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Water in India and Kentucky: Developing an Online Curriculum with Field Experiences for High School Classes in Diverse Settings

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Abstract: Maintaining access to sufficient amounts of clean water for human and environmental needs is a global challenge requiring education and community engagement. We developed a curriculum integrating field experiences with online modules focusing on the water cycle, water quality, and human impacts. This year-long curriculum connected nine public high schools in Kentucky with ten private, English-language schools in eastern India. Curriculum design was informed by the Next Generation Science Standards (the new U.S. education standards for science) and utilized freely available, open-access technology. Each instructional module included a narrated slideshow with general information and examples from Kentucky and India, exercises involving online data sets, and guidelines for class projects. Students developed creative products (e.g., posters and dramatic performances) for community outreach on water issues. Class projects involved literature reviews of local water bodies, collection of data using water-quality test kits, and submission of a research proposal, which was evaluated by scientific professionals with a background in hydrology. The highest-rated team from each country traveled to the other country to present their findings at a professional meeting or workshop. Eight of the Indian schools prepared video summaries of their projects, which were reviewed by an undergraduate class at the University of Kentucky. The curriculum and examples of student work are available on a publicly accessible website. Challenges faced during project implementation included difficulty in assessment of student products and, particularly for Kentucky schools, integrating activities into existing curricula. Nonetheless, the proposals, final papers, and other products indicated that students understood hydrologic concepts and were aware of water-quality issues.

Keywords: *international, water quality, surface water, groundwater, environmental education, outreach, assessment*

Solving the world's myriad water challenges requires not only conceptual understanding of hydrologic processes, but also availability or collection of appropriate monitoring data and community-cooperation awareness (UNESCO WWAP 2012). Engagement of youth, particularly at the high school level, is key to these efforts, but access to appropriate educational materials is uneven (e.g., Wagener et al. 2012). High school involves a transition to adult roles and responsibilities, including civic engagement, as well as learning and identity exploration. It is important for high school students, regardless of where they live, to see themselves as participants in their communities, messengers to various groups, and change agents. Young people play a strategic role in motivating society as a whole toward learning and practicing environmental good (e.g., Thunberg 2019).

The U.S. State Department recognized "a knowledge gap in understanding how water systems work, rising pollution levels and their deleterious effects on human health, and what can be done on the local level to address pollution" within the Indian public (U.S. Mission to India 2016). Consequently, the U.S. Consulate in

Kolkata funded the University of Kentucky (UK) to develop an online, modular curriculum focused on water for high school students. Introductory videos and exercises were integrated with local field experiences and communication of water-quality related issues to the public. The project was intended to enable students to partner in research, to compare and contrast each country's problems, and to work mutually on solutions (U.S. Mission to India 2016).

Researchers at UK and three Indian institutions collaborated with a non-governmental organization based in Kolkata (Association for Social & Environmental Development [ASED]) to identify ten schools in eastern India and nine in Kentucky, which participated during the 2017–18 academic year. The fundamental goal of this project was to develop global citizens who have the skills and knowledge to protect the environment, especially water quality, and consider environmental protection a civic responsibility. Teachers at each school were responsible for the selection of students and the integration of project activities into existing curricula. Student teams submitted research proposals that were judged by professionals with experience in environmental education and hydrology. The school with the highest-rated proposal from each country sent a team of students and teachers to the other country to present research results as part of a scientific and cultural exchange.

In this paper, we provide the rationale for the curriculum and the details of its design. We highlight student activities as well as challenges in implementing and assessing the impacts of the project. We make recommendations for addressing these challenges, and we conclude that the curriculum design and the content generated are broadly adaptable for water education in high schools, contingent upon access to the internet and relatively simple water-quality monitoring supplies.

