Using GLOBE as a simulation lab to prepare STEM ready pre-service environmental science teachers: a liberal arts university’s approach

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Abstract. To prepare Pre-service teachers to meet the demands of an increasingly technological society, a GLOBE (Global Learning and Observations to Benefit the Environment) simulation lab was infused into one of the pre-service teachers’ science courses. This course was designed to support and engage pre-service teachers in understanding how to incorporate meaningful STEM activities into their own learning experiences, and how ultimately to infuse this learning experience into their future classrooms. Organized as a research project, the course emphasizes integrating inquiry-based teaching approaches to the learning environment for pre-service teachers to develop a holistic understanding of basic Earth Science concepts. The GLOBE simulation laboratory is equipped with computers, interfaced LabQuest probes and traditional laboratory equipment that enhance interactive learning and hands-on experiences. A major component of the course is the ability to develop activities into long-term research projects. Data for a 12-months period is highlighted in this paper. Results from an end of course survey indicated that pre-service teachers valued their experiences in the simulation lab and were more confident in their ability to incorporate Geoscience ideas into the learning environment.

1. Introduction

The basic knowledge of earth science is crucial to meeting the environmental challenges that face the planet in our time [1]. It is therefore essential that earth science education begin early in the K-12 education system, which is a pivotal point for young students to understand how the earth works as a system and how humans interact with the planet [2]. Unfortunately, most in-service teachers who teach earth science in K-12 systems may not be adequately prepared to teach it. As a conduit for introducing in-service teachers to science teaching methods that are inquiry based and contain state-of-the-art technology and earth science visualization resources, GLOBE was introduced to a pool of pre-service elementary and middle school education majors. GLOBE is a hands-on, inquiry based global science and education program that brings together students, teachers, scientists and the public in over 120 countries and all the 50 states of USA. The purpose of the GLOBE program is to develop environmental awareness and a sense of global community. GLOBE activities promote the study of science, technology, engineering, math (STEM), geography and social studies. Since GLOBE incorporates many aspects of earth science and uses inquiry-based methods, it is a perfect fit for our Advanced Earth Science curriculum for education majors. One of the main challenges of implementing GLOBE in the K-12 classrooms that have been voiced by school administrators, is the lack of motivation by teachers to include GLOBE activities into their teaching. The Advanced Earth Science course is designed to prepare
and motivate pre-service teachers to teach earth science from elementary to high school levels. The course emphasis is on applying inquiry-based teaching approaches and on developing deep understanding of basic earth science concepts. The purpose of this course is to produce teachers with the necessary in-depth background and understanding of critical environmental issues coupled with the scientific knowledge to conduct GLOBE protocol data collection and recording with their students. The course elements are designed to raise the knowledge and comfort level of teachers as they implement GLOBE learning activities and measurements in their classrooms. This will in turn produce teachers who are not only trained in earth science pedagogy, but who are highly motivated to teach earth science in the K-12 education system [3]. The applied and visual nature of the course help pre-service teachers in articulating the relevancy of course activities to their lives, their communities, and ultimately, to the lives and communities of the K-12 learners [4]. The mainstay of the Advanced Earth Science class is in conducting investigations, sharing ideas with peers and the conviction that K-12 teachers will teach as they were taught. These three pillars are the key to creating innovative teachers who are highly qualified and highly motivated [5, 6].

1.1. Literature context
The importance of pre-service teacher training regarding earth science education has been vastly demonstrated [7, 8]. Historically, the earth science community has focused on enriching a teacher’s earth science content knowledge, but modern earth science teachers need more than just content knowledge. They also need outdoor field experiences, and these have been proved to be highly motivating for students and are recognized as best practices in science teaching [9]. Since the inception of the GLOBE program in 1994, many schools around the country have strived to incorporate GLOBE programs into their curriculum. However, only a small number of in-service teachers have had the opportunity to learn Globe protocols through teacher training workshops organized by GLOBE. Some colleges and universities responded to this need by designing in-service and pre-service teacher programs that produce GLOBE trained earth science teachers. The in-service programs range from one-day workshops to more comprehensive weeklong GLOBE bootcamps [10, 11]. Other in-service programs involve the development of Distance-Learning Courses which allow participants in GLOBE workshops to prepare and review material prior to attending these in-person workshops. Some pre-service teacher programs provided opportunities for teachers to learn GLOBE protocols during weekends or summer training courses [12]. Typical examples include the Wright State University’s Southern Ohio GLOBE Environmental Science Education Initiative (SOGESEI) which provides an in depth understanding of the global nature and complexity of environmental issues. This approach to learning increases the likelihood of student involvement in a proactive, solution-oriented approach to conservation and preservation of earth's natural resources. Through inquiry-based science education lessons and activities appropriate for their grade level, teacher participants have used these experiences to translate and extend their students' understanding of environmental issues. Tennessee State University (TSU) has implemented GLOBE as part of the pre-service teacher program at the Department of Geography and African studies. The University offers a broad variety of lectures and seminars linking to GLOBE. These two programs aim to produce highly motivated earth science teachers. The Advanced Earth Science course discussed in this paper is in many ways like the programs mentioned above. One unique feature of our Advanced Earth Science course is the ability to develop activities into long-term research projects. With this aspect of the course, students work in groups on a long-term environmental investigation which can be continued the following semester by the next group of incoming pre-service teachers.

