Broadening and Sustaining an Air Quality K-12 Curriculum through a Digital Library and Undergraduate Service Learning Course

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Abstract— The availability of low-cost sensors and environmental monitoring technologies is growing rapidly. While researchers are making use of these technologies and validating their results, there is also enormous potential for use in education and outreach. Through the Air Quality Inquiry Project (AQIQ), we are bringing next-generation air quality monitors into the K-12 classroom and developing a curriculum with necessary resources to support student-driven research projects.

This paper will represent year three of the AQIQ project. During year three of the project, one focus has been on the revision and publication of the curriculum. The AQIQ curriculum consists of five modules, which range from fundamental concepts related to air quality monitoring and management to a hands-on project using the monitor for student driven air quality monitoring projects in the local community. The curriculum culminates in an end of semester symposium in which students present their projects to the community. The modules are currently being submitted to the TeachEngineering Digital Library for further dissemination.

Another large thrust for year three of the project has been the development of an undergraduate class to train engineering students to teach the curriculum in a broader number of K-12 classrooms. In this pilot offering of the year-long course, four pairs of engineering students travel monthly to eight science classrooms in rural communities on the western slope of the Rocky Mountains and on the high plains east of Denver where natural gas development is occurring. The course meets weekly to teach air quality monitoring concepts, process students' visits and plan future trips. The course is planned to become a regular course offering in the engineering curriculum at CU in year four. This paper will discuss the developing curriculum, the specifics of the pilot course and the results of our assessments implemented thus far.

Keywords—K-12 outreach, project-based learning, digital libraries

I. Introduction

The AQ-IQ Program (Air Quality InQuiry) combines a low-cost air quality monitoring technology, a project-based learning curriculum, and undergraduate mentors to provide engineering education and outreach in a K-12 setting. This current project grew out of the North Fork Valley Air Monitoring Project [1]. Currently in its third year we have expanded the number of K-12 students we are engaging and we are working to build a sustainable foundation for the program. This paper will focus on the new aspects of the project including progress made with the curriculum, our pilot service-learning course for engineering undergraduates, and preliminary assessment results.

II. Project Development

Delta County CO lacks detailed historic air quality data, and a local community organization, the Western Slope Conservation Center (WSCC), expressed interest in understanding the current state of air quality in the area ahead of proposed oil and gas development. They reached out to contacts at the University of Colorado Boulder' Office of Outreach and Engagement, who in turn reached out to an Air Quality Research Lab led by Michael Hannigan (PhD) in the department of Mechanical Engineering. Thus the North Fork Valley Air Monitoring Project began as a collaboration between these partners with the original objectives of piloting low-cost tools for baseline air quality data collection, and engaging the community in citizen science. During year one, we invited local high school students to assist with the project, but found that they were more interested in asking their own air quality-related questions. We decided to support these student driven projects and after seeing the benefits of this experience to students, particularly in a rural and underserved community [2], we decided to continue this outreach work for a second year. In year one, we worked with three classes across three schools. During year two, the project continued through the NSF funded Sustainability Research Network AirWaterGas (AWG) Project, specifically with the help of the AWG Education and Outreach (E&O) team [3]. Year two activities for the NFV Project included curriculum development, implementation in multiple school districts, and assessment. In year two we worked with seven classes across five schools. In our current year we are working with nine classes across six schools.

We are interested in working with rural districts whose students we have found to be underserved in terms of access to resources and opportunities to learn about engineering and pursuing higher education. A school district partner we have worked with through years one through three, Delta County School District 50 (DCSD), is located on the Western Slope of Colorado in the North Fork Valley. This area is rural and a primarily agricultural community. During the 2013-2014 school year, 50.1% of the students were eligible for free or reduced lunch and in 2014-2015 this number remained relatively constant at 52.5% [4]. Additionally, 10%-20% of county residents have a college degree, which may affect the perceived value of education among high school students considering college [5]. Delta County is a more than four hour drive from Colorado's large state schools making K-12/university partnerships difficult to initiate and sustain.

We are also interested in working in districts affected by current and proposed energy development. K-12 education and outreach is a means of building partnerships and trust with rural communities that may provide pathways for disseminating other results, relating to water quality or health for example, from the NSF-SRN AirWaterGas Project. Many of these communities are currently in the process of deciding how to allow these industries to operate and how to regulate them; having these partnerships in place has the potential to help us provide these communities directly with access to experts and new research. Additionally, basing our program around air quality provides a vehicle to initiate conversations on complex issues surrounding energy development and use with students. In many instances the two target communities described above are one in the same.

