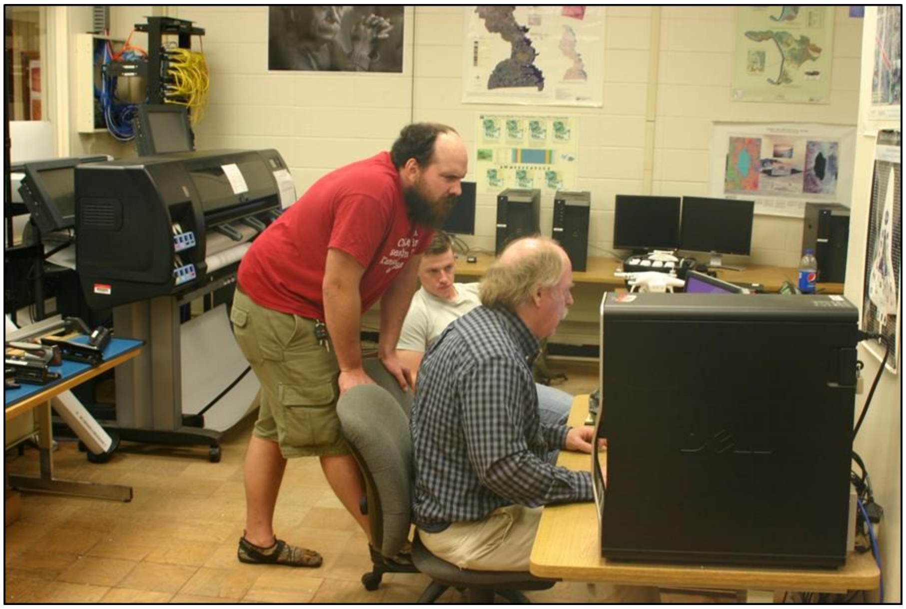

Figure 1. Spatial science faculty interacting one-on-one with an undergraduate student in the ATCOFA GIS Lab

1.2 Height Measurement with Clinometer

Estimating the vertical height of earth surface features has been a component of field-based measurements and spatial science applications for decades. Numerous methods to estimate height have been developed and proven successful. Estimating height for a vertical feature, such as an open grown individual tree, has been traditionally done with a clinometer (Kovats, 1997). Coefficient of determinations between actual tree height and estimated tree height using a clinometer has ranged from 0.9462 to 0.9501 (Williams, Bechtold, & Labau, 1994). Clinometer estimated tree height was within 0.93 meters of actual tree height when estimating loblolly pine tree height (Rennie, 1979).

1.3 Height Measurement with Pictometry

Pictometry data, a relatively new form of digital imagery, are classified as hyperspatial resolution remotely sensed data. Hyperspatial resolution data are defined as remotely sensed data having a spatial resolution smaller than the object of interest. Pictometry data are similar to the data available with commercial grade satellites IKONOS, QuickBird and GeoEye in application, but Pictometry data are acquired at a finer spatial resolution than commercial grade satellite sensors allowing for an improved visual assessment of surface features with a Pictometry image (Sawaya, Olmanson, Heinert, Brezonik, & Bauer, 2003).

Pictometry data are acquired along a predetermined flight path, within an interlocking looping motion, to obtain imagery from multiple perspectives by low flying aircraft including nadir and oblique angles up to 40 degrees. Pictometry image data depict the fronts and sides of vertical ground features in a web based interface. Images acquired contain up to 12 oblique perspectives and are stitched together to create a composite image that a user can use to accurately measure surface object size and position using the Pictometry patented web based interface (Wang, Schultz, & Giuffrida, 2008)

When applied to measuring height of vertical features such as trees, height for citrus trees were estimated with only 89 percent height accuracy due to ambiguity in choosing the tree top and bottom in Pictometry data while an average error of 0.2 meters was found when using Pictometry data to estimate the height of houses and towers (Hohle, 2008). The root mean square error (RMSE) for Pictometry derived heights was 81.98 centimeters when measuring the height of buildings with a conclusion that obtaining accurate height measurements using Pictometry data was very simple (Daily, 2008). Pictometry was not statistically different for measuring heights of baldcypress compared to a telescoping height pole with a liner correlation coefficient of 0.99 between Pictometry and in situ tree height (Unger, Kulhavy, Williams, Creech, & Hung, 2014).

