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Offering a Geoscience Professional Development Program To Promote Science Education and Provide Hands-On Experiences for K–12 Science Educators

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ABSTRACT: Development of an effective strategy for promoting science education and professional development of K–12 science educators is a national priority to strengthen the quality of science, technology, engineering, and mathematics (STEM) education. This article reports the outcomes of a Geoscience Professional Development Program (GPDP) workshop organized for targeted middle and high school science educators in Forsyth and Guilford County, North Carolina. The objective of the GPDP workshop was to promote hands-on experience for K–12 science educators in the use of modern analytical techniques and instrumentation in geoscience education for the analysis of Salem Lake water in a guided-inquiry setting. Current pedagogy and innovative curriculum development to promote students' success in K–12 science education were also discussed. The expectations and challenges of first-year college students in STEM fields and methods of resolving these challenges were highlighted at the workshop to alert the teachers to the specific areas where more efforts are needed at the K–12 science education level. The workshop also served as an avenue where the specific needs and challenges of classroom instruction and technology in K–12 science education and strategies to resolve these challenges were discussed. The GPDP aimed to transform the knowledge gained from the workshop into the foundation for establishing effective STEM curricula at K–12 schools, ultimately motivating students in pursuing careers in STEM fields. A follow-up survey of GPDP participants indicated that 25% of the participants have already incorporated some aspects of the knowledge gained from the workshop into their courses in the middle and high school curricula. The majority of the participants also found the GPDP to be very exciting and highly beneficial to their professional development.

KEYWORDS: *General Public, Analytical Chemistry, Public Understanding/Outreach, Hands-On Learning/Manipulatives, Inquiry-Based/Discovery Learning, Atomic Spectroscopy, Water/Water Chemistry, Environmental Chemistry, Continuing Education*

INTRODUCTION

Effective training of more students in science, technology, engineering, and mathematics (STEM) is critically needed in today's globally competitive economic environment and for homeland security.[1] Underrepresented minorities (URMs) make up about 30% of the U.S. population, but only 17% of the STEM B.S. degrees and 7% of the STEM Ph.D. degrees.[2−6] Consequently, the development of effective teaching strategies to increase underrepresented student persistence in STEM majors continues to be a big challenge and of active pedagogical interest. Studies have also shown a continued large disparity between the retention and graduation rates of URM students majoring in STEM compared with non-minority STEM majors.[7−15] The overall retention and four-year graduation rates in most HBCUs are generally low (≤20%) due to various reasons. Promoting STEM education at the university level can only be achieved and sustained through a proactive comer grass-roots approach that will strengthen K–12 science education. For instance, most K–12 school districts, particularly the low achieving and poor performing schools, are under-funded and lack the basic resources required to teach science subjects due to severe educational budget cuts in the past several years. The provision of hands-on experience using modern analytical instrumentation and techniques and professional development programs for K–12 science teachers is also very limited due to the continued budget cuts. Consequently, large numbers of K–12 students from disadvantaged and low-income school districts are poorly prepared for undergraduate STEM degree programs, resulting in low retention and graduation rates for URM in STEM majors.

Strong collaborations between colleges and local county school districts to provide the necessary resources and professional development for K–12 science educators may be a viable strategy to alleviate the current challenges and to

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promote national science education.[16−22] Herein, we report the result of the collaboration between Winston-Salem State University (WSSU), a Historically Black College University (HBCU), and local school districts to provide resources and a Professional Development Program workshop for K−12 science educators from targeted schools in Forsyth and Guilford County in North Carolina to foster quality grass-roots K−12 science education.

GEOSCIENCE PROFESSIONAL DEVELOPMENT PROGRAM WORKSHOP FORMAT

A five day intensive Geoscience Professional Development Program (GPDP) workshop was conducted for targeted local STEM teachers and school districts in order to promote and integrate geoscience education in the classroom through interdisciplinary applications of modern analytical instrumentation and instructional technology. The GPDP was a part of a WSSU geoscience initiative funded by the National Science Foundation (NSF) in summer 2012. The GPDP workshop participants were made up of 14 science educators from targeted schools in Forsyth and Guilford County North Carolina. The participants composed of 14% males and 86% females. Twenty-nine percent of the participants had a B.S. degree in chemistry, 43% in biology, and 28% in other STEM majors. In addition, 29% of the participants had M.S. degrees in STEM disciplines. The years of K−12 teaching experience of the participants varied widely and ranged between 3 and 40 years.

