Stormy WATERS: COVID-19 Transition to Online Learning for an Environmental Education Middle School Curriculum

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Abstract

This exploratory study examines how a team of three seventh grade teachers from a rural/suburban middle school in the Mid-Atlantic region of the United States adapted the WATERS curriculum for asynchronous online delivery. The study shows that many hurdles can be mitigated with intentional planning, dedicated resources, and professional development. Students who engaged with the WATERS curriculum made statistically significant gains in their watershed content knowledge. This study highlights both the barriers to transitioning instruction online and the resources that support this transition. The study also illuminates factors that decision-makers must consider as they craft policies related to continuing education remotely during times of crisis and school closures.

Introduction

Purpose

The goal of the research presented in this article is to examine how a team of middle school teachers in the mid-Atlantic region of the United States adapted a field-based, data-rich environmental education (EE) curriculum designed for face-to-face delivery to an asynchronous online remote learning format during the spring of 2020 and how students engaged with this adapted online EE curriculum/resources. In the spring of 2020, schools around the world closed in response to the global outbreak of COVID-19, an infectious disease caused by a newly discovered coronavirus. "The COVID-19 pandemic has created the largest disruption of education systems in history, affecting nearly 1.6 billion learners in more than 190 countries and all continents. Closures of schools and other learning spaces have impacted 94 percent of the world's student population, up to 99 percent in low and lower-middle-income countries" (United Nations, 2020, p. 2). Responding to this crisis necessitated immediate and profound restructuring within the education sector. It sparked innovative approaches to support continuity in students' education as the duration of the closures lengthened, averaging from 7 to 19 weeks by the end of June 2020 (Schliecher, 2020).

Throughout this crisis, we are reminded that change is possible. During this time of radical restructuring of education, applied research for learning and sharing what works is more important than ever. According to UNICEF's Office of Research, there must be an "increased focus on implementation research to develop practical ways to improve teacher training, content production, parental engagement, and leverage the use of technologies at scale" (Dreesen et al., 2020). As a research community, we must seize the opportunity to learn from this crisis by studying the diverse ways that schools and teachers responded to the challenge.

The immediacy of the crisis did not afford the educational community the luxury of a large-scale systematic response that can be researched and evaluated. Instead, the lessons learned from this global upheaval reside in the many stories of innovative educators who did what needed doing to meet the learning needs of their students. Teachers had to adapt to new pedagogical approaches and formats of instruction for which they received no prior training. While much of "the hastily assembled online education is likely to [have]

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Table 1. Curriculum overview

Lesson	Summary	Instructional Activities
1: Discover Your Local Watershed	Students define and describe a watershed. They locate their local watershed within the nesting of larger watersheds and explain how human activities impact water quality. **Teachers recorded demonstrations of the Crumpled Paper Watershed and Model My Watershed.*	- Crumpled Paper Watershed demonstration led by teacher - Questions including virtual drawing option - Model My Watershed demonstration - Career video
2: Stream Study—What Do Stream Organisms Tell Us?	Students visit their local stream to catch and identify aquatic macroinvertebrates and use them to assess the health of the stream via a biotic index. **Teachers used existing videos of macroinvertebrates for students to identify and count in order to complete a biotic index.*	- Visit local stream to catch and analyze bugs (hands-on) - Use biotic index to assess stream health - Questions - Career video
3: Stream Study—What Does the Chemistry Tell Us?	Students measure water chemistry parameters in their local stream and use them to assess the health of the stream They will then identify potential sources of pollution. **Teachers went to the stream and recorded themselves conducting the colorimetric water quality tests. Teachers held up the test vials next to the colorimeter scales for each test and students had to determine the value and record their data.*	- Use kit to measure water chemistry parameters in local stream (hands-on) - Use virtual data entry tables to share and analyze results - Questions - Career video
4: The Water We Drink	Students explain the difference between different types of pollution. They also describe the function of drinking water treatment and wastewater treatment facilities. They then look to identify the source of water used for drinking in their school and what happens to wastewater from their school. **Students independently completed this lesson online as originally written without modifications.*	- Content videos - Reading - Questions - Career video
5: Runoff Simulation	Students learn about three ways water moves through a watershed and model changes using an online site storm simulation to discover how land cover and soils affect the movement of water in the three pathways. **Teachers recorded instructional videos to demonstrate how to use the Site Storm Model.*	- Reading - Using an online Site Storm Model simulation - Questions - Career video
6: Exploring My Schoolyard	Students first learn about different conservation practices that improve watersheds by increasing infiltration and decreasing runoff. They map the land covers on their schoolyard, identify pervious and impervious surfaces, as well as areas where conservation practices are already installed, and indicate where new conservation practices could be installed. **Teachers created a video tour of the schoolyard where they describe how water flows and is managed on the schoolyard.*	- Reading - Exploring and mapping schoolyard outdoors including surface types and conservation methods - Questions - Career video
7: Investigating My Schoolyard	Students use sensors to collect data about their school property. They then analyze and compare data from various study sites to determine how those sites impact their local watershed. **Teachers created videos where they tested two sites on the schoolyard and shared the sensor data with students to record and analyze.*	- Reading - Video tutorial - Placing and collecting data from sensors outdoors in schoolyard - Entering data online - Questions - Career video
8: Modeling Improvements to My Schoolyard	Students map their schoolyard using a watershed modeling web app to identify current conditions and impacts on the watershed. The students model installing conservation practices on their school's property and develop a best watershed plan for their schoolyard that maximizes the health of the watershed by increasing infiltration and reducing runoff. **Teachers recorded instructional videos that demonstrated how to use Model My Watershed.*	- Reading - Using Model My Watershed (GIS [Geographic Information System] online model) to model the impacts of schoolyard conservation practice installations - Questions - Career video
9: Road Map to Action!	Students work together to identify an environmental issue in their watershed and evaluate real-life solutions and positive actions that mitigate the negative effects of this issue.Students work together to adapt and apply the knowledge they constructed during Lessons 1-8 to design an action project meaningful to their own lives, including planning for feasibility, materials, partnerships, expenses, and steps needed to make the project a success. **Teachers omitted this lesson from the curriculum.*	- Group collaboration and brainstorming
10: Communicating My Action Plan	Students work together to communicate an action plan to their classmates, including an explanation of an environmental issue; a plan to take meaningful action to address the issue; the materials, partnerships, and expenses necessary for the action; and why the action plan matters to them personally. Students also evaluate the plans presented and how well their classmates effectively communicate their ideas. **Teachers omitted this lesson from the curriculum.*	- Group presentations - Evaluating classmates' presentations

