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Partnership to Develop and Deliver Curriculum Supporting Student-Led Air Quality Research in Rural Washington State

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Abstract

Background: This paper describes the process and educational materials developed and implemented for high school students through a partnership between an urban public university and a rural, non-profit university. This specific partnership was novel but originated within a long-standing community-academic partnership. This project took place in a rural community impacted by air pollution and a higher asthma hospitalization rate compared to the rest of the state.

Objectives: The objectives of this paper are to describe the development and implementation of a high school program where students conducted their own research on local air quality using low-cost monitors with the guidance of undergraduate student mentors.

Methods: University faculty, researchers, and students collaborated to develop an air quality curriculum relevant to local issues. This curriculum was delivered to high school students through an existing after school program, and guided students in conducting their own research on community air pollution. The students used university-provided low-cost monitors for their research, and presented their research to community members. Student learning was supported through hands-on activities and conducting research projects. Student projects examined air quality variation indoors within their school, outdoors in their community, and at home.

Conclusions: This curriculum can be adapted for use with students in many different communities. It will likely be most successful and engaging if adapted to local air pollution sources and issues, and implemented through an existing programmatic structure with a high mentor to student ratio.

Keywords

Curriculum; Mentors; Education; Students; Environmental Health; Community health partnerships; Community health research; Power sharing; Northwestern United States

Background

The lower Yakima Valley in south-central Washington is on the eastern slopes of the Cascade mountain range and is home to the reservation of the Confederated Tribes and Bands of the Yakama Nation, a sovereign nation pursuant to the Treaty of 1855. About 30% of jobs in this region are in agriculture,[1] especially tree fruit, wine grapes, and hops,[2] highly important to the WA state economy. Despite this essential work, ongoing structural racism and settler-colonialism,[3] unjust labor practices,[4] and harmful immigration policies[5,6] create challenges and barriers in this region. At least 38% of people live under 185% of the federal poverty level[7] and the population experiences health care gaps.[8] This project took place in Toppenish and White Swan, both located in the Yakama Nation reservation. The population in Toppenish, White Swan, and nearby areas is about 23% Indigenous, 58% Latino/a/x, and 17% white.[9] Many people in the Latino/a/x communities in Yakima Valley are descendants of or are themselves migrant agricultural workers.

The topography of Yakima Valley creates conditions that cause prolonged wintertime inversions, trapping air pollution low in the atmosphere. Yakima Valley experiences relatively high concentrations of fine particulate matter ($PM_{2.5}$) compared to the rest of WA[10] and ranks fifth most polluted in the USA for number of days with high exposures to $PM_{2.5}$.[11] Contributions include wildfire smoke, agricultural residue and field burning, animal agriculture activities, diesel orchard heaters, truck traffic, woodstove and other residential heating, and backyard burning. The Yakama Nation Environmental Management Program (EMP) oversees air quality on the reservation, and the Yakima Regional Clean Air Agency oversees air quality in Yakima County outside of the reservation.

PM exposure is well established as a cardio-respiratory disease risk: PM is implicated in the development and exacerbation of asthma and chronic obstructive pulmonary disease, respiratory-related hospital visits, and respiratory, cardiovascular, and all-cause mortality.[12,13] Exposure to $PM_{2.5}$ from age 10–18 reduces lung function[14] and increases the risk of developing asthma even among children with good lung function.[15] While many factors contribute to asthma development and exacerbation, it is notable that the asthma hospitalization rate in Yakima County has been consistently higher than in WA state from 2000–2014.[16] From 2010–2014, the age-adjusted asthma hospitalization rate was 9.04 per 10,000 people in Yakima County compared to 6.22 in WA state.[16] This paper describes the process and educational materials used by a University of Washington (UW) and Heritage University (HU) team to provide guidance and mentorship to White Swan High School (WSHS) students in conducting their own research on air quality in their community.

Methods

Partnership Development

UW is a large, public university about 2.5-hours' drive from Yakima Valley, and HU is a small, private, nonprofit university local to the valley. HU is federally designated as a Hispanic Serving Institution and a Native American Serving Non-Tribal Institution.[17] 85% of students are first-generation college students.[17] HU is a commuter campus, and many students and faculty are from the local community. WSHS is a public high school serving about 250 students. 98% of students are eligible for free lunch.[18]

Since 2010, HU and WSHS had established a long-standing relationship through the EnvironMentors program. EnvironMentors is a National Council for Science and the Environment program where students are paired with university or community mentors who guide them in conducting their own research.[19] In the HU chapter, housed in the Center for Indigenous Health, Culture & the Environment (CIHCE), faculty and undergraduate students from HU mentored students at WSHS. During the years of the program discussed in this paper, 50% of the HU student mentors were Indigenous, 33% were white, and 17% were Latino/a/x. 70% of the WSHS students were Indigenous, and 30% were Latino/a/x.