III. The Technology and Accessibility

For several years, an Air Quality Research Lab led by Michael Hannigan (PhD) has been developing and piloting an air quality monitor that utilizes low-cost sensors for air quality research. The monitor is an open-source design that can be constructed for under $1000 per monitor [6]. The U-Pod is capable of recording data for multiple pollutants (e.g., carbon dioxide, carbon monoxide, volatile organic compounds, ozone, and nitrogen dioxide) continuously. New technologies such as this one are extremely valuable for STEM education not only because of their increasing affordability, but also because students can take a hands-on look at something they could build themselves. Students can open up the U-Pods and consider the different engineering necessary to build and run this technology.

To make this technology available to teachers who would like to implement the AQ-IQ project-based learning program, we are organizing a "check-out" program. Teachers will be able to rent kits that include two U-Pods, a small laptop, a user manual, and other accessories (e.g., batteries and power cords). This check-out program will be based out of the CU Museum of Natural History and we will use the same model and procedure as is used by another outreach program that makes fossil kits containing specimens available to teachers [7]. The kits are easy to transport and available for the cost of shipping. This allows teachers flexibility in their participation and commitment; for example, they do not have to commit to a high cost technology that they may not use year after year to use or that may require more technical support than they had anticipated. In addition to simplifying access to the technology for the teachers, we believe this is a sustainable model from the research lab's perspective as well. This check-out model incorporates the work of getting the technology to and from teachers into the existing outreach work being done by the museum, but also maintains a connection to the lab on the CU campus. Thus the lab can provide technical support for this second set of U-Pods as it continues to use and develop the U-Pod for other air quality research.

Researchers examining pathways to technology integration in K-12 settings used a large data set containing the following variables: teachers' readiness, teacher's beliefs, age, years of teaching, overall support, technical support, computer proficiency, and computer availability. These researchers found that after controlling for all other variables only readiness, beliefs, and computer availability had significant direct effects on integration [8]. They also found that teacher readiness is affected by proficiency, overall support, technical support, years of teaching, and computer availability [8]. According to these results computer availability both directly and indirectly effects the integration of technology. And support is also important as it directly affects teachers' readiness to integrate technology. Through this check-out program we are simplifying access to a next-generation technology and we are putting in place mechanics to provide both overall support and technical support to teachers.

As researchers implementing robotics programs have found, hands-on learning experiences with new technologies can generate interest and curiosity around STEM in general and engineering in particular (cite). We hope that using the U-Pods provides a more true-to-life research experience for high school students and inspires them to consider both higher education and engineering. By bringing the technology to students in rural and underserved schools, we hope to provide a more locally relevant research experience where students are supported as they investigate their own and their community's questions. Similarly to researchers working to broaden participation in computing in urban schools, who found that providing culturally relevant curriculum and inquiry based learning to be more effective at engaging students from urban schools [9].

IV. The Curriculum

To facilitate the use of U-Pods in student projects, a project-based learning curriculum with five modules has been developed to augment student project development and instruction. Table 1 provides a description of the five modules and the skills covered under each module. The modules are currently under review by the TeachEngineering Digital Library.

The modules were extensively tested and revised during the 2015-2016 academic year via undergraduate teaching in the K-12 classrooms. The curriculum is aligned with K-12 teaching standards, designed for use with other technologies besides the U-Pod and available to support long-term projects or for short-term activities through the use of specific links directly to the module activities.

Table 1: Description of the AQIQ Curriculum by Module

Module	Title	Skills
1	Introduction to air quality research and the U-Pod (lecture and demo)	Background knowledge and vocabulary for air quality and engineering and concepts
2	Data collection (activity)	Using the U-Pod, Critical thinking regarding sources of error and results
3	Data analysis (activity)	Basic statistics and data visualization information, Using Excel for calculations and graphing,
4	The Project (planning, data collection, data processing and analysis)	Planning and carrying out a research project (scheduling, logistics, designing data collection, etc…), Processing raw instrument data, Analyzing data in Excel
5	Interpreting data and presenting results	Data interpretation, Communicating results, Making a scientific poster or presentation

V. SERVICE-BASED LEARNING COURSE

A component of the project that is new this year is a service-based learning course for engineering undergraduates. This year the course was set up as an independent study in each students' respective department and students received 3 credit hours for the course (the typical amount for an elective). Students from mechanical engineering, environmental engineering, and computer science participated and were interviewed prior to admission. The entire course lasted through both Fall and Spring semester, with a slightly lighter workload per semester. Key components of the course included a series of lectures, weekly meetings, visits to assigned high schools, and assignments. The lectures covered air quality background, technology training and troubleshooting, and K-12 teaching/education and outreach. The class was led by a professor in Mechanical Engineering and a faculty member with expertise in education, outreach, and assessment; it was also assisted by a graduate student with technical expertise regarding the U-Pods. In our pilot year, eight students participated. We will utilize a similar model for 2016-2017 school year, however, the course will be listed as a Mechanical Engineering elective.