*Adaptations teachers made to the curriculum for online delivery.

been both less effective in general than traditional schooling, and to reach fewer students," there are lessons to be learned from the myriad of innovative solutions implemented in individual classrooms, both in what worked and what hurdles still need to be overcome (Dorn et al., 2020).

While the scale of the crisis was novel, this exploratory study examines the challenges and celebrations experienced by a team of three seventh grade science teachers in the Mid-Atlantic region of the United States tasked with adapting a data-rich, hands-on, field-based middle school watershed curriculum—designed for face-to-face delivery—to an asynchronous online remote learning format. Asynchronous online learning is defined as online learning "commonly facilitated by media such as e-mail and discussion boards, [which] supports work relations among learners and with teachers, even when participants cannot be online at the same time" (Hrastinski, 2008). The three seventh grade science teachers adapted the Watershed Awareness using Technology and Environmental Research for Sustainability (WATERS) curriculum previously developed by the project partners with funding from the National Science Foundation (NSF).

Table 2. WATERS alignment with NGSS.

Performance Expectations	
MS-LS2-1: Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem (Lessons 2,3)	
HS-ESS2-2 Analyze geoscience data to make a claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems (Lesson 5)	
HS-ESS3-6 Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity (Lesson 5)	
MS-ETS1-1 Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions (Lesson 8)	
Science and Engineering Practices	Developing and Using Models (Lessons 1,2,4,5,6,8) Constructing Explanations and Designing Solutions (Lessons 1,2,3,4,5,6,7,8,9,10) Analyzing and Interpreting Data (Lessons 2,3,4,5,6,7,8,9,10)
Disciplinary Core Ideas	ESS2.C The roles of water in Earth's surface processes (Lessons 1,5,6,8) ESS3.C Human impacts on Earth's systems (Lessons 1,4,5,6,7,8,9,10) ETS1.B: Developing Possible Solutions (Lessons 6,8,9,10)
Crosscutting Concepts	Systems and System Models (Lessons 1,4,5,6,8) Patterns (Lessons 1,2,3,5,6,7,8,9) Cause and Effect (Lessons 1,2,3,4,5,6,7,8,9)