Water Issues in Eastern India and Kentucky

Water quantity and quality problems are increasingly prevalent across India. As reviewed by Mukherjee et al. (2015), the Indian subcontinent hosts ~23% of Earth's population within only ~3% of global land area. Per capita availability of water in India decreased from 4000 m^3/yr in the 1980s to < 1900 m^3/yr by 2008 (Babel and Wahid 2008). Rapid population growth and intensive pumping of groundwater for irrigation are causing water scarcity in much of the country, but water quality is generally a greater issue than water scarcity in eastern India. The region is humid, with annual precipitation ranging from ~100 to 800 cm/yr, and is drained by the Ganges and Brahmaputra Rivers, which are ranked #14 and #5 in the world by discharge, respectively (Dai and Trenberth 2002; Mukherjee et al. 2015). Intense seasonal rainfall and rejected recharge result in frequent flooding in eastern India. The alluvial aquifers of the Ganges-Brahmaputra basin are extensive and highly productive, although other aquifers are less productive and the areas in which they are located are more susceptible to shortfalls in monsoonal rains. Surface waters are commonly polluted by sewage, municipal and industrial wastes, and agricultural activities (Babel and Wahid 2008). Groundwater is impacted by elevated concentrations of naturally occurring arsenic and fluoride, particularly in West Bengal state (Mukherjee et al. 2015). In addition, seawater intrusion is occurring in coastal areas as a consequence of groundwater pumping, and it may be aggravated by sea-level rise (Michael et al. 2013).

Water issues in Kentucky are primarily linked to non-point source pollution and hazards such as flooding rather than water supply. Precipitation averages 100 to 130 cm/yr (Carey 2017). The Ohio River basin drains 97% of the state and surface sources supply about 95% of water used in Kentucky, including about two-thirds of public water systems (KGS 2014; Carey 2017). Approximately 97% of the population receives drinking water from public water systems, but only 52% are on public wastewater-treatment systems (Carey 2017). Primary non-point sources of surface-water pollution include mining (31%), agriculture (29%), land disposal/septic systems (20%), and urban runoff (10%), whereas municipal sewage-treatment plants account for 70% of point sources of surface-water pollution (KGS 2014). Potential sources of groundwater pollution include unplugged oil and gas wells, septic tanks, underground storage tanks, inactive landfills, and dumps (KGS 2014). Approximately 38% of Kentucky is underlain by carbonate rocks whose dissolution has resulted in karst terrain (Currens 2002). This development of integrated surface and subsurface drainage networks, which link sinkholes, conduits, and springs, facilitates rapid movement of non-point source pollutants (Currens 2002).

Project Goal and Objectives

Although the overarching goal of the project was to promote the development of global citizens who have skills and knowledge to protect the environment, especially water quality, and consider environmental protection a civic responsibility, this paper focuses on the accomplishments of three major objectives. These are: 1) the creation of three interactive, inquiry-based, online environmental science modules that engage students in water quality and quantity issues; 2) increasing students' content knowledge of environmental systems, especially hydrologic systems and water quality; and 3) enhancing students' understanding of and attitudes toward water quality and other water issues. Concepts regarding water quality and water-quality awareness (WQA) were interwoven into each of the three integrated online modules. More specifically, Frick et al. (2004) hypothesized that environmental knowledge may lead to pro-environmental behaviors and has three domains, including 1) an understanding of natural processes within ecosystems and the effect of human-nature interactions (system knowledge); 2) an understanding of actions that might be taken to address environmental problems (action-related knowledge); and 3) knowing about options and how effective one may be when choosing from a list (effectiveness knowledge). Therefore, exercises that address the domains of Frick et al. (2004) appeared in each module.

Curriculum Design and Content

Our curriculum design was motivated by the desire to facilitate and encourage interactions between the students in the online/hybrid environment (Wanner and Palmer 2015), a factor that is essential to the success of such instruction (Song et al. 2004). The project presented a series of problems requiring collaboration among students. This form of "inquiry-based learning" has been shown to be very effective in the geosciences (Apedoe et al. 2006).

Next Generation Science Standards (NGSS 2013) informed the design of the curriculum. Through the implementation of these science standards, educators attempt to increase students' ability to conduct scientific practices, including "planning and carrying out investigations" and "asking questions and defining questions." Because some of the participating teachers in Kentucky taught this project in AP Environmental Science classes, the learning outcomes for the overall curriculum were also aligned to the learning outcomes of AP Environmental Science, particularly concerning Earth systems and land and water use (College Board 2018).

In developing the online curriculum, we utilized only freely available, open-access technology to equalize, as much as possible, the technological resources that are available for students in a variety of high schools (e.g., Lane 2009). We also used a free Google service to build the project website. Our initial version was private, but after the project was completed, identifiable student work was removed and a mirror site (https://sites.google.com/view/wiiky-friends/) was published so the curriculum and educational materials could be publicly accessible.

