Students Education and Engagement at Minority Institution

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Dr. Cadance Lowell, Central State University

Dr. Cadance Lowell is a Professor of Agriculture at Central State University and Chair of the Department of Agricultural and Life Sciences. She received a B.S. in Botany from Duke University, a M.S. in Botany from the University of Florida, Gainesville, and a Ph.D. in Horticulture from the University of Florida, Gainesville. She did post-doctoral work with the USDA in Peoria, IL as a biochemist in soybean oligosaccharides before joining Central State University in 1989. Dr. Lowell maintains a research program in directed energy to kill weeds as an integrated pest management strategy. She mentors undergraduate students in funded research projects who have gone on to present at local, state and national conferences.

Dr. Xiaofang Wei, Central State University

Dr. Xiaofang Wei, Professor of Geography, GIS, and Remote Sensing at the Department of Water Resources Management (WRM) at Central State University. Dr. Wei received her bachelor degree from Wuhan Technical University of Surveying and Mapping and her doctoral degree from Indiana State University. Her research interests are focused on the applications of remote sensing and GIS in Land use/land cover change study, harmful algal bloom monitoring, forest biomass estimation, crop evapotranspiration estimation, and imagery atmospheric correction. Dr. Wei serves as PI (Principal Investigator) or Co-PI for multiple NSF and NIFA research projects. She employs quantitative tools and computational approaches of remote sensing and GIS, including 6SV1 (Second Simulation of a Satellite Signal in the Solar Spectrum), FLAASH (Fast Line-of-sight Atmospheric Analysis of Spectral Hypercubes), SEBAL (The Surface Energy Balance Algorithm for Land), and SWAT (Soil & Water Assessment Tool). Dr. Wei has involved and guided undergraduate students in her research, as an effort to increase STEM recruiting, retention, and completion.

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A Design of Research Based Summer Workshop for STEM Undergraduate Students Education and Engagement at Minority Institution

A workshop on harmful algal bloom in Ohio surface water was designed to engage STEM students to conduct environmental and geographical studies and research at Central State University (CSU). CSU is a historical black university (HBCU) offering bachelor degrees for multiple STEM programs, including environmental engineering, sustainable agriculture and computer science. In 2018 and 2019, a total of thirteen STEM students were recruited for a four-week summer workshop to study multidisciplinary technologies for harmful algal bloom detection and monitoring. The goal of the workshop is to equip students with multidisciplinary cutting-edge theories and technologies in GIS, remote sensing, biology, and water chemistry. It further improves the students' success in their academic study and future career. In the first two weeks of the workshop, students participated in lectures, lab experiments, technology demonstration, field trips, research lab visiting, and etc. Through these activities, student participants had opportunities to develop hands-on experience on multiple novel technologies and instrument, including ArcMap, ArcGIS Pro, Unmanned Aerial Vehicle (UAV), GPS, Inducted Coupled Plasma Mass Spectroscopy (ICP-MS), and ASD spectroradiometer. In the third week, participants were assigned with project tasks: select an Ohio inland lake to investigate the occurrence of algal bloom in the past decades, and further relate the risk of algal bloom to land cover and land use pattern observed within the watershed. Upon the completion of the project, students have practiced using ArcGIS, Google Earth Pro, and EPA Water Quality Portal for map design, landscape inquiry, and water quality data analysis. In the fourth week, participants presented their project findings to the workshop advisors. The follow-up monitoring of participants' academic and research success were conducted to provide feedback on the workshop design, implementation and improvement. The paper presents the overall design of the workshop, and highlights the preliminary evaluation of the workshop.

1. Introduction

1.1 Institutional Background

Central State University (CSU) is a public owned undergraduate Historical Black University (HBCU). CSU has recently received the 1890 Land Grant Institution designation and moving from a teaching emphasized institution towards a research based undergraduate institution. To smooth the transition, faculty at CSU are encouraged to carry out interdisciplinary undergraduate research activities to offer CSU students a distinctive research based college learning experience. These activities are also expected to further engage and prepare students for post-graduation education and career.