Current pedagogy and innovative curriculum techniques, including active learning, student engagement, curriculum modification strategy, and the use of technology in the classroom to promote student success in K−12 science education, were discussed at the workshop in an interactive format. The expectations and challenges of first year college students, including good prior preparation, peer-pressure, time management, and critical thinking in STEM fields and methods of resolving these challenges were highlighted at the workshop to alert the teachers on the specific areas where more efforts are needed in K−12 science education. The workshop also served as an avenue where the specific needs and challenges of classroom instruction and technology in K−12 science education and strategies to resolve these challenges were discussed.

Selected guided-inquiry (GI) lab experiments involving Salem Lake water analysis were conducted to demonstrate scientific techniques and instrumentation. The workshop served as an avenue to update the participants and to reinforce the use of common analytical techniques, including gravimetry, titrimetry, analytical spectroscopy, separation techniques, sample and standard preparation strategies, and instrumental calibration. A seminar on general global water resource distributions, water utility, and water quality parameters (chemical and biological) was presented to the participants. The sources of water pollution and contamination and the effects of the contamination on humans, ecosystems, and environments, including the depletion of oxygen in water resources, acid rain, waterborne diseases, and food contamination were also discussed during the seminar. Additionally, various sampling techniques and analytical methods for water quality analysis were discussed at the seminar presentation.

To further expose the participants to a real-world water quality treatment protocol, the participants were given a 2 hs tour of the R.A. Thomas water treatment facility. This facility is responsible for the water treatment in Forsyth County from Salem Lake and other major rivers in the area. At the water treatment plant, an overview of the water purification protocols was presented to the participants, followed by a walking tour of the facility to see things first hand. Furthermore, K−12 science educators were encouraged to participate in the summer research to further enrich and update their scientific and technology skills.

GUIDED INQUIRY HANDS-ON EXPERIENCE OF SALEM LAKE WATER ANALYSIS

Salem Lake was selected for the study because of its proximity to the WSSU campus. Salem Lake is commonly used for local fishing, boating, and other recreational purposes. People often walk, run, and ride bikes around the lake. There was no indication of any industrial effluent discharge into the Salem Lake water. The participants were divided into five groups (3 teachers per group) to facilitate team-work. The Salem Lake water sample was collected in a precleaned container and immediately transported to the laboratory for chemical analysis. The chemical analysis of the Salem Lake water sample was performed using standard water analysis techniques.[23] In brief, nonconservative water parameters such as temperature and pH were immediately recorded in the field. The pH meters used were calibrated using commercial pH buffer standards before use. The suspended particles were determined by filtration of a known volume of water sample through preweighed filter paper. The filter paper was then dried and the suspended particle content was determined gravimetrically. The dissolved particles were determined gravimetrically by evaporation of a known volume of a filtered water sample to dryness in an evaporating dish. Water hardness was determined by an EDTA titration technique using Eriochrome black T indicator. The total organic matter (TOM) was determined by solvent extraction of a known volume of water sample with an immiscible organic solvent (ether). The organic liquid phase was subsequently decanted into a preweighed beaker and evaporated to dryness on a water-bath. The TOM was then determined gravimetrically. Similar studies were conducted for tap water for comparative analysis.

To further expose the participants to the use of modern analytical instrumentation, the levels of Ca in the water samples were analyzed using a flame atomic absorption spectrophotometer (Shimadzu, AA-6300) and a premixed burner air-acetylene flame. Working range Ca standard solutions (1−10 ppm) used to construct the calibration curve were prepared by serial dilutions of a 1000 ppm of Ca standard stock solution. The standard solutions were subjected to FAAS analysis, and the calibration curve was constructed by plotting the absorbance against Ca concentration. All necessary quality assurance protocols including proper AAS spectrometer calibrations and instrumental checks were observed to ensure the accuracy of the results of the water analysis.