HU is also a long-standing collaborator in a local community-academic partnership, El Proyecto Bienestar (EPB). EPB was formed in 2004 through a grant obtained by UW to address environmental and occupational health concerns among agricultural workers in Yakima Valley.[20] EPB is currently housed by the local Spanish-language radio station KDNA. Community priorities guide EPB's involvement in research.[21–24] In 2014, at two EPB meetings, UW faculty (Department of Environmental and Occupational Health Sciences) presented an EPA grant opportunity focused on community-engaged air pollution research using low-cost air quality monitors. The HU faculty (Science Department and CIHCE) who leads the local chapter of EnvironMentors proposed a UW-HU partnership centered around EnvironMentors. Air quality is a community priority, and EPB consensus was supportive. The HU faculty discussed the idea with Yakama Nation Department of Natural Resources (DNR), and then UW and HU applied for that grant opportunity, which became Next Generation Sensors and Scientists (NextGenSS, STAR Grant #RD83618501), funded from 2016–2019. A timeline of the NextGenSS research project is shown in Figure 1.

UW and HU developed educational curriculum for HU's EnvironMentors chapter at WSHS. Collaboration was key in creating and delivering a successful air quality research education program. The community of focus for this program was the HU and WSHS student participants and their families and social circles. The WSHS community served by EnvironMentors was predominantly Yakama and other North American Indigenous community members, a generally different demographic than the community served by EPB, which is predominantly Latino/a/x agricultural workers and their families. UW and HU faculty therefore convened a separate Project Advisory Committee (PAC) for NextGenSS that included a key member of EPB from radio KDNA as well as representatives from Yakama Nation EMP, WSHS' school district, Indian Health Service, and a tribal health nonprofit. Perspectives from NextGenSS partners about the collaboration early in the research are described in a separate manuscript.[25] As part of NextGenSS, but separate from the EnvironMentors program, UW faculty and a graduate student partnered with Yakama Nation EMP to conduct air pollution research.[26] That research partnership continues, currently focused on wildfire smoke. The NextGenSS study was approved by the HU (HU2017-HS-090) and UW (STUDY00000513) Institutional Review Boards and the EPA Human Subjects Research Review (HSR-000762).

Curriculum Development and Implementation

The HU faculty had been leading the EnvironMentors program at WSHS since 2010; for this project specifically, she obtained permission from the principal and the biology teacher. The HU faculty also received a letter of support from leadership at Yakama Nation DNR, which reports to Tribal Council. Yakama Nation EMP (which is part of DNR) specialists provided guidance through the PAC and participated in aspects of the program as they decided on a case-by-case basis, for example facilitating the co-location of student air monitors with their regulatory monitor, and speaking about their work at a community event.

Based on the HU faculty's experience with EnvironMentors, the team established a program model rooted in mentorship that included three academic "generations": a) faculty from HU and researchers, faculty, and graduate students from UW, b) undergraduate student mentors from HU, and c) high school students from WSHS. Within the HU mentors were 1–2 lead mentors per year. The lead mentors were responsible for bringing HU and WSHS student feedback to UW, and for ensuring that their fellow HU mentors understood the material to deliver it to the WSHS students. Roles and responsibilities for the program are shown in Table 1. Objectives of the program included: 1) Enable students to design air quality research projects, 2) Encourage community engagement on air quality topics, 3) Develop student data analysis skills, and 4) Support student communication of scientific results. These objectives connect to air quality curriculum skills and activities (Table 2).

This program used Participatory Action Research (PAR) as the theoretical framework because it engages participants as co-researchers (not objects of research), emphasizes collaboration, and is value-driven.[27] The objective of PAR is to create positive change, focusing on issues significant to the participants.[27] PAR values reflection,[27] and talking as a group with the students about their data and next steps was essential. The students know that their health, and their family and community members' health, is important, and using PAR they creatively engaged with air quality issues as co-researchers.

For student projects, UW faculty selected low-cost data-logging optical particle air monitors, including the Dylos DC1700 PM, a monitor created in-house at UW, and the Purple Air PA-II-SD. The monitors selected automatically started logging data when plugged in. Prior to the EnvironMentors program, UW researchers and graduate students visited HU to teach the mentors how to use the equipment. HU mentors were paid positions and were recruited by the HU faculty.