Pictometry was statistically more accurate than LiDAR and not different from a laser rangefinder for building height from a measuring pole (3.75 m actual height). Pictometry had a 0.11 m RMSE (average 3.68 m measured height); the laser rangefinder a 0.14 RMSE (average 3.82 m measured height); and LiDAR a 0.16 RMSE (average 3.66 m measured height). Pictometry and LiDAR underestimated building height, whereas the laser rangefinder overestimated building height (Kulhavy, Unger, Hung, & Douglass, 2015). Pictometry was more accurate than the clinometer and the laser rangefinder for heights of light poles measured with a telescopic height pole (Unger, Hung, & Kulhavy, 2014).

1.4 Height Measurement with Drone

With the continuous advancement of Unmanned Aerial Vehicles (UAVs), commonly known as drones, it is possible to record the height of vertical features in a landscape by flying a drone along the vertical profile of a given feature via a drone’s ability to acquire and transmit visual and height data along a vertical profile. The term UAS refers to an unmanned aircraft and the associated support equipment, control station, data links, telemetry, communications and navigation equipment to operate the system. A drone is the flying portion of the system flown by a pilot from a ground control system or on-board computer and communication links (Themistocleous, 2014). Okamoto and Shimazaki (2015) found that altitude elevation measured from a DJI Phantom 2 drone was not as accurate as expected when compared to traditional ground based methodologies. Based on 52 university and park trees observed, no statistical difference was found between the Parrot AR.Drone 2.0 method and the conventional ground urban tree hazard rating of the Council of Tree and Landscape Appraisers (CTLA) method for overall hazard rating based on six variables of trunk condition, growth, crown structure, insects and diseases, crown development, and life expectancy. A strong correlation was observed based on the Spearman’s rank-order analysis. However, the AR.Drone 2.0 could reach areas not accessible or viewable from the ground (Kulhavy, Unger, Hung, & Zhang, 2016).

1.5 Study Objectives

ATCOFA senior undergraduate students initiated a multi-course project with the assistance of ATCOFA faculty members. The students conducted undergraduate research designed to expand their understanding of spatial science within a natural resource context and to generate a reliable process for conducting a research project. The overall goal was for the students to demonstrate proficiency in understanding how to apply aerial photo interpretation, satellite remote sensing, global positioning system and geographic information systems technology to quantify, qualify, map, monitor and manage natural and environmental resources at the local and landscape scales. Students applied this concept within a quantitative resource assessment, whereby the students compared the conventional methodology of measuring height of vertical features within a landscape using a clinometer with the newer ways of measuring height using Pictometry and drone acquired digital imagery. Overall objective of the study was to compare conventional height assessment methods with newer technological methodologies to determine the most efficient and accurate way to quantify vertical height of a natural resource within a landscape.

2. Methods

2.1 Study Location

The study area for this project involved a central parking on the campus of SFASU in Nacogdoches, Texas (Figure 2). A central parking was chosen for this study since it contained light poles that had not changed in height over time, was easily accessible, and could be assessed under the time constraints of an undergraduate class schedule.