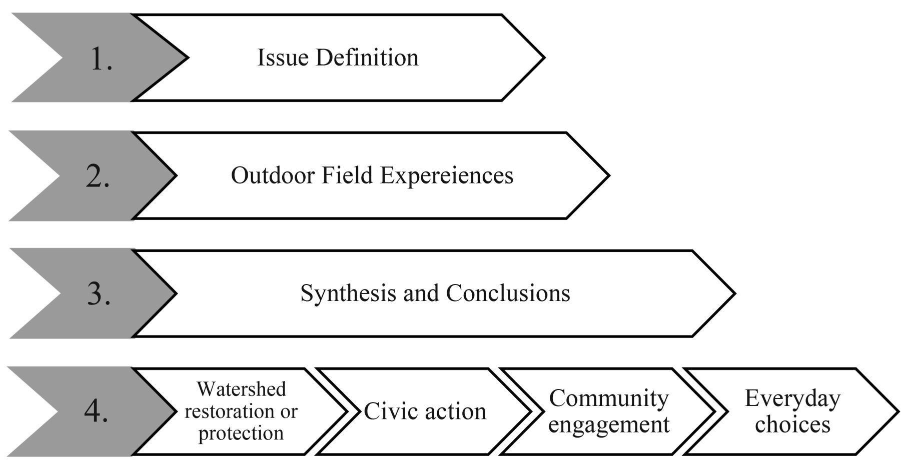

Figure 1. MWEE Essential Elements

WATERS curriculum

The WATERS curriculum consists of a series of 10 lessons (see Table 1) that are aligned to the Next Generation Science Standards (NGSS) and include watershed content, science and engineering practices, and crosscutting concepts designed to support learning watershed concepts and stewardship and increasing career awareness through improved environmental literacy (see Table 2). Topics covered in the WATERS curriculum include watersheds (definition, components, nesting), human impacts on watersheds (issues and solutions), sustainability, STEM careers, macroinvertebrates and their role as biological indicators of stream health, chemical assessments as indicators of stream health (temperature, turbidity, pH, nitrate, and dissolved oxygen), point source and nonpoint source pollution, wastewater treatment process and the path of wastewater, sources of drinking water and the drinking water treatment process, conservation practices, and the hydrodynamics of watersheds (systems thinking and the role of precipitation, evapotranspiration, infiltration, and runoff). Students identify pervious and impervious surfaces, discover impacts of land cover and soil groups on watersheds, map their schoolyards (identifying land covers and surface types, and predicting locations for conservation practice installations), and employ scientific methodologies in data collection and analysis using technology and first-person observations. They also use an online Geographical Infromation Systems (GIS) modeling application to identify current conditions on their schoolyard and model sustainability plans to improve watershed health. Students collaboratively identify issues and develop solutions (including an action plan) to improve watershed health (sustainability) and evaluate proposed action plans and the effectiveness of team communications.

The North American Association of Environmental Education (NAAEE) report Developing a Framework for Assessing Environmental Literacy: Executive Summary describes an environmentally literate citizen as one who is prepared to make decisions concerning the environment; is willing to act on these decisions to improve the well-being of other individuals, societies, and the global environment; and participates in civic life (NAEE, 2016; Hollweg et al., 2011). To engage students in exploring their local watershed, the WATERS project builds upon the Meaningful Watershed Educational Experiences (MWEEs) curricular framework developed by the National Oceanic and Atmospheric Administration (NOAA, 2017). By design, MWEE's "are multi-stage activities that include learning both outdoors and in the classroom, where students investigate topics both locally and globally that are of interest to them, learn they have control over the outcome of environmental issues, identify actions available to address these issues, and understand the value of those actions. The MWEE framework includes four essential elements: issue definition, outdoor field experience, synthesis and conclusions, and stewardship and action" (NOAA, 2017; see Figure 1).

The WATERS curriculum embodies a data-rich MWEE where students use scientific data, knowledge, and practices to participate in evidence-based decision-making about issues impacting their local watersheds. Adapting this field-based, data-rich, problem-oriented curriculum posed many challenges. Teachers adapted lessons 1-8 for asynchronous online delivery. Due to time constraints and concerns about facilitating the activity online, teachers decided not to adapt the final two lessons, including the environmental action plan.

Theoretical Framework

Our research is grounded in a constructivist theoretical framework rooted in Vygotsky's (1978) sociocultural theory and Bandura's (1977) social learning theory. Environmental science is an interdisciplinary subject. A constructivist theoretical framework supports interdisciplinary study and problem-based pedagogy where student knowledge is socially constructed and where students are viewed as active agents in their learning. We are guided by the belief that EE learning is constructed through experiences that provide students with opportunities to engage in sense-making using environmental data in their local environment. The research looked at the effort of the teachers to create opportunities for students to engage with the curriculum using a constructivist approach that included data collection, analysis, scientific modeling, and decision-making, even though COVID did not allow for face-to-face classes. These experiential and socially mediated experiences support EE learning as they are inherent to our awareness of our local environment. This exploratory study examines how a team of three seventh grade teachers from a rural/suburban middle school in the Mid-Atlantic region of the United States adapted the WATERS curriculum for asynchronous online delivery. The following research questions guide the study.

Exploratory Research Questions

1. How are teachers adapting EE (environmental education) lessons for online delivery?
2. How are students engaging with online EE resources?

Methods

Study Design

The exploratory study used a mixed methods design involving the simultaneous collection and analysis of quantitative and qualitative data to investigate the above research questions (Creswell, 2013). Data were collected in June of 2020. In investigating how teachers adapted the EE lessons for online delivery, we used a qualitative research methodology. According to Creswell (2013), qualitative research starts with ideas, points of view or perceptions, and the study of a research problem inquiring into the meaning individuals assign to a social issue or phenomenon. To study this phenomenon, the qualitative research uses emerging qualitative approaches to inquiry, the collection of data in a natural setting, and data analysis that establishes patterns or themes. To investigate how students engaged with online EE resources, we used a mixed methods approach that included quantitative analysis of student assessment data and qualitative analysis of open-ended written responses.