Over the past ten years, CSU has experienced full time enrolled (FTE) student population decreased by 24% from 2,322 in 2011 to 1,761 in 2017, and then slowly rose after 2018. According to student population statistical inventory conducted by CSU Institutional Research office in 2018 [1], a total full time enrolled student population at CSU was 2,099 in 2018 Fall semester. The main student body was reported to be African American (88% in 2018), and 54% of students were first time enrolled freshman. The decreased population was primarily attributed to the low student retention rates across the entire university. Additionally, it was reported the first time enrolled freshman students in 2018 had an average ACT score of 16.5 and a mean high school GPA of 2.74. This data implies that students were not fully college ready and an effective

strategy on increasing students' engagement and further improve their course completion is crucial for student retention.

College of Engineering, Science, Technology and Agriculture (CESTA) at CSU houses two departments: Department of Agricultural and Life Sciences and Department of Engineering, Technology, Mathematics and Computer Science. A total of 10 academic programs in STEM areas are offered by the two departments. The mission of the college is to prepare graduates for job markets in the fields of engineering, agriculture and science. In 2018, there are 463 FTE students enrolled in CESTA. The faculty at CESTA are encouraged to help the college to increase the enrollment number through curriculum strengthen and student engagement.

A U.S. Department of Agriculture NIFA grant was awarded to a research group lead by CSU faculty in Water Resources Management and Sustainable Agriculture in 2016. One of the primary objectives of the project is to enhance multiple STEM programs' curriculum and engage students majored in the related disciplines, further increase the STEM major retention, graduation and academic performance. The workshop training is also expected to foster researchers and scientists with interests in natural science and agricultural areas, who are capable to explore advanced ideas and solutions to solve agricultural related priority issues identified by the state of Ohio, such as algal bloom.

1.2 Research-Based Education Approach

Research-based education approach is to teach novel skills and techniques to students in order to prepare students to conduct research [2]. It has been proved that student engagement and persistency can be improved through research-based learning experience [3]. This method has been particularly effective for retaining minority STEM undergraduates on the pathway to a scientific career [4]. For example, a study conducted by Hernandez et al. [5] with multiple institutions for 10-year found that the students with undergraduate research experiences (URE) showed improved academic performance and higher persistency than those of similar students who had not been involved in any URE activities [5].

CSU, a minority institution who has experienced decline in student retention and enrollment, can substantially benefit from the integrated pedagogy of research and teaching for engaging students and improving retention. The workshop practices a research based learning strategy, which utilizes a research topic as the main theme and outreaches students in STEM programs during the summer break. Throughout the four-week workshop study, participants are exposed to a variety of content related to their academic coursework and also essential to their research projects. Meanwhile, there are multiple opportunities offered by the workshop to visit and connect to perspective industrial employers and graduate institutions.

2. Project Description

2.1 Project Justification

The project selects the remote sensing technology as the main theme, along with a variety of other advanced scientific tools and methods, to demonstrate their application in surface water algal and harmful algal bloom monitoring. According to the International Lake Environment Committee survey, 48% of lakes and reservoirs in North American suffer from excessive nutrient loading and undergoes eutrophic condition frequently. Surface waters in Ohio have experienced substantial eutrophication over times due to excessive nutrient inputs from statewide agricultural

land areas. The eutrophication causes frequent observed conventional and harmful algal (i.e., cyanobacterial) blooms in a variety of Ohio inland surface water, such as the Lake Erie, Ohio River, and Grand Lake Saint Mary [6]. Particularly, the algal blooms occurred in the western basin of the Lake Erie during summer since 2000 were revealed consist of a mixture of algae and cyanobacteria. Cyanobacterial harmful algal blooms have been discovered along with various adverse impacts since last century. Recently, it raised more concerns due to its increasing incidence occurred in both fresh and marine waters. Cyanobacterial blooms generally consist of multiple species but are often dominated by a single genus or species. Examples in Ohio include the Microcystis aeruginosa-dominated blooms in the Western Basin of Lake Erie and Grand Lake St. Marys' Planktothrix-dominated blooms. More than one toxin released by cyanobacteria during the blooms were detected in public water systems, recreation water and along shores of inland lakes. The released toxins can target on human's liver and neuro system. Other associated harms were also reported placed on aquatic ecosystem, livestock and wildlife species.