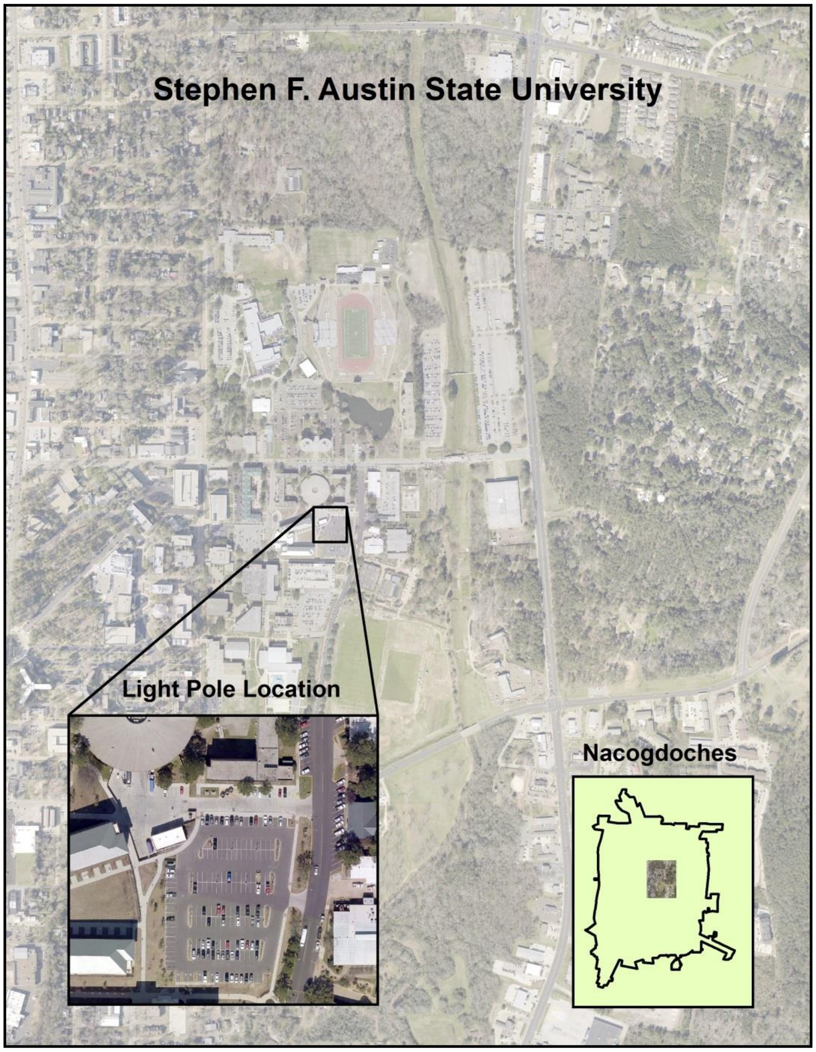

Figure 2. Study site location in a parking lot at Stephen F. Austin State University

2.2 Actual Height Measurement

Students were introduced how to accurately measure the height of vertical features within a landscape. As a class, students were taken outside in groups and instructed how to accurately measure the height of a vertical feature *in situ* with a telescopic height pole. After demonstration, each student demonstrated their skill by accurately measuring the height of a light pole on the campus of SFASU. A light pole was chosen for analysis since its height does not change over time for comparison with digital aerial imagery taken at a different date than the *in situ* measurements (Figure 3).

Figure 3. Measuring *in situ* height with a telescopic height pole

2.3 Conventional Height Measurement

Students within spatial science programs are taught how to quantify the height of vertical features within the landscape using a clinometer. Standing a set distance from a vertical feature, students were instructed how to measure the slope to the top and bottom of a vertical structure using a clinometer which can easily be converted into an estimate of vertical height. Students, after being instructed on how to properly read a clinometer, demonstrated their proficiency by estimating the height of a light pole on the campus of SFASU (Figure 4).

Figure 4. Estimating *in situ* height with a clinometer

2.4 Height Measurement with Pictometry

In lieu of *in situ* data collection, students were introduced how to collect field data measurements using Pictometry remotely collected digital imagery. The digital imagery is captured by low-flying aircraft that includes nadir within each image and side views up to a 40 degree angle. The images depict up to 12 oblique perspectives and are stitched together to create composite imagery. Pictometry, the name of a patented aerial image capture process that records digital aerial imagery and shows the fronts and sides of vertical ground features, allows for the measurement of object size and position by taking advantage of viewing an object digitally from more than one direction with multiple angles of view. Within an online web interface, students were instructed how to obtain accurate size measurements of surface object remotely via the Pictometry online web interface (Figure 5).