Data Collection and Analysis

Teacher data included a focus group with all teachers followed by individual interviews. The focus group and interviews used a semi-structured phenomenological interview protocol (see Table 3) that consisted of three questions for the focus group and seven questions for the interviews. The interviewer took accompanying field notes. The focus group and individual interviews were conducted via Zoom video conferencing software, where they were recorded and transcribed. Participants received copies of the recordings and transcripts to check for accuracy. The researcher used open-ended and descriptive coding that would become the future themes (Saldana, 2016). As the interviews and focus groups were being transcribed, the researchers consulted the field notes that were taken during both sessions. The themes were coded without the use of an electronic database such as Atlas TI. The themes that developed were motivation, teamwork, technical hurdles, and equity. This coding process (open-ended and descriptive coding) is the transitional process between the data collection and more extensive data analysis. The developed codes were categorized into themes, the outcome of coding.

Table 3. Interview Questions

Focus Group Questions	What motivated you to adapt the WATERS curriculum for online (remote) learning?
	How did the group decide what changes needed to be made to successfully move the online (remote) curriculum?
	What features of the curriculum, as written, were the most useful in the online (remote) transitions? Easiest to modify? Most difficult?
Individual Interview Questions	What were the most essential changes you had to make?
	What changes were the most impactful for the students?
	Do you think the online unit was effective?
	What additional technology/curricular support did you need?
	What support do you wish you had?
	Were the students engaged? What were the barriers? Affordances?
	Do you think the curriculum was effective in introducing students to a new career?

To investigate how students engage with online EE resources, we administered a pre- and post-test via Qualtrics software. The pre- and post-tests consisted of 15 multiple-choice watershed content knowledge questions adapted from the NOAA B-WET Evaluation System Plan: Student Item Bank (Zint & Kraemer, 2012), three open-ended questions where students applied what they learned, and one multi-select item asking what curriculum changes they recommend (see Table 4).

Table 4. Post-Test Student Feedback Questions

Question	Response
Is your local watershed healthy? Give three pieces of evidence to support your answer.	Open-Ended
Describe two specific things you learned about your watershed.	Open-Ended
Describe two activities from the online watershed unit that BEST helped you learn about your watershed.	Open-Ended
What ONE thing would you change about the online watershed unit?	a. I wanted to work with other students
	b. I wanted to do the activities outside instead of watching movies of others doing the activities
	c. I wanted to do more hands-on activities
	d. I wish there were fewer questions to answer in each lesson
	e. I wanted more movies and less reading
	f. I wanted to go OUTSIDE to learn about the watershed
	g. Loved everything!

Participants

Three science teachers from a middle school in the Mid-Atlantic region of the United States participated in this study. The teachers were recruited to pilot the WATERS curriculum before the outbreak of COVID-19. A science curriculum administrator in the state recruited teachers for the WATERS project that met the following criteria: 1) Teachers are at schools that serve significant numbers of minority, rural or urban, or low-income students; 2) Classrooms have access to computers and networking for classroom implementation; and 3) Teachers enroll as members of groups of two or more from the same building, where possible. As part of the WATERS pilot, teachers received a week of face-to-face professional development training on the curriculum in the summer of 2019. Throughout the 2019-2020 school year, they provided feedback on the curriculum design and revisions and attended monthly meetings with the WATERS project team. Two of the teachers identify as White females and one is a Latino male. Two of these individuals are mid-career teachers, each with over 20 years of experience, and one is a novice teacher with less than 3 years of experience. In addition, 252 seventh grade students enrolled at the same middle school participated in the study.

Results

Teachers adapting EE lessons for online delivery

The teachers were tasked with delivering the WATERS curriculum in a virtual setting, which required them to modify instructional modes while maintaining the embedded constructivist approach to engage students in authentic learning experiences. The existing online components of the WATERS curriculum provided a solid foundation from which teachers could make adjustments lesson by lesson. Schedule changes restricted teachers to a weekly lesson format that only allowed for completing the first eight lessons in the curriculum (one lesson per week over eight weeks). Teachers disseminated lesson assignments and adaptations through the class Schoology platform (CMS1), including information about the lessons, handouts, and support videos. Two live Zoom sessions were scheduled each week, one to introduce the lesson and another to answer questions and provide support to students in need. Students completed the lessons mostly asynchronously, so many teacher-directed inquiry-based activities became more curriculum-directed. All adapted lessons included text and question prompts that shifted from class participation to independent reading and responses (including the career videos with accompanying questions) that were delivered via the Learn Portal (CMS2), the project-funded course management system. Lessons that originally included hands-on or outdoor activities were converted to video recorded activities conducted by teachers who demonstrated the methods and provided the data collected for students to report in the CMS2. For example, the teachers maintained student engagement during the chemistry portion of the stream study by video recording themselves performing the water chemistry tests stream-side. As they conducted each chemistry test, they methodically showed each colorimetric result to the students. The students had to actively interpret and record the data shown in the video before analyzing the results. This provided students with a more authentic experience, although some may have interpreted data slightly differently.