2. Materials and implantation
The Advanced Earth Science course is designed for education majors as they prepare to teach Science in the K-12 education system. The course emphasis is on applying inquiry-based teaching strategies and on deepening their understanding of basic earth science concepts. Activities include a continuous research project, interactive lectures and hands-on in-class and field-based experiences. The in-class activities are mainly Earth Science laboratory experiments. A typical example that is related to water
usage is a lab in which students use data on the world’s water distribution to calculate the percentage of water that is available to humans and examine graphics that illustrate that distribution. At the end of such an activity student will have a sense of where the world’s water is located and how it moves through the Earth. During the semester students review major content areas in Earth Science within the context of GLOBE. Contents of the GLOBE Program are related to the Next Generation Science Standards (NGSS) and the State Science Benchmarks. GLOBE provides an excellent example of the NGSS and three-dimensional learning in action. A GLOBE student demonstrates the practices of science as they collect and analyze data. A GLOBE student’s learning takes place within the context of the science disciplines of Earth, Physical and Life Science. GLOBE students understand the interrelationships of the science disciplines through "big ideas" of science that crosscut all of the sciences. Finally, students in GLOBE continually apply their science knowledge in meaningful endeavors and demonstrate that the observations and learning’s that take place in GLOBE demonstrate that what we learn about our environment can be used in the relationships between engineering, technology, and the applications of science. The two major areas covered in a semester are atmosphere/climate and hydrology. The primary emphasis of this course is on discovery rather than memorization, and students work in teams and on individual projects. The main features of the course are the simulation lab, continuous research project and peer sharing of research ideas. The course is structured to meet 2.0 hours each class period for two days a week to allow ample time for field and in-class activities. The specific goals of the Advanced Earth Science course are for students to:

a. Use global maps to discover and interpret patterns of environmental data, then draw conclusions and make predictions based upon the patterns.
b. Engage in continuous research projects and sharing of ideas with peers.
c. Gain a deeper understanding of research and inquiry-based pedagogy related to teaching and learning Earth Science.
d. Enhance the understanding of earth science from a systemic perspective. Emphasis is on the study of the atmosphere/climate and hydrology.
e. Use the Next Generation Science Standards as a guide for integrating Geoscience topics in future lessons in the K-12 education system.
f. Teach mini lessons to other classmates to demonstrate their understanding of Earth Science Concepts and to learn how K-12 students might respond to their style of teaching.

All in-class activities take place in a specially designed GLOBE Simulation Laboratory. This is a large six-desk classroom equipped with computers, interfaced LabQuest probes and traditional laboratory equipment that enhance interactive learning and hands-on experiences. The GLOBE simulation laboratory was designed to give students a hands-on teaching and learning experience. Students use this room to do role playing. Some students will play the role of a teacher and deliver lessons on an Earth Science topic. By the end of the semester, every student would have a chance to play the role of teacher and student. In addition, we have acquired a min-weather station that contains the instruments needed for all the atmospheric measurements. These are the same instruments that teachers use at any school participating in GLOBE. We also have a designated outdoor open area where students do atmospheric aerosol and surface temperature measurements. An important aspect of the course is the continuous research project. The continuous research project undertaken thus far is to investigate atmospheric aerosols. The specific focus undertaken by the students during the past three semesters was to investigate the daily, monthly and seasonal variation of atmospheric aerosols in the New Orleans area. This investigation offers students the opportunity to learn scientific methods, analyze scientific data, learn how to present scientific results, and become proficient in utilizing national databases to compare and analyze experimental results. Students are organized to work in pairs and as individuals to ensure that data is collected every day. To achieve continuity in data collection, research students are employed during the summer months. The first three classes of this course have investigated the monthly and seasonal variation of aerosol optical thickness (AOT) using a handheld sun photometer. The data compiled by two classes over a 12-month period is described here to illustrate the continuous research project component of the class. AOT
measurements are done 6 times a day (7:00am, 9am, 11am, solar noon, 3pm and 5pm). The students are organized to make sure that at least one person is available to make measurements at each of the 6 times each day. Figure 1 shows variation of the average monthly AOT measured at XULA over a 12 months period. Average ozone optical thickness corrections of -0.01 and -0.03 are applied to the 505-nm and 625-nm optical thickness values [13]. Figure 2 shows the average AOT values per season. The seasons are categorized as follows: winter (December, January and February), spring (March, April and May), summer (June, July and August) and fall (September, October and November). This data and the analysis done on the data led to the first publication from the continuous research component of the Advanced Earth Science class [14]. Subsequent classes will not only continue collecting data but will also look at other aspects of atmospheric aerosol investigation. These include establishing the size distribution of the aerosols, identifying the source and nature of the aerosols and comparing their data with the nearest professional aerosol monitoring stations such as AERONET [15].