RESULT OF SALEM LAKE WATER SAMPLE ANALYSIS

The summary of the results of the Salem Lake water analysis are presented in Table 1. There was no indication of industrial effluent discharged into Salem Lake; consequently, the observed levels of pH, total suspended, total dissolved particles, total organic matter, and hardness were within the normal range of natural lake, river, and water quality.[24] The constructed calibration curve for Ca resulted in a square correlation coefficient (R^2) of 0.9995 (Figure 1). The high R^2 value obtained for the calibration curve demonstrated that the participants were proficient in accurate standard solution preparation and the use of the AAS

Table 1. Comparison of Water Quality Parameters

Parameter	Salem Lake Water	Tap Water
Temperature	25.1 °C	24.0 °C
pH	7.23	8.00
Total suspended particles (ppm)	250.2 ± 1.5	<5
Total dissolved particles (ppm)	44 ± 2	34 ± 1
Total organic matter (ppm)	68.0 ± 1	<1
Hardness (ppm)	30.05 ± 0.12	21.28 ± 0.11
Ca (ppm)	8.82 ± 0.23	4.66 ± 0.11

spectrometer. Using the constructed calibration curve, the levels of Ca were found to be 8.82 ± 0.23 ppm in Salem Lake water.

■ ASSESSMENT AND EVALUATION OF TEACHERS EXPERIENCE AND SUCCESS OF GPDP WORKSHOP

To evaluate the experience of the participants and the success of the GPDP workshop, a post workshop discussion and a follow-up survey questionnaire (Table 2) was administered to the participants. The analysis of the follow-up survey of teacher participants indicated that 25% of the participants have already incorporated some aspects of the knowledge gained from the workshop into their courses in middle and high schools in the fall 2012. Other participants plan to incorporate the experience gained from the GPDP workshop in the teaching of future courses in middle and high schools. Overall, the GPDP workshop was incredibly successful, with the majority of the participants having found the GPDP very exciting and highly beneficial to their professional development. Some of the selected comments of the participants about their GPDP workshop experience are provided below:

"knowledge gained from chemistry concepts will be very helpful to provide instruction to my student that is aligned with the Standard Course of Study for the subject that I teach"

"great program, very helpful and informational that will inspire me to do more with middle school science students".

"from a science standpoint, I felt the tour was very informative as it demonstrated how important chemical and biological concepts are for determining water quality. This is something that as a teacher, I can pass along to my students to illustrate how science impacts the quality of their lives"

"some of the slides can be shown to the 8th graders to help them gain a better understanding when we cover the topic of the Hydrosphere"

"I enjoyed the treatment plant tour...The information given on the plant operations was very beneficial. The tour provided a look into how and where my water is being treated. I didn't even realize that the plant was even there"

Table 2. Results from the Post-PDPG Workshop Survey

Statements	Teachers' Responses[a,b]					
	1	**2**	**3**	**4**	**5**	**Avg.**
1. I plan to use information from this activity regularly in my educational work setting.	0	2	3	6	3	**3.7**
2. This activity was appropriate for my work setting.	1	2	3	4	5	
	0	3	3	4	4	**3.6**
3. This activity covered topics/methods that were up-to-date.	1	2	3	4	5	
	0	0	0	6	8	**4.6**
4. Overall, the instructor(s) was/were good.	1	2	3	4	5	
	0	0	1	4	9	**4.6**
5. The instructor(s) was/were responsive to participant needs.	1	2	3	4	5	
	0	1	0	4	9	**4.5**
6. Appropriate opportunities for discussion were provided during this activity.	1	2	3	4	5	
	0	0	1	4	9	**4.6**
7. Demonstrations or laboratory/field experiences were organized effectively.	1	2	3	4	5	
	0	0	1	6	7	**4.4**
8. Demonstrations or lab/field experiences can be duplicated in my classroom.	1	2	3	4	5	
	1	4	3	5	1	**3.1**
9. The level of challenge in this activity was appropriate.	1	2	3	4	5	
	0	0	0	7	7	**4.5**
10. The time scheduled for this activity was convenient.	1	2	3	4	5	
	0	0	0	5	9	**4.4**
11. The amount of work was appropriate for the credits received.	1	2	3	4	5	
	0	0	0	6	8	**4.6**

[a]Teacher Responses (N = 14). [b]1 = strongly disagree; 2 = disagree; 3 = neutral; 4 = agree; 5 = strongly agree.