Algal bloom events generally covers a large area and persists for a few weeks. Particularly, cyanobacterial biomass and community composition is highly inconstant spatially and temporally [7]. To capture the bloom events' variability, conventional ground level monitoring and measurement can be costly and time consuming [8]. Modern remote sensing technologies, such as multispectral imaging, hyperspectral imaging, and Unmanned Aerial Vehicle (UAV) have shown advantages over ground level sampling, especially in real-time monitoring. Algae and cyanobacteria species have a variety of pigments in their cells (e.g., Chlorophyll a, Phycocyanin and Phycocerythrin), which are highly fluorescent and responsible for the majority of the light emission from surface water while the bloom dominating the water column (Zamyadi et al., 2016). Therefore, detection of the algae and cyanobacteria by aerial imaging can be done based on fluorescent reflection from surface water. Furthermore, several algorithms were developed over the past decade to correlate the aerial light reflection spectrum to the algae biomass and species for the purpose of bloom monitoring and prediction. Interdisciplinary knowledge on geography, biology, surface hydrology, computer science and mathematics are required to work on this research project. Students recruited to work on this project will have the opportunity to apply the skills learned in their own major courses, meanwhile, expose themselves to novel research topics.

2.2 Project Objectives

The goal of the workshop is to provide experiential learning opportunity for students to learn the cutting-edge sciences and technologies under the guidance of faculty from diverse disciplines of Sustainable Agriculture, Biology, Geography, Environmental Engineering, Math, Computer Science, and Water Resources Management. The workshop will also equip student with critical thinking and problem solving skills that can be applied in agriculture, natural resources, and other related research and industrial works. Meanwhile, students are expected to be incented with academic learning, in return, will further improve their academic performance. Upon the completion of the workshop, students are anticipated to be better prepared for diverse career paths in various organizations, such as government agencies, the geospatial technology industry, and research and educational institutions.

3. Workshop Design and Implementation

3.1 Student Recruitment and Selection

In the summers of 2018 and 2019, two groups of CSU undergraduate students majored in STEM programs were selected to participate in the workshop education activities. Student recruitment was conducted in the prior fall semester. Workshop flyers and brochures were developed and distributed to the campus to attract excellent students. Approximately, 20 applications were received each year. Excellent candidates were selected in the following spring semester according to applicants' academic performance, cohort standing, and course work completion. Five and eight students from multiple STEM programs, Water Resources Management (WRM), Environmental Engineering (ENE), Sustainable Agriculture (Sus Ag), Biology (BIO), Computer Science (CPS), and Mathematics (MTH) were selected in 2018 and 2019, respectively. Their cohort status in May prior to the workshop, is listed in Table 1 along with their majors.

Table 1. 2018 and 2019 workshop participants' major and cohort status.

Cohort Status	Freshmen	Sophomore	Junior	Senior	Graduating Senior	Subtotal
WRM		2	2		1	4
ENE			2			2
Sus Ag		1	3			4
BIO				1		1
CPS			1			1
MTH	1					1
Total	1	3	7	1	1	13