Figure 1. Shows the variation of the monthly average AOT values measured at XULA over the 12-month period. AOT values were measured with two channels at wavelengths 625nm and 505nm and ozone correction was applied to this data.

In order to promote the sharing of ideas with their peers, students are expected to participate in at least one GLOBE Student Research Symposium (SRS) or GLOBE boot camp while enrolled in the course. At these symposia, students share results from their research investigations which included data collected using GLOBE protocols and data obtained from the GLOBE data base. They also share ideas with professional scientists, learn from each other and receive feedback on their research. In addition, the symposia provide a good opportunity for students to experience a STEM conference and learn about STEM careers. These experiences offer invaluable opportunities to enrich and enhance learning as well as to increase student confidence and enthusiasm in the subject [2, 16].
Figure 2. Shows the seasonal variation of AOT at the XULA site. Seasons were categorized thus: winter (Dec, Jan, and Feb), spring (March, Apr, May), summer (Jun, July, Aug) and fall (Sept, Oct, Nov).

To assess student learning in this class, a systematic progression of assignments is used to track student achievement over time. Table 1 shows all the components involved in the final assessment of the students in the Advanced Earth Science class. Strong emphasis is placed on learning through research. It is for this reason that the group research project has the highest contribution towards the final grade. Apart from the specific technical skills that are gained in the in-class activities, the research project offer students an opportunity to engage in the scientific process in a way that teaches them to think critically and scientifically and to work as a team [17,18].

Table 1. Final grade assessment for IPSC4010 Advanced Earth Science.

| Component                  | Contribution to Final Grade |
|----------------------------|----------------------------|
| In-Class Activities        | 15%                        |
| Atmospheric Investigations | 20%                        |
| Lesson plan/Lesson Presentation | 20%                    |
| Professional Disposition   | 10%                        |
| Research Project           | 30%                        |
| Participation              | 5%                         |

3. Results and discussions
After 2 semesters, a follow-up study was conducted to seek evidence for the effectiveness of the GLOBE simulation Lab and the Advanced Earth Science class in general. Data was collected via a 5-item anonymous survey sent to the first pre-service teachers who completed the course [19]. 67% of the students responded to the survey. The first three questions on the survey required students to use a scale between one and five (one being poor and five being excellent) to rate certain aspects of the course. The other two questions were open ended. The survey questions are listed below:
1. The clarity of the course was
2. Agreement between course objectives and materials taught was
3. Opportunities for learning in this class were
4. What was the major strength of the course?
5. Was the class experience you had in this class useful in your work in the K-12 system

The average rating for survey question 1 was 4.3, and for survey questions 2 and 3 the average rating was 4.6. The verbatim responses to questions 4 and 5 all demonstrate a great enthusiasm for the class. Table 2 and Table 3 shows a sample of these verbatim responses.

**Table 2.** Student responses to survey question 4: What was the major strength of the course?

| What was the major strength of the course? |
|--------------------------------------------|
| Major strength was creating hands-on activities that allow us to work actively while learning about various topics. Another strength is providing ideas of how to teach science |
| Course connected all activities to teaching (how we would teach) |
| Learning about the environment and checking temperature, pressure, rainfall, clouds, and relative humidity. Earth science is pretty self-explaining, it was very much hands on which is what I enjoyed most |
| Lots of hands on and constructing of knowledge- I learned a great deal |
| The atmospheric aerosol research was my favourite aspect. |
| The best aspect of the course was becoming a part of GLOBE program and actually being able to present a real lab experiment with data/results to other staff within the GLOBE program. This was a great opportunity to learn something new and interesting in regard to science. |
| The best aspect of this class was the group/class assignments we, as students, were expected to complete. We were to report at our outdoor site to record temperatures, relative humidity, pressure and weather. We each were responsible for going check on a particular day and at a particular time. We were to come together with our records to keep track of the data. We learned to work as a team. We were able to assist one another, and Dr. G was always available to give extra assistance. He was awesome at explaining the purpose, the instructions and expectations. In the end, we were given the opportunity to present our data before the members of GLOBE community. We also learned how to understand climate change and a number of other activities/experiments, which was quite interested. |
| Making measurement at the mini-weather station and presenting our procedures and data to the visitors at the end of the GLOBE boot camp. |