Three modules were developed to increase student knowledge and affect attitudes toward water quality (Table 1). The homepage for each module gave the title, driving questions, and a list of learning objectives. An introductory PowerPoint presentation followed as a narrated video and as an editable PowerPoint file with the narration text available within the slide notes. Modules included case studies from both India and Kentucky, and activities (i.e., exercises) primarily utilizing local- to regional-scale data sets available online. These data sets include rainfall (IMD 2019; UKAWC 2019), groundwater levels in wells in India (India Water Tool 2019), stream levels from the Bangladesh Water Development Board (BWDB 2019), stream flow from the U.S. Geological Survey (USGS 2019), and surface-water quality (USGS

Table 1. Curriculum modules and learning objectives.

Module	Learning Objectives
(1) Water on Our Planet	• Identify water bodies (reservoirs) of the water (hydrologic) cycle. • Identify processes by which water moves from one reservoir to another (fluxes). • Speculate about variability in the movement of water in the water cycle in one's home area. • Describe the availability of water on Earth. • Identify connections between personal water use and flux within local water bodies.
(2) Problems with Water	• Define various chemical and physical measurements of water quality. • Speculate how water quality will vary with changing natural and anthropogenic conditions, both spatially and temporally. • Plan a water-quality research project and collect pilot data.
(3) Humans and Water	• Speculate about the long-term effects of human activities on the water cycle. • Interpret long-term patterns in local and regional fluxes within the water cycle. • Execute a research project to include acquisition of data, analysis of data, and interpretation of results. • Analyze strategies for reducing the human impact on water bodies within their community and select the most appropriate technique(s).

2019; WBPCB 2019). Assignments followed the introduction and folders were included into which students could upload their work. Each assignment addressed a driving question (Table 2).

Each module contained optional formative assessments and a summary project. The formative assessments provided teachers with questions for their students that reinforced concepts in the introductory PowerPoint presentations. The summary projects were designed to scaffold the development of students' final research projects across the three modules. In module 1, students identified an important water body within their community that they wanted to study throughout *all* three modules. In addition, students had the opportunity to explain their water body's cultural and scientific significance and discuss its relevance to their community. In module 2, students studied how to measure water quality. As the summary project for module 2, students were asked to synthesize ideas about water-quality monitoring for their chosen water body and submit a research proposal, which formed the basis of the final project in module 3.

Modules 2 and 3 included simple, local water-quality projects using test kits and multimeters. Each participating school received a waterproof digital wand for measuring temperature, electrical conductivity, and total dissolved solids. Each Indian school received a test kit that used reagents to quantify pH, hardness, chloride, residual chlorine, nitrate, and fluoride, plus a Secchi disk for measurement of turbidity, as well as a kit with reagents for quantitative detection of fecal coliform bacteria (Octopus Inc., Vadodara, India). Each Kentucky school received a LaMotte Earth Force Low-Cost Water Quality Monitoring Kit (Carolina Biological Supply Company, Burlington, NC, USA) with reagents to quantify pH, dissolved oxygen, biochemical oxygen demand, nitrate, phosphate, and total coliform, as well as a liquid crystal thermometer and turbidity measuring scale. As a possible form of project/problem-based learning, field experiences have been shown to be very successful at the secondary school level (Ho and Chan 2015). These exercises helped students make connections between knowledge gained and potential benefit to the local community.

Table 2. Instructional activities and associated driving questions.

Instructional Activity	Driving Questions	Environmental Knowledge Domain
Module 1 Wiki 1	Where is water stored?	System
Module 1 Activity 1	How does water move from place to place?	System
Module 1 Wiki 2	How much water is on our planet and how much is available for our use?	System
Module 1 Summary	Which part of the hydrologic cycle is most visible in your area? Where did the water in it come from? How has this water body shaped your local culture? How does community water use affect the amount of water in this water body?	System
Module 2 Wiki 1	How do you measure water quality?	System
Module 2 Activity 1	How could water quality vary?	System
Module 2 Summary	What is the water quality of your chosen water body? How was or is the water in this body being used? What is your research question? What data need to be collected and what methods will you use? What are your anticipated results?	System, Action
Module 3 Wiki 1	How have humans contaminated water?	System
Module 3 Activity 1	How have fluxes in the hydrologic cycle varied over time?	System
Module 3 Wiki 2	What can humans do to improve water quality?	Action, Effectiveness
Module 3 Summary	What is the water quality of your chosen water body? How was or is the water in this body being used? What is your research question? What methods did you use and what are your findings?	System, Action