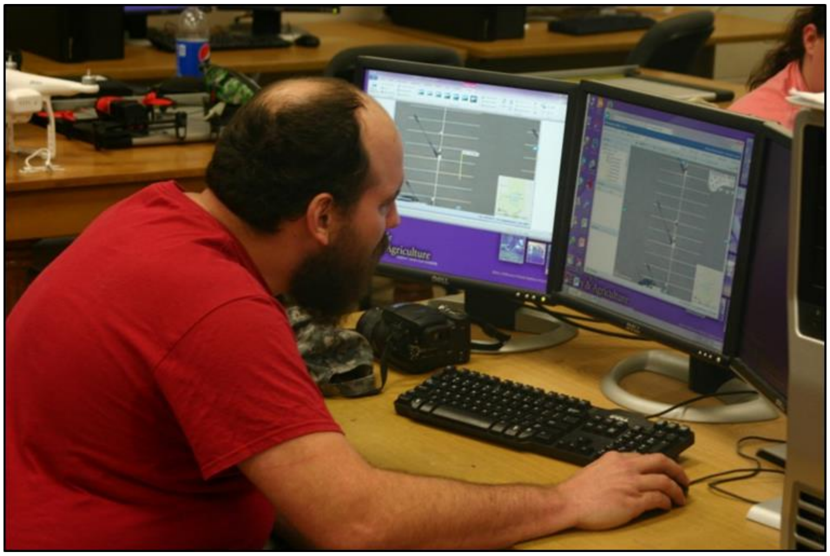

Figure 5. Estimating height onscreen within the Pictometry online web interface

2.5 Height Measurement with Drone

In lieu of *in situ* data collection, students were also introduced how to collect field data measurements remotely using a DJI Phantom 3 drone. Prior to flying the DJI Phantom 3, both the remote control and the battery for the drone are activated. Before flying the drone, the GPS signal needed to be locked onto the drone for height measurements. The DJI Phantom 3 is steady in flight controlled by a 3-axis gimbal allowing time to record the height measurements of a vertical feature. The DJI Phantom 3 drone has a built-in GPS unit that allows for capturing geographic coordinates as well as height measurements. Height measurements were recorded with Live View using the streaming technology LightBridge directly from the screen on the remote controller. Students were instructed how to fly the drone next to the light pole on the SFASU campus while recording the vertical height of the light pole using the DJI Phantom 3 in conjunction with an iPhone and the free app AR.FreeFlight 2.4 for a visual assessment (Figure 6).

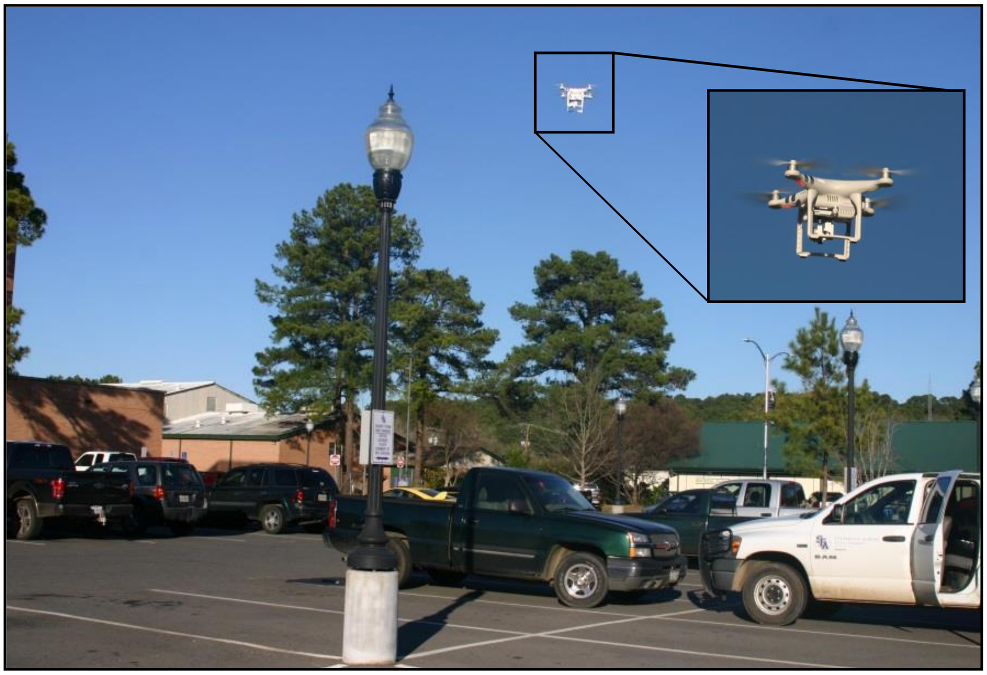

Figure 6. Estimating height *in situ* with a DJI Phantom 3 drone

2.6 Data Analysis

After data collection, students were instructed how to statistically analyze their *in situ* field data. The actual height of the light pole was compared to the clinometer, Pictometry and drone estimated height for 30 observations. Statistical analysis included calculating the standard deviation and mean of the estimated height by clinometer, Pictometry and drone (Table 1). For accuracy assessment, errors were calculated by comparing each estimate to the light pole’s actual height (5.35 meters) measured with a height pole and the mean error, the mean absolute error, and the RMSE per estimate method were reported (Table 2 and Figure 7).