Interestingly, in adapting the lessons, the teachers became the students as they collaboratively huddled together to review each lesson, create plans for modifications, and identify and distribute tasks matched to each teacher's skill set. Throughout the spring of 2020, the teachers were using many of their acquired teaching skills while rapidly learning new skills and techniques to navigate this new educational landscape.

The semi-structured phenomenological methodologies provided insights into how teachers adapted EE lessons for online learning and resulted in the following discoveries. The following themes—motivation, teamwork, technical hurdles, and equity—were coded from the focus group and individual interviews with participating teachers.

Most notably was the drive of the teachers (motivation) to prepare an online component for the hands-on pieces created in the CMS2.

Motivation

The WATERS curriculum included 10 lessons, typically taking 10 class periods to implement in face-to-face instruction. When the COVID-19 outbreak closed the middle school, the teachers were tasked with creating asynchronous online delivery lessons that addressed science, technology, engineering, art or math (STEAM) concepts. One teacher commented in the individual interview, "We had to figure out how to work within the time constraints we were given. Instead of science every day, we had to split the time with humanities. Two days were spent on science and two days were spent on humanities." The teachers could have selected any content area. Since the teachers received extensive professional development on the WATERS curriculum prior to the outbreak of COVID-19 with their NSF partners, and the lesson materials were already embedded in an online platform, teachers saw it as a beneficial curricular unit to transform into a fully online learning experience. Another teacher commented, "Most of the curriculum was already in an online format. We were planning to teach it in class. The outside, the hands-on component, was the main thing we needed to figure out how to teach online [remotely] and still engage the students." The WATERS curriculum encompassed science, technology, and math from the STEAM edict. The teachers report that using an existing curriculum allowed them to focus not solely on curriculum construction but adaptation to online delivery and to support the needs of their online learners. The existing online components of the WATERS curriculum included a grant-funded online course management system (CMS2) that served as a repository for lesson directions, student readings, instructional videos, career exploration, and embedded online simulations/models, which all were to be delivered in class with teacher guidance. The project portal was designed to support, not replace, face-to-face teaching and learning. Teachers were motivated by the challenge of adapting the curriculum, including the outdoor elements and hands-on activities, to an online delivery format.

Teamwork

When the group of teachers met, they discovered that each teacher had an individual strength. During the interviews, one teacher said, "I was really good at contacting the students and encouraging them or helping them figure out what they could do to keep going. My colleagues had different skills. One colleague was much younger than me, and she was able to be our technology person. She would make suggestions to help us less technology-minded folks. The third colleague on the team was our organizer. He kept us on track for completion of tasks." Each teacher took the lead in adapting a lesson for asynchronous online delivery. One teacher stated, "Each of us [a member of our team] took a lesson and made the components work for online [remote] learning. For example, one colleague took the lesson on water chemistry and went to the water source we were using and recorded herself completing the hands-on components. She did not give them [the students] the answers but held up the water and strips for the students to look at and make decisions." By working together, the teachers were able to support each other and share the work required to adapt WATERS for an online (remote) format and meet the needs of the students.

Having a team allowed the members to share and brainstorm answers to challenges. The victories were shared with each other and with the larger project team. Each team member indicated that having regular monthly online meetings with the project partners allowed them to voice concerns, share positive outcomes, and brainstorm solutions.

Technical Hurdles

The abrupt transition to online instruction did not provide the school district ample time to offer teachers adequate technology training or sufficient internal information technology (IT) support. Teachers reported that they relied on each other, the K-12 Subject Area Supervisor, and the project staff to successfully transition the WATERS curriculum online.

One significant technical hurdle was trying to integrate two course management systems. The WATERS curriculum used CMS2 to access content and to track student completion. The district's course management system (CMS1) was used to deliver online instruction, which the teachers were required to use as the primary platform for instruction. Teachers noted that having two course management systems was a hurdle because it required students to move between them, making it more difficult for them to navigate the curriculum. The project's CMS2 was most troublesome for students because it was new to them. As a result, students struggled to access the WATERS system and often created multiple competing logins. Teachers indicated that if the curriculum were delivered face-to-face, they would have been able to help the struggling students log into the WATERS system. Without this technical support from teachers, some students gave up out of frustration.

Students also faced technical hurdles in lessons that included the use of the watershed modeling application. When analyzing student completion, researchers noted the most significant drop in student persistence in Lesson 8 (see Table 5). Students used Model My Watershed, a previously developed GIS application. For Lesson 8, 44% of the students who completed half of the lesson did not complete the next 30% of it. Lesson 8 involves students modeling changes to their watershed with Model My Watershed. Even though the lesson was designed to be delivered online and includes step-by-step procedures for selecting distinctive features of the model, there is still a learning curve as to how to use this or any new application independently in online learning.