Many assignments were open-ended, including the summative assessment for each module and the overall final project for the course, thus promoting creativity and cooperation. Students were encouraged to make connections between water and culture, customize their final projects to their own regions and interests, and use a variety of formats to address their research questions. Students could take a scientific approach through making visualizations of existing data and/or collecting new data, but could also make visual and/or verbal representations of concepts and connections through documentary film-making or other art forms. Some assignments took the form of wikis, encouraging students to build community knowledge by disseminating online videos, posters, podcasts, and brochures (Notari 2006; Parker and Chao 2007). The advantage of a flexible approach is that it accommodates a broad range of learning styles, background knowledge, access to technology, and cultural preferences (e.g., Germain-Rutherford and Kerr 2008; Grünewald et al. 2013). This approach also promotes place-based case studies, which help students to make connections between global-scale issues and their local communities (Semken and Freeman 2008). The combination of multiple formats for presenting work facilitates the integration of all three domains of successful environmental education: system knowledge, action-related knowledge, and effectiveness knowledge (Frick et al. 2004).

Implementation

Participating schools in Kentucky were selected based on previous experiences with the authors, while Indian schools were chosen with help from ASED and other Indian collaborators. Because of the need for effective communication between participants from two countries, only schools that use English as their primary instructional medium were considered for the project. A result of this requirement was that all the Indian schools selected were private. Twelve teachers from nine Kentucky public high schools and 10 teachers from 10 schools across eastern India participated. This group included schools from six Kentucky counties: Fayette, Jefferson, Muhlenberg, Pike, Pulaski, and Woodford. Fayette and Jefferson counties are predominantly urban (Lexington and Louisville, respectively), whereas the others are predominantly rural. Participating Indian schools were located in five cities in three different states: Kolkata, Kharagpur, and Durgapur in West Bengal; Ranchi in Jharkhand; and Guwahati in Assam (Figure 1). University of Kentucky Institutional Review Board (UK IRB) consent and assent forms were obtained from 290 Kentucky students. The principal investigator (Hanley) visited all participating schools in Kentucky to encourage the completion of those forms. However, visiting schools in India was cost-prohibitive, and completion and collection of forms (to meet UK IRB requirements for publicizing assessment results) from afar proved unmanageable.

The Kentucky and Indian students investigated 120 water bodies in total. Almost all were surface-water bodies (Figure 2), ranging from large reservoirs and rivers (e.g., Lake Cumberland and the Kentucky River in Kentucky; the Hooghly [lower Ganges] and Brahmaputra Rivers in India) to local creeks, canals, and ponds (e.g., Beargrass Creek in Louisville; the Chowbaga Canal and Jodhpur Park Lake in Kolkata). One Indian school focused on the East Kolkata wetlands and one Kentucky school chose to study groundwater by testing ten wells.

After completing modules 1 and 2, schools submitted research proposals to UK for judging (seven proposals from Kentucky and eight from India). The Kentucky proposals were scored by a team of four faculty and staff at UK with experience in water-resources research, current water issues, and outreach to K-12 schools. The Indian proposals were scored by a team of three professionals from UK and one from Indian Institute of Technology (IIT) Kharagpur with similar experience.

As part of module 3, students submitted final research papers, which were scored by two members of the project management team using the same rubric as the research proposals (see https://sites.google.com/view/wiiky-friends/modules/module-2 and https://sites.google.com/view/wiiky-friends/modules/module-3). However, grading of individual work was at the discretion of the teachers, even when products were evaluated by outside judges.