For the learning assessment, students were given an initial assessment of their progress at midterm and a final assessment at the end of the class based on the rubric in Table 2. Assessment included both their progress on assimilation and using information from Benchmark 1, to Milestone 2, to Milestone 3, to Capstone 4. The categories for assessment were: Evaluation of Information; Creative Thinking; Problem Solving; and Communication of Content. There are two assessment criteria for each of the four assessment topics for a total of eight for each of the four categories as identified in Table 2.

Table 1. Actual light pole height versus estimated light pole height

Pole Height (meters)	Estimated Height per Method		
	Clinometer (meters)	Pictometry (meters)	Drone (meters)
5.35	5.00	4.96	5.10
5.35	5.67	4.97	5.00
5.35	5.33	4.97	5.20
5.35	5.33	4.95	4.80
5.35	5.67	5.01	5.00
5.35	5.67	4.96	5.10
5.35	5.33	5.10	5.40
5.35	5.67	4.81	5.60
5.35	5.33	4.97	5.70
5.35	5.33	5.10	6.10
5.35	5.33	4.96	6.30
5.35	5.67	4.97	6.50
5.35	5.67	4.96	6.60
5.35	5.67	4.96	6.80
5.35	5.67	4.96	7.00
5.35	5.67	4.96	5.00
5.35	5.67	4.96	5.00
5.35	5.67	4.96	5.40
5.35	5.67	5.10	5.30
5.35	5.67	4.96	5.00
5.35	6.00	4.96	5.10
5.35	5.67	4.96	4.30
5.35	5.33	4.96	4.40
5.35	5.67	4.81	4.90
5.35	5.33	4.96	4.90
5.35	5.67	5.11	5.40
5.35	5.33	4.96	5.40
5.35	5.33	4.97	5.50
5.35	5.67	4.96	5.40
5.35	5.33	4.81	5.60
Mean	**5.53**	**4.97**	**5.43**
Standard Deviation	**0.21**	**0.07**	**0.66**

Table 2. Rubric to assess student higher order thinking skills

Capstone	**Milestones**		**Benchmark**
4	**3**	**2**	**1**
Evaluation of Information			
A. Synthesizes in-depth information from relevant sources representing various points of view/approaches.	A. Presents information from relevant sources representing various points of view /approaches.	A. Presents information from relevant sources representing few points of view/ approaches.	A. Presents information from a single point of view/approaches.
B. Organizes and synthesizes evidence to reveal insightful patterns, differences, or similarities related to task.	B. Organizes evidence to reveal important patterns, differences, or similarities related to task.	B. Provides evidence, but the organization is not effective in revealing important patterns, differences, or similarities.	B. Lists evidence, but it is not organized and/or is unrelated to task.
Creative Thinking			
A. Develops a logical, consistent plan to address problem, recognizes consequences of and can articulate reason for choosing plan.	A. Having selected from among alternatives, develops a logical, consistent plan to address the problem.	A. Considers multiple approaches to addressing problem.	A. Relies on intuition alone to solve a problem.
B. Transforms ideas or solutions into entirely new forms.	B. Synthesizes ideas or solutions into a coherent whole.	B. Connects ideas or solutions in novel ways.	B. Does not recognize existing connections among ideas or solutions.
Problem Solving			
A. Information is taken from source(s) with enough interpretation/evaluation to develop a comprehensive analysis or synthesis. Viewpoints of experts are questioned thoroughly.	A. Information is taken from source(s) with enough interpretation/evaluation to develop a coherent analysis or synthesis. Viewpoints of experts are subject to questioning.	A. Information is presented with some interpretation/ evaluation, but not enough to develop a coherent analysis or synthesis. Viewpoints of experts are taken as mostly fact, with little questioning.	A. Information is presented as fact, without question.
B. Thoroughly analyzes own and others' assumptions and carefully evaluates the relevance of contexts when presenting a position.	B. Identifies own and others' assumptions and several relevant contexts when presenting a position.	B. Questions some assumptions. Identifies several relevant contexts when presenting a position.	B. Shows an emerging awareness of present assumptions. Begins to identify some contexts when presenting a position.
Communication of Content			
A. Issue/problem is stated clearly and described comprehensively, delivering all relevant information necessary for full understanding.	A. Issue/problem is stated, described, and clarified so that understanding is not seriously impeded by omissions.	A. Issue/problem is stated but clarity is somewhat impeded by omissions.	A. Issue/problem is stated without clarification or description.
B. A variety of types of supporting materials make appropriate reference to information that significantly supports the work.	B. Supporting materials make appropriate reference to information that generally supports the work.	B. Some supporting materials make appropriate reference to information that partially supports the work.	B. No supporting materials make reference to information or analysis that minimally supports the work.