Student persistence was lower during the more technologically challenging lessons and higher during less complex lessons that could be completed quickly. Trends in student completion were best observed when focusing on students with varying levels of completion of the eight assigned lessons. We classified students who completed at least 12.5% but less than 85% of the eight lessons as having variability in their engagement with the curriculum. When looking only at students whose completion of the curriculum's lessons varied, we see the highest average completion percentage, 77%, for Lesson 4 (see Table 6). Lesson 4 is the shortest and least complex lesson (no simulations, models, data collection, or data entry). Additionally, Lesson 4 was the only lesson to break the steady downward completion trend as online learning continued. For reference, the next highest average completion percentage was 65% for Lesson 1. It is also worth noting that Lesson 4 was not mentioned in the student post-assessment as a lesson that best helped them learn about watersheds (see Figure 2). In fact, the most common answer for the lessons that helped students learn the best was "simulations/models," despite these lessons having lower completion percentages and higher reports of student struggle.

Another hurdle related to the project's CMS2 was the ability to give instructional feedback to students. The project's CMS2 system gave teachers the ability to provide feedback; however, when students logged in, they had to go back to the lesson in which the feedback was given to retrieve it, which few students did. To make the process more user-friendly, teachers indicated it would be better if the feedback from previous lessons popped up on the home screen when the students logged in. Additionally, due to the asynchronous nature of the district's online learning format, teachers could not interact with students to do formative assessments and provide real-time feedback. This lack of real-time interaction with the students caused the teachers to feel disconnected from the students' learning progression.

Another example of a curriculum-based technical hurdle was the need to adapt the stream study (Lessons 2 on macroinvertebrates and 3 on water chemistry) to an online format. Deciding how to use technology to adapt these field-based lessons to engage students

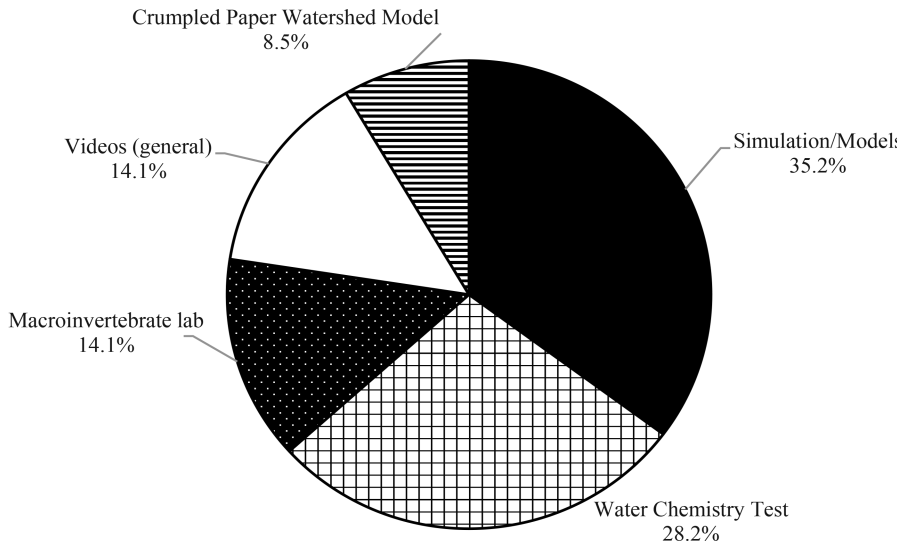

Figure 2. What activity BEST helped you learn about the watershed?

in the data collection was difficult, but working as a team, the teachers overcame this technological hurdle. For example, in Lesson 2, teachers created a virtual stream that simulated the types of macroinvertebrates that students would have collected in the outdoor exploratory activity. For the modified activity, the students needed to classify the given invertebrates and then analyze their data to determine the health of the virtual stream. This lesson was particularly difficult because instead of students simply watching a demonstration video, they were conducting their own virtual investigation and analysis.

For Lesson 3, the original version of the lesson required students to conduct a series of chemical tests, upload the data to CMS2, and analyze the data. To transition this lesson to an online format, one teacher went to the local stream and recorded a video of herself collecting the water and performing the individual chemical tests. The teacher narrated the testing process and displayed the data for students to record in the CMS2 and analyze using the online tools. The video was available for students to view asynchronously.

Using their experiences adapting Lessons 2 and 3, teachers found it easier to adapt later lessons. For Lesson 6, teachers created a schoolyard tour video that allowed students to view their campus and look for pervious and impervious surfaces as well as look for areas to implement conservation practices during a time when they did not have access to the grounds. In Lesson 7, a video about sensors allowed students to observe students their age (one of the teacher's children) completing the activity and modeling appropriate use and data analytics of the sensor. This data was then provided for the students to analyze on their own in order to increase authenticity.