3.2 Educational Activity Design

An intensive multi-disciplinary four-week summer workshop was designed to achieve the aforementioned project objectives. The workshop primarily focuses on delivering scientific knowledge, tools, technologies related to surface water algal blooms to the participants. The educational program was designed as a combination of classroom teaching, hands on practicing and field visiting. Traditional classroom teaching was offered by four faculty (i.e., three from CSU and on from OSU) to illustrate the causes, impacts, monitoring, and prediction of algal blooms from three related disciplinary areas. The learning was further incented by the outside classroom activities, such as lab experiments, software tutorials, and field work practice. Experiential learning and training were provided on the subjects of Geographical Information System (GIS), Remote Sensing, water chemistry, and agricultural sciences for workshop participants to form comprehensive knowledge profiles of algae and harmful algae (i.e., cyanobacteria). Some of the innovative technologies and instrumentation practiced and demonstrated during labs and tutorial practicing included but not exclusive, Unmanned Aerial Vehicle (UAV), UV/Visible spectrophotometer, YSI ProDSS Multiparameter Water Quality Meter, Trimble GPS, ArcGIS Pro, ENVI data fusion, microscope classroom, etc. Data mining and sorting skills were demonstrated and practiced using Microsoft Excel. Multiple database was introduced including EPA STORET water quality database, Google Earth Pro Water Application, USGS National Hydrography Dataset, etc.

By the end of the workshop, each participant was required to complete a case study on surface water algal blooms independently. They were first introduced with data on algal bloom occurrence (i.e., frequency and intensity) in major Ohio surface water over the past decade. Each participant was advised to select one surface water to investigate its hydrological

properties. Participants were also directed to collect data on surrounding land cover / land use, non-point / point pollution sources, historical nutrient loadings, algal bloom related water quality parameter levels (e.g., chlorophyll a. and Phycocyanin). Additionally, with the faculty guidance, students were able to create morphology and physiology profiles for blooming algae species, and explored potential methodologies to relate remote sensing spectral data to the spatial and temporal extents of the bloom. Each student presented their case study finding to faculty, and certificates were awarded to students who had successfully completed case study with evidence showing learning of majority of taught skills and techniques.

3.3 Workshop Implementation

In the summer of 2018, the workshop was first time implemented. The workshop offered theme lectures, laboratory experiment, field data/sample collection, and GIS/remote sensing software training. Additionally, field trip was conducted to the Maumee Bay to collect water samples, practice instruments, and make a field survey of Maumee Watershed. A tour to Vision Lab at University of Dayton was conducted to learn more about the image processing and analyses, beyond the areas of natural resources management, in facial recognition, autonomous car artificial intelligence, oil/gas pipeline reconnaissance, brain pulse monitoring, and image neural network analyses.

In summer of 2019, modification of the workshop activities was carried out based on the first year workshop feedback and observation. More activities which are hands-on driven were added to the program, such as field operation practice for surface water sampling and flow measurement, data searching and management, microscopic identification of algae species, etc. Particularly, the UAV was flown over the area at multiple altitudes and live show through Facebook during one of the field trips to the nearby Peterson Park and Indian Mound Reserve. A campus tour to Ohio State University was carried out from May 23, 2019 to May 24, 2019. The faculty and workshop students attended the lectures, visits the spatial and climatology labs, and explore the graduate programs at OSU.






Figure 1. Pictures of workshop activities: upper pictures (left to right) are participant's project presentation, Maumee Bay field trip, and University of Dayton's Vision Lab visiting; lower pictures (left to right) are field trip to Peterson Park and Indian Mound Reserve, campus tour to the Ohio State University, and the certificates awarded to 2019 participants.

4. Assessment of Academic and Research Performance for Participants

Among the 13 student participants, one senior graduating student was awarded with B.S. degree prior to the workshop. The data on her academic and research performance in the subsequent academic year was not included in the assessment. Following assessments were conducted with the other 12 students on their retention, graduation, academic performance, research achievement and post-graduation career preparedness.

4.1 Graduation of Workshop Participants

The only one senior participant who completed the 2018 workshop study was granted with B.S. degree in May 2019. There are seven (two 2018 sophomore participants and five 2019 junior participants) participants currently working towards graduation. Their graduation eligibilities all have been audited by academic advisors and university registrar by the end of December 2019. Applications for graduation were all submitted, and upon successfully complete the courses in Spring 2020, they will receive their bachelor's degrees. One 2019 sophomore participant is on the track toward 2021 graduation. One 2019 freshmen participant was not assessed for graduation. Collectively, there are seven participants anticipating to complete the curriculum requirement for graduation within four years as they persist in their current programs.