Students participating in this course learn by teaching. During each site visit they teach a lesson/activity from the curriculum, which takes their high school class through air quality background, data collection, data analysis, study design, and presenting study results. They also mentor the HS student teams by advising them on choosing a research question, helping them troubleshoot during data collection, and working with them through data analysis and interpretation. The weekly meetings for the independent study provide an opportunity for the CU mentors to discuss questions or problems with other mentors and the program leadership.

Incorporating service learning into engineering is not a new idea. The EPICs project at Purdue engages engineering undergraduates in a multi-year design project for the benefit of a community partner. There are also examples of engineering service-learning for the benefit of K-12 partners such as the NSF-funded GK-12 Teaching Fellows Program. Assessments on the impact of participating in service-learning have revealed that these experiences enhance "soft skills" needed for engineering like communication and teaching skills [10], help to accomplish learning objectives defined by the Accreditation Board of Engineering and Technology [11], and the skills students gain during their participation having a lasting impact into their careers and graduate school [12].

VI. ASSESSMENT RESULTS

Assessment for the current year has been focused on the new, service-learning course with K-12 student pre and post-surveys, assessment of the undergraduate mentors via a post-survey and focus group, and a post-survey of the K-12 teachers. The air quality inquiry (AQIQ) program was assessed against the following goals

1. Introduce air quality topics to K-12 students in rural areas.
2. Encourage K-12 students to learn more about STEM fields.
3. CU mentors travel monthly to high schools to oversee and teach.
4. The program implements an air quality curriculum focused around hands on projects for students
5. Incorporate air quality monitoring technology.

Overall the results indicated high satisfaction among K-12 students, undergraduate mentors, and K-12 teachers for the

AQIQ program with good amount of the quantitative ratings above the target rating of 4.00/5.00. The surveys provided valuable feedback on strengths of the program as well as improvements to be made for future years which can be seen listed below.

K-12 teacher feedback can be seen in Table 2 below. Feedback was supportive of student learning and skill development with one teacher commenting, “I think this program really has benefits for my students and gives them experience "doing" science.” For an improvement, teachers wanted more technical support for the pod technology deployed in their classroom. This is being partially remedied this year by the development of a new pod that is easier to use and the development of an instruction manual.

Table 2: K-12 teacher feedback

Answer Options 5 point scale	Rating Average
My students learned more about the scientific method and the research process.	4.33
Skills my students learned through this project will be valuable in future classes.	4.33
My students learned new information about air quality.	4.00
My students’ engagement increased through participation in this project.	4.00
I received enough technical support in terms using the pods, looking at data, using excel, etc....	3.67

Undergraduate mentor feedback can be seen in Table 3. Overall, undergraduates marked the impact of the program on their skill and teamwork and communications as well as their impact on the K-12 students with one mentor saying,

Table 3: Undergraduate mentor feedback

Answer Options 5 point scale	Rating Average
Developed teamwork skills.	4.71
Developed communication skills.	4.43
Was satisfied with the availability of the course instructors.	4.29
Think that my work having an impact on K-12 student knowledge of science and engineering.	4.14
Believe that sufficient training was provided for me to be effective in the classroom.	3.71

“This course was very helpful to me in that it helped me with my public speaking and it was very cool to expose kids to STEM education.” Mentors did express an interest in receiving more training on teaching skills and using the pod. This will be addressed in the coming year with a teaching skills workshop and additional training in using the pods before entering the classroom.

Pre and post K-12 student feedback can be viewed in Table 4. Students reported strong gains in their skills and knowledge, but dropped in their interest. Plans for next year include additional content on how air quality knowledge could be integrated into their lives and useful for their communities in the hopes of increasing interest.

Table 4: K-12 student feedback

Answer Options 5 point scale	Pre-Rating Average	Post-Rating Average
I understand how issues related to air quality impact my community.	1.92	3.90
I understand how to measure air quality with monitoring technology.	3.79	4.31
I understand the importance of engineering and scientific research on environmental issues.	3.84	4.18
I am interested in learning more about air quality.	3.54	3.16

VII. FUTURE PLANS

As the program continues to grow we will work to standardize our assessment methods and obtain larger samples. At this point out primary objectives are to inform our final edits to the curriculum for posting in the digital library, refine our next offering of the service-based learning course, and our overall approach to education and outreach through the AQ-IQ program.

Future plans target the sustainability of the AQIQ program beyond the grant funding cycle. Our plans are to develop a check-out program (supported by our lab), to implement the service learning course as an on-going tech elective in the College of Engineering and Applied Science at CU and to post and refine our TeachEngineering curriculum. Efforts are also being made to secure additional funding to support program costs.

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