As initially designed, the WATERS curriculum included a series of short career videos embedded in each lesson. The videos featured various jobs in the water industry that required different levels of education ranging from a high school diploma to a doctorate in science. Although designed to be an integral curricular component of the curriculum, the career videos "fell flat." One of the teachers said, "We don't do enough [with] career discussions. Students said they liked the videos and the questions at the end of the videos, but I think I would have engaged them, set the students up a different way if I were doing the videos in class." The teachers did indicate that the questions asked at the end of the video were relatable to the students' perspectives. For example, a typical question asked, "What part

Table 5. Student participation in the online WATERS curriculum

Module	Students who **started** the module	Students who **finished** at least 50% of the module	Students who **finished** at least 80% of the module
1	252/308 (82%)	185/308 (60%)	152/308 (49%)
2	203/308 (66%)	173/308 (56%)	149/308 (48%)
3	205/308 (67%)	162/308 (53%)	152/308 (49%)
4	205/308 (67%)	190/308 (62%)	175/308 (57%)
5	190/308 (62%)	167/308 (54%)	150/308 (49%)
6	155/308 (50%)	138/308 (45%)	138/308 (45%)
7	163/308 (53%)	132/308 (43%)	125/308 (41%)
8	151/308 (49%)	111/308 (36%)	61/308 (20%)

*Started is defined as completing at least one activity in the module.

Table 6. Completion rates for each lesson for students who completed between 12.5% and 85% of the lessons.

Lesson	Completion Rate
1	65.7%
2	62.1%
3	59.7%
4	77.0%
5	60.6%
6	38.8%
7	35.6%
8	20.2%

of the scientist's job did you like the most?"

Equity

Some students did not have access to a computer or high-speed internet at home. The school district attempted to mitigate the technological inequity by providing computers and personal hotspots; however, there were not enough hotspots to distribute to all students. The school district designated the online learning "optional" during the spring 2020 COVID-19 outbreak to address problems with equity of access to technology. Because the school district did not provide additional IT resources to students, due to the abrupt transition to online learning, students without Internet connectivity or those encountering technology issues were left unassisted.

Students engaging with online EE resources

Students were encouraged by the school district and their science teacher to participate in the online learning, but participation was voluntary and not graded. 252 of the 308 (82%) enrolled seventh grade students chose to engage in the WATERS curriculum at the start of online learning. 254 (82%) students took the pre-assessment; 166 (54%) students completed the post-assessment, and 109 (35%) students completed both the pre- and the post-assessment. No data were available to determine why the remaining 56 students failed to access the curriculum. Student participation remained relatively steady for Lessons 1-7, with an average of 48% of students completing at least 80% of each lesson; participation declined for the last lesson, where the completion rate was 20% (see Table 5).

Students who engaged with the WATERS curriculum made significant gains in their watershed content knowledge, as evidenced by the statistically significant difference in the students' mean scores on the 15 watershed content pre-assessment items ($M=8.032$, $SD=2.091$) and the students' mean scores on the 15 facsimile watershed content post-assessment items ($M=9.555$, $SD=2.425$); $t(106)=5.971$, $p=0.000$. In addition, 66% of students could provide specific evidence from the WATERS curriculum to support their assessment of the health of their local watershed (see Table 7).

To better understand students' experiences engaging in the online WATERS curriculum, students were asked to describe two activities from the online watershed unit that BEST helped them learn about their watershed. 63% of students mentioned the simulations/models and the water chemistry testing activities (see Figure 2). The simulations/models are online tools. The water chemistry testing activity is typically an outdoor activity (that was modified to be a video demonstration) that requires students to enter data directly into CMS2 for analysis. This is notable as these two activities, by design, were most reliant on technology. As mentioned previously, students reported that these lessons were challenging, and the models/simulation lessons had the lowest completion rate.

To further explore the aspects of the WATERS curriculum that were not well received, students were asked to identify ONE thing they would change about the unit from a list of choices. I wanted to go outside to learn (29%); I wanted to work with other students (20.4%); I wanted to do more hands-on activities (14.0%) were the top three responses. These three responses all related to the inherent limits of online learning during a time of mandated social isolation (see Figure 3).

Table 7. Students provided examples of evidence to support their assessment of watershed health.

Selected Student Responses Evidence to support their assessment of watershed health
"Insects that are sensitive to pollution are able to live in our watershed."
"The water temperature is the ideal temperature for living thing (*sic*) in the water."
"When we were testing for critters we saw that there was a huge variety."
"There are many fields and grassy areas so infiltration can take place."
"There's a lot of farmland that gets treated with fertilizer and manure, which gets soaked into the ground."
"A lot of the bodies of water have crayfish and other not pollution tolerant (*sic*) bugs in it."
"Our school doesn't have porous paving in the parking lot or bus loop."