The top-rated research proposals were from DAV Model School–Durgapur (studying the Barakar River at Asansol, West Bengal), and from

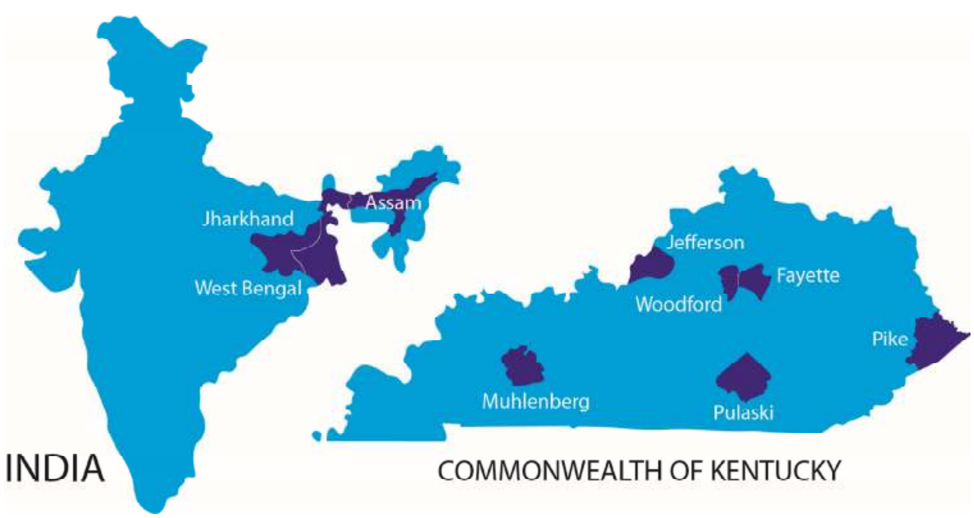

Figure 1. States in India and counties in Kentucky where participating schools are located.

Belfry High School in Pike County, Kentucky (groundwater study) (https://sites.google.com/view/wiiky-friends/modules/module-2). The team from DAV Durgapur traveled to Kentucky and Tennessee April 10-17, 2018 (Figure 3). They attended the Geological Society of America (GSA) Southeastern Section meeting, where a poster on the project was presented. They visited the Great Smoky Mountains National Park and Cumberland Falls State Park in Kentucky, as well as cultural sites, and they met with Kentucky teachers and students. The Belfry team traveled to Kolkata June 19-23, 2018. They presented their final project (https://sites.google.com/view/wiiky-friends/modules/module-3) at a final ceremony at the American Center along with eight of the Indian schools (Figure 4). The Belfry team also visited cultural sites and schools.

Figure 2. Selected water bodies: (a) Dhurwa Dam, Ranchi, India (from Delhi Public School, Ranchi); (b) Chowbaga Canal, Kolkata (from The Heritage School, Kolkata); (c) Hooghly River, Kolkata; (d) Kentucky River; (e) Town Branch, Lexington, Kentucky; and (f) well in Pike County, Kentucky (from Belfry High School).

Figure 3. DAV Durgapur team at (top) 2018 GSA Southeastern Section meeting and (bottom) Cumberland Falls, Kentucky.

Figure 4. Belfry High School and Sri Sri Academy teams along the Hooghly River in Kolkata.

Eight Indian teams submitted final videos for module 3, which were reviewed by 31 undergraduate students at UK in a topical course on World Water Issues (see https://sites.google.com/view/wiiky-friends/modules/module-3 for the video review rubric and examples of videos). Many of the review comments for the videos recognized the success of the high school students in integrating their knowledge of water and environmental systems, actions-related knowledge, and effectiveness knowledge (Frick et al. 2004). The top-rated videos (from DAV Model School–Kharagpur and The Heritage School [Kolkata]) were recognized at the final ceremony at the American Center.

Results

To determine the project's impacts, the UK management team measured students' attitudes toward WQA (project objective 3) and their water-quality content knowledge (project objective 2). The WQA instrument (see link to supplemental appendix), which was adapted from questions developed by Kaiser et al. (1999), Mayer and Frantz (2004), and Brügger et al. (2011), measures connectedness to nature. The instrument included 19 questions regarding the most important uses of water in students' communities, reasons why water quality is declining in those communities, and ways to protect water quality. The instrument used a Likert-type format with five response options: 1) strongly disagree, 2) somewhat disagree, 3) neither agree nor disagree, 4) somewhat agree, and 5) strongly agree. In addition, the WQA instrument included three questions that asked students the top three most important uses of water in their community, reasons for water quality degradation, and ways to protect water quality. There were 11 options for question 1, 10 for question 2, and 10 for question 3. The instrument was pilot-tested with Kentucky high school students using Qualtrics survey software (Qualtrics, Provo, Utah) in June 2017. Results were downloaded into SPSS 24 (IBM, Armonk, New York) and the resultant reliability was $\alpha = 0.839$. The instrument was then administered to participants through Qualtrics as a pretest in September 2017 and responses were downloaded into SPSS 24. After missing data were coded for the Kentucky pretest responses, the reliability for this sample was found to be $\alpha = 0.803$. The readability of the WQA instrument was determined through the Perry Marshall (2018) readability calculator. Average words per sentence were 11.6 and the mean reading level was 8.0, using the Flesch-Kincaid Grade Level Scale. The posttest was also administered through Qualtrics in February and March of 2018, depending on when teachers completed module 3.