**Table 3.** Student responses to survey question 5: Was the class Experience you had in this class useful in your work in the K-12 system?

| Was the class Experience you had in this class useful in your work in the K-12 system |
|--------------------------------------------------------------------------------------|
| This course allows us to develop ways to teach science as well as interpret interesting science topics |
| This course allowed us to be able to explore potential hands on lessons |
| I plan to include the hands-on activities in my lessons as a teacher |
| I learned about things in science I did not know. |
| Yes, the class experience was useful in my work in the K-12 system. It was because we learned how to use different tools, network with others using the same program, and practice showing others (who will be our students in the future) how to do the procedures. |
| In terms of the course being useful in my work in the K-12 system, I can’t really say because I haven’t had the chance to put those skills I learned and practiced using with a set of students. But the course has opened up my eyes to ideas to make Science a less boring subject for students and ways to present Science lessons to make learning more effective through hands-on activities. |
This class experience was quite useful and a great learning experience. Many of the class experiments and assignments would be awesome in a K-12 classroom. Students would learn so much while having fun. I have not been working in the system just yet, but I have learned things that I can use and incorporate in my lessons. Dr. G’s enthusiasm and willingness influenced my perspective on the sciences even more.

Being my first-year teaching, I haven’t had the opportunity to use the knowledge that I gained in this class, but I believe that the more I teach, the more I will access the concepts I learned.

This survey validates the effectiveness of the GLOBE simulation lab and the Advanced Earth Science class in general. In addition to the specific technical skills that students gained during the in-class activities, the research project offered students an opportunity to be engaged in the scientific process in a way that fostered critical thinking. The continuous research aspect of this class has led to one publication and has the potential to produce more publications as more data is collected. The mandatory GLOBE boot camps and student research symposia that students are required to attend during the course help students to connect with people in the field even before they graduate. This course also helps to increase collaboration between faculty in the department of education and those in STEM areas. Faculty with a solid STEM background should be the prime candidates for teaching Geoscience courses to pre-service teachers. It has been our experience that their in-depth knowledge enables a seamless implementation of New Generation Science Standards with Geoscience content. To expand their knowledge base and to increase the available pool of Geoscience teachers, these faculty members should also provide ongoing GLOBE professional development workshops for in-service teachers. College and University faculty should factor in student reflections when designing Geoscience lessons. Reflections are crucial for showcasing the skills that may have been acquired by the pre-service teachers and can also be useful as a motivational tool for the University faculty members who teach the Geoscience course. These elements become critical as the faculty member continues to plan the best pedagogical approaches and assessments in Geoscience courses. From the performance of the students in the class activities, it was clear that students with a STEM background were more comfortable with the mathematical requirements of the course.

3.1. Limitations
The main limitation of running this course is the heavy investment in GLOBE equipment necessary to run the class. For the course to be effective, it is essential that the students are exposed to as many of the equipment needed to do GLOBE protocols as possible. Many schools doing GLOBE are only limited to one or two of the many GLOBE protocols depending on their resources. Also, GLOBE hydrology protocols require proximity to a suitable water body. If the water body is far away from the school, it could present scheduling problems. One of the main pillars of this course is the continuous research project. For this project, measurements are taken throughout the year, this could be a problem if the course is offered only once a year as was in our case. In order to keep the project going we had to use research students from other classes to take measurements when the class is not running. In order to truly assess how this course has impacted our students, we need them to be employed at a school that practice GLOBE after graduation, but this is not often the case.

4. Conclusion
Preparing pre-service teachers who are STEM ready, knowledgeable of Geoscience content, and cognizant of how adolescents learn, is a formidable yet noteworthy task for many Colleges and Universities. Based upon the observations and outcomes from the evaluation of this class, the following recommendations are provided as a guide for preparing pre-service teachers for success in Geoscience courses.

1) Pre-Service teachers must have solid preparation in mathematics prior to enrolling in the GeoScience Course. To ensure that pre-service teachers are able to perform the mathematical
calculations and understand the instrumentation that is used in data collection, colleges and Universities must provide pre-service teaches with a strong mathematics curriculum that is grounded in content and in knowledge of how school aged children learn mathematics.

2) Pre-service teachers must be provided with multiple opportunities to analyse and articulate the scientific meaning behind the data in order to effectively communicate its Geoscience content to their own students.

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