Discussion

The teachers tasked with transitioning instruction online in the spring of 2020 explained that having a well-developed curriculum with a robust online presence was a great starting point because it afforded them the ability to focus not on curriculum construction but on adaptation and supporting the needs of the online learner. In this exploratory study, working as a team and relying on the diversity of each teacher's strengths, teachers found novel ways to adapt planned face-to-face instruction and outdoor hands-on field experiences for asynchronous student participation. Lessons were adapted using web-based simulations, models, and video demonstrations. These lesson modifications did not address students' expressed desire to go outside, work alongside peers, and engage in more hands-on activities. Still, they permitted students to engage in an authentic watershed education curriculum, resulting in statistically significant gains in their watershed knowledge and environmental literacy via online learning.

The study also highlighted many hurdles to remote asynchronous online instruction that decision-makers must consider as they craft policies related to continuing education remotely during this current crisis and potential extension in the future. Teachers who are creating asynchronous online lessons need technical support to produce impactful lessons for students. This group of teachers had extensive training and support from the project team and were able to transform the hands-on lessons into online ones in the absence of IT support from the school district. This was likely not the case for the majority of educators during the COVID-19 crisis.

With intentional planning, dedicated resources, and professional development, many hurdles can be mitigated. For example, remote instruction requires not only access to technology and high-speed internet, but it also requires timely technical support to help educators and students navigate hardware and software issues. In this study, the school district attempted to mitigate the difficulties by providing laptops, wireless hotspots, and technology support for teachers and students. However, the need was more significant than the allocated funds and resources. Equity, in terms of access to technology, high-speed internet connectivity, technical support, and adult support at home, are all potential barriers that must be addressed to prevent further exacerbating inequity in online learning opportunities and amplifying the learning gaps across socio-demographic groups (Brossard et al., 2020; Hereward, 2020). Despite the hurdles exposed in the spring of 2020, the project team used the experiences from this team of teachers as inspiration to modify the 10 lesson WATERS curriculum into an online version that could be completed by students asynchronously and remotely with limited teacher intervention, which was implemented in the Year 2 pilot extension. This online version contained embedded videos to provide detailed instructions and examples to replace the demonstrations and activities that would have occurred in the classroom, a shift from collaborative group work to individual responses, and a stream study simulation that provided students with an opportunity to virtually conduct a stream study complete with habitat observations, a biological assessment, and water chemistry tests.

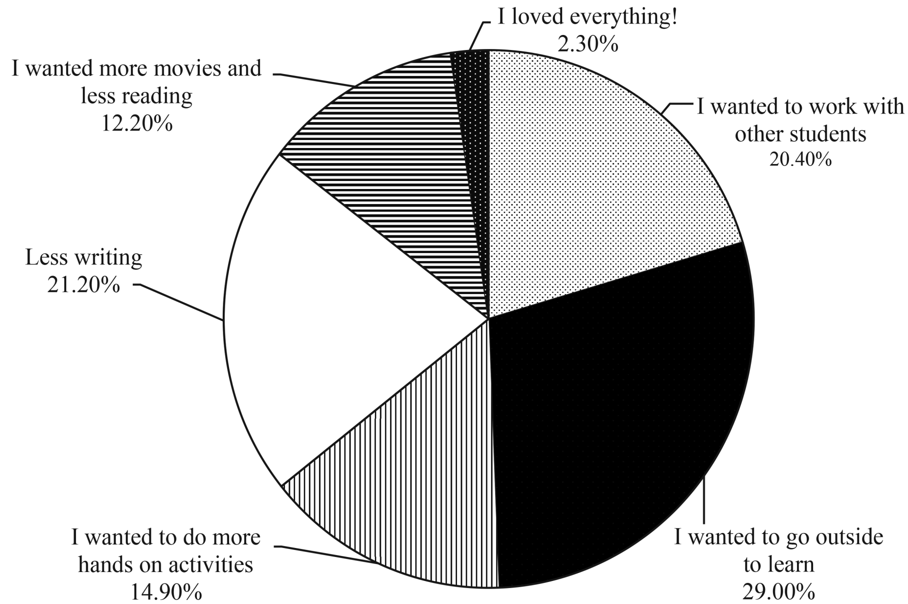

Figure 3. What ONE thing would you change about the online watershed unit?

Further Research

The significance of this research extends beyond the COVID-19 pandemic, as the challenges do not end with the immediate crisis (Hereward, 2020). Moving forward, additional instances of online instruction can be expected from K-12 schools across the country as distance learning approaches are used to address traditional problems (Schliecher, 2020). For example, many schools are replacing inclement weather days with online learning (Hernandez, 2020). Using the lessons learned from the spring of 2020 and the assumption that online learning is not going away anytime soon, the project's fully online version of the WATERS curriculum will be freely available to the public at the completion of the WATERS research study.

We have entered a new era in education. More research is needed to understand the role of online instruction as a supplement to instruction during short-term school closures, what training is needed to support teachers in developing and delivering online instruction, and what IT support is required to assure equitable access to online learning.

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