The reliability for the posttest with the Kentucky students was α = 0.777.

A paired difference test showed there was no significant difference (α = 0.05) between pre- and posttest means for the Kentucky students' scores on the WQA instrument. For each of the three categories on the instrument, the top two choices remained the same between pre- and posttests (Table 3). Students considered the most important uses of water in their communities (category 1) to be "drinking water" and "fish and wildlife" (which were tied with "domestic uses" on the posttest). The top reasons why water quality was declining (category 2) were "sewage discharge" and "lack of concern", and the top two ways to protect water quality in communities (category 3) were

Table 3. Water-quality awareness responses from Kentucky students.

Name the three most important uses of water in your community	Pre-test (%)	Post-test (%)
Drinking water	93.2	85.1
Fish and wildlife	43.6	34.2
Sanitation	40.7	33.5
Domestic uses	26.1	34.2
Livestock	24.9	18.6
Irrigation	18.4	28.6
Industrial uses	17.5	19.3
Recreation	16.0	28.0
Fishing	11.6	17.4
Transportation	9.5	12.5
Tourism	4.5	11.8
Name three reasons why water quality is declining in your community	**Pre-test (%)**	**Post-test (%)**
Sewage discharge	53.1	50.9
Lack of concern	51.3	44.7
Fertilizer runoff	43.0	41.0
Pesticide runoff	33.8	39.1
Lack of education	30.6	45.3
Lack of regulations	27.3	36.6
Fluids leaking from vehicles	21.4	21.7
Pet waste	19.0	19.3
Exposed soil	11.0	8.1
Runoff from washing cars	9.2	11.2
Name three ways to protect water quality in your community	**Pre-test (%)**	**Post-test (%)**
Improve education	56.4	75.8
Increase regulations	53.1	67.7
Increase government's presence	39.8	50.9
Increase collaboration among concerned groups	33.8	27.3
Protect plants that grow along waterways	30.6	19.3
Increase soil and forest conservation programs	28.8	19.3
Reuse more water	27.3	16.8
Prevent soil from eroding at construction sites	16.3	6.8
Limit growth around water bodies	13.6	10.6
Raise the price of water use	3.3	6.8

"improve education" and "increase regulations". Unfortunately, we are unable to report results for Indian students because of the lack of signed IRB assent and consent forms.

Students' understanding of water-quality content knowledge was measured with an instrument developed by faculty in the UK Department of Earth and Environmental Sciences. However, the results will not be reported because the instrument had low reliability.

Discussion

Through their proposals, final papers, and videos, students demonstrated system knowledge (Frick et al. 2004) of the water cycle and human interactions with that system. Through community outreach activities, students also demonstrated action-related and effectiveness knowledge (Frick et al. 2004) for addressing water-quality problems. Examples of outreach (posters, public theater performances, workshops) are shown in Figure 5 and in Wiki Project 3 of module 3 (https://sites.google.com/view/wiiky-friends/modules/module-3). The activities of several Indian teams and the Belfry (Kentucky) team were also publicized by wire services, regional newspapers, and television, as well as on social media (see https://sites.google.com/view/wiiky-friends/publicity).

One challenge was finding appropriate, valid, and reliable instruments to measure water-quality content knowledge. Each of the three modules was to have a short pre/post water-quality content knowledge assessment. After searching the literature for a suitable validated assessment instrument, the Earth and Environmental Sciences faculty attempted to design one. The three assessments asked students to apply their knowledge in hypothetical situations (ConcepTests), a strategy that has been shown to be successful for encouraging and testing active learning at the college level (Mazur 1997;

Figure 5. Examples of publicity: (a) DAV Durgapur poster (translation from Bengali: "Let's put a halt to bathing of animals in water bodies. Let's make water pollution-free"). (b) DAV Kharagpur poster.