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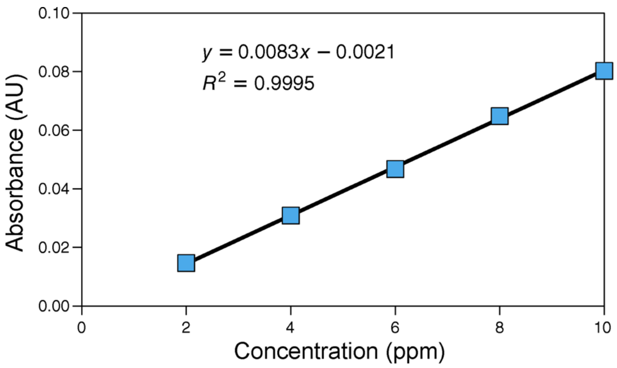

Figure 1. Calibration curve constructed for Ca determination using FAAS.

> *"in middle school we do not have access to some of the instrumentation. If next year, maybe we can have a couple of the experiments with chemicals and instruments appropriate for middle school"*
>
> *"the science activities provided knowledge for me; however, much of it was above the level of my students, and I don't have the lab equipment in my classroom. However, I need the knowledge to be more efficient at my job. Some of the concepts can be utilized but with modifications for my classroom and grade level"*
>
> *"wonderful workshop! Loved the instructor! The only problem lies with the time constraints that we have in our classrooms. We don't have 3 hs to complete a lab. We have approximately 60 min a class. This is however a great way to expose teachers to a true lab. In my experience, most middle school science teachers have very little lab exposure"*

The outcome of the workshop was successful in promoting the professional development of the K−12 science education participants. However, most participants expressed challenges and concerns such as a lack of necessary chemicals, lab supplies, glassware, and analytical instrumentation for teaching science subjects at middle and high school levels. To address some of these challenges, WSSU has initiated a robust partnership and collaboration with Forsyth and Guilford school districts to promote science education at middle and high schools. For example, WSSU is making a significant effort to donate used analytical instrumentation to many middle and high schools for teaching and demonstrations. WSSU faculty members have also established science clubs in K−12 schools, where simple, exciting, and fun science experiments are conducted to motivate students into science subjects. These science club experiments also serve as avenues to further expose K−12 students to common analytical techniques and instrumentation available to conduct scientific experiments.

More importantly, through the WSSU Geoscience Education Outreach (GEO) program, several middle school students have been recruited each summer to participate in a two week intensive GEO summer camp, where the student participated in geoscience educational activities, geospatial workshops, and career exploration field trips. Each middle school student was also assigned to a WSSU student mentor. These mentors not only helped K−12 students to understand basic scientific fundamentals but also provided crucial insight on college expectations in STEM fields. Finally, WSSU is planning to develop a summer research experience program for K−12 teachers, where they will be further exposed to more effective instructional pedagogy and student engagement techniques, analytical techniques, modern instrumentation, and other research activities.

■ CONCLUSION

The outcomes of a GPDP workshop organized for targeted K−12 science educators in Forsyth and Guilford County, North Carolina to promote K−12 science education were reported. K−12 science educators were exposed to hands-on experience in the use of modern analytical techniques and instrumentation for Salem Lake water analysis in a guided-inquiry format. Additionally, strategies utilizing current methodologies and technologies to develop innovative curricula to meet specific needs and challenges to promote student success in K−12 science education were discussed. The result of the analysis of a follow-up survey of GPDP participants showed that a quarter of the participants have already incorporated some aspects of the knowledge gained from the workshop into their courses in middle and high school's curricula. This is critical because several K−12 students will be motivated to participate in science education, ultimately increasing the number of students, particularly the underrepresented minority students in STEM majors. Overall, the GPDP workshop was incredibly successful, with the majority of the participants finding the GPDP to be very exciting and highly beneficial to their professional development.

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Notes

The authors declare no competing financial interest.

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