3. Results

By solely looking at the mean of estimate heights, students discovered that there was minimal difference between actual light pole height and estimated mean light pole height. It appeared that the drone had a mean height estimate (5.43 meters) that is closest to the actual height with 1.4% error, while the Pictometry mean estimate (4.97 meters) was farther away from the actual height with 7.1% error, followed by the clinometer (5.53 meters) at 3.3% error. In the meantime, students also discovered that the drone estimated light pole height was more variable and less precise with the largest standard deviation of 0.66 meters compared to the clinometer (0.21 meters) and Pictometry (0.07 meters) estimated light pole height (Table 1). Figure 7 and Table 3 accounted individual errors, the difference between each estimated height and the actual height of the pole. The students discovered that the drone still achieved a mean error of 0.077 meters that is the closest to 0. An overall trend was found with the clinometer which consistently overestimated the height resulting in a positive mean error of 0.184 meters, while Pictometry consistently underestimating the height with a negative mean error of -0.383 meters. The reason the mean error of the drone being close to 0 was due to its higher variation in height estimate that canceled out the errors. This reflects the fact that the drone had the highest standard deviation of height estimates. When absolute errors were observed, a different picture revealed where the clinometer was the most accurate method with the lowest mean absolute error of 0.222 meters and the lowest RMSE of 0.276 meters, with the drone being the least accurate with mean absolute error of 0.487 meters and RMSE of 0.658 meters.

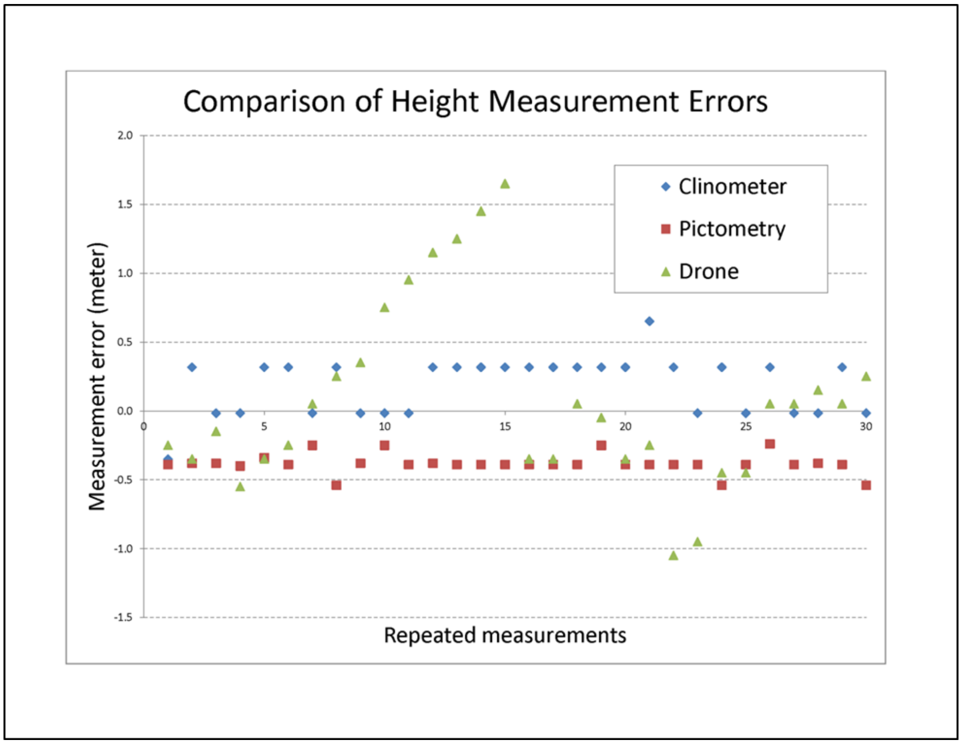

Figure 7. Graph of estimated light pole height errors

Table 3. Statistics of errors of light pole height estimate by method used

	Height estimate method		
(meters)	Clinometer	Pictometry	Drone
Mean error	0.184	-0.383	0.077
Mean absolute error	0.222	0.383	0.487
RMSE	0.276	0.389	0.658