McConnell et al. 2006). We wrote the questions around common misconceptions about water (Munson 1994; Khalid 2001; Feller 2007; Cardak 2009; Francek 2013).

The three assessments were piloted in two college-level online courses, Environmental Science and Oceanography, and one high school science class, involving a total of 85 students. The initial pilot tests showed low reliability; therefore, the best questions from the three assessments were combined into a single, longer assessment that could be used pre/post. Unfortunately, this instrument also had low reliability. Our difficulty in assessing learning gains points to the need for a reliable and valid instrument to assess student learning within the field of hydrology specifically.

Throughout this project, students had multiple opportunities to engage in scientific practices, focusing mainly on asking questions and planning and conducting investigations (including applying statistics, critically reading scientific literature, and communicating scientific and/or technical information), as stated in project objective 3. These opportunities were most likely an introduction to some students, but for others, they may have been a chance to practice previously learned skills. Students improved in some areas, but their improvement was inconsistent. For example, students learned to plan and conduct water-testing investigations, but they still need additional practice in writing research questions and hypotheses.

The time commitment was a major challenge, especially for Kentucky teachers and students, who were required to follow school- and/or district-wide curriculum maps or standards-based curricula. Additionally, when school days were canceled due to inclement weather or other reasons, instructional time was difficult to make up. The schools in India, all of which were private, appeared to have considerably more curricular flexibility. Because of plans to have the winning teams visit each other's countries, those teams needed to be selected by early January. Therefore, schools had to work through the first two modules, including writing their research proposal, during a single semester.

The compressed schedule compounded other logistical challenges, such as the time difference between Kentucky and India (9.5-10.5 hours). Although Kentucky and Indian teachers were paired so they could exchange information about their schools, cooperation did not appear to happen as often as hoped. Another challenge was the Google documents format for uploading assignments, which discouraged students from giving each other feedback. Some schools had problems accessing the Google folders, perhaps because of internet security constraints. Finally, the overall completion of activities declined with time. For example, Kentucky students completed the WQA instrument pretests at a higher rate than the posttests. Even though all schools were encouraged to finish and showcase their projects, two of the Indian schools did not submit either a final paper or a video. Only three of the Kentucky schools submitted final papers and none submitted videos. We attribute this partly to time conflicts and partly to disengagement after the winning teams were selected.

Conclusions

Problems of insufficient water quality and quantity occur in both developed and developing regions and require creative solutions that are greatly enhanced by including youth engagement. Our project suggests that environmental education focused on water issues can improve science literacy. We found that online education can combine well with field-based, data-rich research experiences. Participating teachers and students are now familiar with basic water testing, and the online curriculum is freely available for public use. Challenges included obtaining consent and assent forms from overseas participants; finding reliable and valid instruments; finding a free, user-friendly online platform for course materials; and reconciling a compressed project timeline with existing curricular schedules. Nonetheless, the proposals, final papers, and videos indicated that students understood hydrologic concepts, and the project affected their awareness of water issues. We have maintained contact with students and teachers involved in the project and are publicizing the project website (e.g., Fryar et al. 2018).

Based on feedback from students and teachers and our observations, we make the following recommendations if a similar project is pursued. First, social media could be a rich way to promote cross-cultural environmental education and more interaction between schools (e.g., Dabbagh and Kitsanas 2012). This could serve as at least a partial substitute for travel, which can be expensive. Because of concerns with student privacy, social media groups would need to be private, even though members might post their final products on YouTube as some of the Indian schools did. Second, the student videos (which were encouraged but not required) were especially powerful, and this format might be emphasized over a traditional research paper format. Third, mandated curriculum schedules may make it necessary for teachers to keep only scaffolded assignments leading to the design and implementation of the research project, perhaps integrating them into existing course materials, rather than working through all parts of the three modules. An alternative solution would be to spread the assignments over an entire school year, rather than doing two of three modules during one semester. It might be possible in some schools for teachers to partner with their colleagues to team-teach or co-teach the modules. For example, a biology teacher may partner with a chemistry teacher to enhance student learning of water chemistry. Or, a science teacher might co-teach proposal writing with an English/language arts teacher to improve student technical writing. We recognize the difficulties inherent in these recommendations but put them forth because of the opportunities they afford students.

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