Table 2. Four- and five-year graduation rates by cohort class.

	SAGER Student	4 Year SAGER Graduation Rate (CSU Rate)	5 Year SAGER Graduation Rate (CSU Rate)
Senior Class	1	0%	100%
Junior Class	7	Expected 71.4%	Unknown
Sophomore Class	3	Expected ≥ 66.7%*	Unknown
Freshmen Class	1	Unknown	Unknown

* Two sophomore participants enrolled in the workshop in 2018 are expected graduate in May 2020, one enrolled in 2019 has not been assured for graduation schedule.

Data on university wide graduation rates were reported by CSU university assessment office. According to the results for the past five years, the six-year graduation rate ranges between 19 to 26% for cohorts enrolled in year 2008 to 2012. Four-year graduation rates over the same period were less than 11%.

4.2 Retention of Workshop Participants

One-year-retention was investigated for all participants, except the graduating senior participant (degree granted before coming into the workshop). The class registration and attendance were checked for all participants in the beginning of the subsequent semester after completing the

workshop (i.e., Fall 2018 and Fall 2019) to gather evidence for their persistence. The one-year-retention rates were calculated by dividing the number of persistent participants in the following fall semester by the total participant number. Additionally, the rates were calculated separately for each workshop year to evaluate the continuous improvement of workshop on retention. The assessment results show that majority of the participants (except one 2019 junior participant) were retained in their current majors for the investigated fall semester. Follow up investigation on spring semester is planned as more data become available. Table 3 lists the participant retention rates by cohort for 2018, 2019 and two-year average.

Table 3. Participant retention by year of participation and cohort class.

Cohort Class	2018 Workshop Participant Retention (persist / total)	2019 Workshop Participant Retention (persist / total)	Two-year average retention rate (persist / total)
Senior	100% (1/1)	NA (0/0)	100% (1/1)
Junior	100% (1/1)	83.3% (5/6)	85.7% (6/7)
Sophomore	100% (2/2)	100% (1/1)	100% (3/3)
Freshmen	NA	100% (1/1)	100% (1/1)

CSU assessment office publishes data on university wide student retention every spring. University retention data was calculated based on the first-time enrolled freshmen (FTE) number. To compare with the workshop retention rate, conversion of the university FTE data to individual cohort-based data was conducted. For example, second year (i.e., sophomore) retention rate was calculated by the ratio of returned students number in the beginning of third year to the enrolled student number in the second year. The results show that the average second year retention rate over the past ten years (2009 – 2019) is 72.8%, and third year (junior) average retention rate is 84.6%. The sophomore workshop participants were completely retained (100% retention rate), which is significantly higher than the average university rate (72.8%); and average junior workshop retention rate (85.7%) was found slightly higher than the average university rate (84.6%) as well.

4.3 Participants Academic Performance

Data on participants' GPA was collected before and after the workshop to assess the short term impact of workshop learning on their academic performance. Overall, prior to the workshop, the sophomore participants had an average cumulative GPA of 3.30, and junior participants average GPA was 3.08. Post workshop, the term GPA of the participants were investigated for the following fall semester. The average term GPA for sophomore participants increased to 3.42, indicating an improved academic performance after workshop studies. Average GPA for junior participants decreases slightly to 3.01. The varied impacts on academic performance of sophomore and junior can be attributed to the correlation between workshop training and third year course studies. Therefore, beneficial impacts have been observed on sophomores' academic performance. Comparing with that, the impact on junior academic performance was not observed during their fourth year study. Specifically, one of the junior participants from 2018 workshop was observed with a dramatic fall of GPA in Spring 2019 from 3.15 (cumulative) to 1.56 (term), while all other participants maintained consistent academic performance in their subsequent fall semester course studies. This sharp decline of single participant GPA led to a noticeable impact on average junior participant term GPA given the small participant number

over the two-year workshop practice. And, through the followup investigation, the dramatic term GPA decline of the single participant was attributed to external factors (e.g., family issues, financial difficulties, and health problems).