Assessment for each of the four student learning criteria (Evaluation of Information, Creative Thinking, Problem Solving and Communication of Content) increased for each of the two criteria for each topic from the initial assessment at the midpoint of the class and at the end of the class (Table 4). One student reached the Capstone for evaluation demonstrating synthesis of material and creativity in learning. The other eight students reached Milestone 2 or Milestone 3. One student excelled at both the use of the DJI Phantom 3 and *in situ* measurement with Pictometry and a clinometer and was asked to co-author the article as a mentored undergraduate as part of the MUGS program. The intent of the MUGS program was for students to work one-on-one with a faculty member for training and problem solving of a project for original research. As anticipated from earlier hands-on mentoring and collection of data in a senior level spatial science course (Kulhavy, Unger, Hung, & Douglass, 2015; Henley, Unger, Kulhavy, & Hung, 2016), a junior and sophomore forestry course (Unger, Kulhavy, Hung, & Zhang, 2014), and a freshman environmental science experimental learning course (McBroom, Bullard, Kulhavy, & Unger, 2015), students responded well to the one-on-one mentoring. Exceeding at the capstone level of the MUGS rubric meant synthesis of the data and insight into meaningful patterns, transforming ideas and solutions into new forms, and interpreting the assumptions of the information; and communicating the ideas clearly and concisely. ATCOFA strives to provide one-one-one instruction to provide students with skills to enter their chosen profession, and to “Make a Difference; Work Outdoors; and Use High End Technology.”

Table 4. Student formative assessment results for use of the DJI Phantom3 and Pictometry for pole height estimate based on the rubric from Table 2

Student No.	Evaluation of information				Creative Thinking				Problem Solving				Communication of Content			
	AI[a]	AF	BI	BF	AI	AF	BI	BF	AI	AF	BI	BF	AI	AF	BI	BF
1	4[b]	4	4	4	3	4	4	4	4	4	4	4	3	3	3	4
2	2	3	2	3	2	2	2	2	2	3	2	3	2	2	3	3
3	2	2	2	3	1	2	1	2	2	3	2	3	2	2	2	2
4	3	3	3	4	2	2	2	3	2	3	2	3	2	2	1	2
5	2	2	2	3	2	2	2	2	2	3	2	3	2	2	2	2
6	2	2	2	3	1	2	2	3	2	2	2	3	2	2	1	2
7	3	3	3	3	2	3	3	3	3	3	3	3	3	3	3	3
8	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
9	2	3	2	3	3	3	3	3	3	3	3	3	3	3	3	3

[a] AI: Initial assessment A, AF: Final assessment A, BI: Initial assessment B, BF: Final assessment B

[b] 1= Benchmark, 2 = Milestone 2, 3 = Milestone 3, 4 = Capstone

(See Table 1 for the rubric)

4. Conclusion

Using spatial science technology senior undergraduate students under the direction of spatial science faculty learned how to accurately measure the height of vertical features in a landscape that could be used for observation and decision making purposes. This project allowed students not only to collect real-world data using different methods, but also learn how to analyze the collected data and interpret the outcome properly. The results from the study and the students’ ability to acquire multifaceted spatial science information validate the hands-on instruction methodology employed in the spatial science curriculums within ATCOFA at SFASU. The results also reinforce ATCOFA’s mission by empowering students with the capability of employing sophisticated remote sensing technology to accurately quantify, qualify, map, and monitor natural resources. Students learned that by integrating research into a hands-on senior level undergraduate spatial science course that knowledge and cognitive retention increases along with improved insights into spatial science applications within a natural resource context.

The integrated of the DJI Phantom 3 drone into the education process enhanced the ATCOFA message of work outdoors, make a difference and use high-end technology as active learners. The direction provided by the MUGS program reinforced higher order thinking skills and student achievement by integrating on-screen Pictometry measurements with *in situ* drone measurements compared to traditional height measurement techniques. Further research will be to explore the use of Pictometry and drone in quantifying natural recourses not only in height measurement, but also in area and volume measurements.

Acknowledgements

This research was supported by the Mentored Undergraduate Scholarship of Stephen F. Austin State University and McIntire Stennis Cooperative Research funds administered by the Arthur Temple College of Forestry and Agriculture.

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