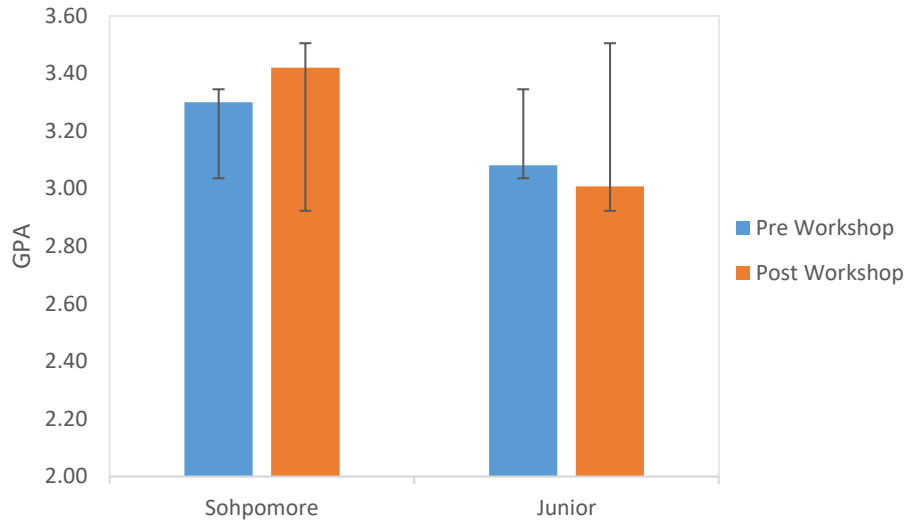

Figure 2. Average GPA for sophomore and junior participants pre and post workshop study.

4.4 Assessment on Research and Post-Graduation Readiness

To investigate the participants' post workshop research and preparedness for post-graduation, a survey was conducted in the following spring semesters (i.e., 2019 Spring and 2020 Spring). The survey investigated participants' research involvement and intern employment before and after the workshop. According to the survey data, four participants had experience working on research before taking the workshop. Their work was conducted either with CSU faculty or other institution. Six participants (i.e., two sophomores, three juniors and one senior) were recruited in the following summer and fall by CSU faculty to work on research projects in multiple areas, including HAB, water quality impact on aquaponics production, artificial intelligence application in precision agriculture. Particularly, two participants (i.e., one 2018 sophomore participant and one 2019 junior participant) have been involved in two research projects. Number of presentations (oral and poster) made at local and national conferences after workshop were also surveyed to evaluate participants' research achievement. By the end of 2019, there are totally five presentations given.

Additionally, three participants (i.e., one sophomore and two juniors) were employed by government agencies and municipal organizations as summer interns after completing the workshop studies. Two of them have reported permanent employment potential with their intern employers. Also, two of the junior participants have been accepted by graduate schools in top U.S. universities. These experiences will produce positive impacts on participants' post-graduation career and education.

5. Conclusions

The practice of summer research based workshop teaching on the selected theme (i.e., harmful algal bloom) over the past two years has shown various impacts on minority STEM undergraduate education and research. The beneficial impacts were observed on sophomore participants' retention, graduation, academic and research improvement. Particularly, the

sophomore participants showed increased term average GPA in the following fall semester after completing the workshop. Sophomore participants also showed higher involvement in conducting research than junior participants. Junior participants exhibited slightly higher persistency than the students across all disciplines in the university. As junior participants are more engaged in course completion for graduation, their research involvement is lower than sophomore participants, instead, they showed higher interests and participations in the career development activities, such as intern employment and graduate school application. Throughout these assessment analysis, it reveals that the workshop can be further improved by designing and implementing target specified activities (e.g., research oriented vs. career oriented) to serve cohorts at different levels.

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