The program took place over an academic year, one hour weekly after school. A program timeline is provided in Figure 2. WSHS administration was highly supportive and provided a space to meet. Weeks 1–4 of the program were spent recruiting WSHS students and having informal conversations to build relationships. Recruitment occurred through: announcements by the biology teacher over three weeks at the beginning of school, an event organized by the HU faculty after school with pizza, and word-of-mouth from students who previously participated in EnvironMentors.

The UW team and the HU faculty together brainstormed curriculum topics, then the UW graduate student drafted the curriculum one week at a time. The curriculum included slides and hands-on activities. Using slides increased WSHS students' experience with them to help prepare for undergraduate studies. The curriculum materials are available from https://deohs.washington.edu/air-quality-curriculum-student-led-research-projects.

The UW graduate student met over video with HU lead mentors weekly. The goals of these meetings were to ensure that HU mentors felt comfortable with the upcoming material to teach the WSHS students, provide an opportunity for HU mentors to edit the curriculum to be more relevant and effective, and for HU mentors to provide feedback on the previous week. WSHS students provided feedback to the HU mentors, who communicated that feedback as well as their own ideas to the UW graduate student. This series of discussions allowed for ongoing feedback on the curriculum (Figure 3), and for incorporation of that feedback into an updated version.

Each week, the HU lead mentors met with the other HU mentors to review that week's material. During weeks 5–8, the HU team and WSHS students taught and learned the curriculum as a group. After that, mentor-mentee pairs were assigned with each HU mentor having 1–2 WSHS students as their mentee. Over weeks 9–12, the mentor-mentee pairs primarily learned the curriculum separately in their groups. When the mentors noticed that multiple students were stuck on one step, they reviewed that step as a large group before continuing. The HU faculty attended each meeting as an overall support.

The program included opportunities for HU and WSHS community engagement through field trips and guest speakers, including foresters and a wildlife refuge ranger. Yakama Forest Products, a Yakama Nation enterprise, was especially engaged by providing meeting spaces and facilitating visits to a sustainable logging forest.

By December, once WSHS students were familiar with air pollution, they chose research project topics. HU mentors ran the project ideas by the UW team for feedback, and then worked with the students to site the air monitors. Mentors and students worked together to download data from the monitors regularly.

Student projects included: comparing $PM_{2.5}$ in different rooms within WSHS, comparing low-cost monitor data to regulatory monitor data, examining variation of $PM_{2.5}$ over time and space, quantifying wintertime inversion occurrences, and comparing indoor and outdoor $PM_{2.5}$. WSHS teachers and staff were essential to the success of several projects by facilitating placement of air quality monitors throughout the school. The biology teacher hosted air quality monitors and incorporated air quality topics into his curriculum. Yakama Nation EMP specialists were essential to the success of student projects that used tribal air monitor data.

With guidance from HU mentors, WSHS students selected the variables and time periods of data they needed to answer their research questions. HU mentors discussed data needs with the UW graduate student and uploaded data to a shared drive. The UW team transformed the data to make it accessible for the students to apply statistical techniques utilizing Microsoft Excel. The UW graduate student explained this process to the mentors, who explained it to the WSHS students. HU mentors worked with WSHS students to develop plans for analyzing the data, and when needed, the UW team provided additional guidance with step-by-step analysis plans. Throughout this process, HU mentors had WSHS students describe the methods for collecting, cleaning, analyzing, and presenting the data as much as they could before providing guidance.

To create their research posters, WSHS students visited HU for a full day to compare different methods of presenting their data. HU mentors shared the posters with the UW team for feedback, then guided students in incorporating that feedback.

WSHS students presented their posters at a community science fair event each April that celebrated the students' accomplishments, broadened community engagement around air quality, and provided an additional opportunity for students to practice communicating about their research and receive feedback. The UW and HU teams planned the events with guidance from the PAC. Each event took place at WSHS or the neighboring middle school and was advertised via Yakama Nation radio and the Spanish-language radio station KDNA. Speakers included a Yakama Nation EMP specialist and the director of a local community non-profit. Activities included food, raffle prizes, and community health screenings. Each June, students traveled to the EnvironMentors national science fair in Washington, D.C. and presented posters.

Outcomes

12 HU undergraduate mentors and 10 WSHS students participated in the program (multiple students and mentors participated more than once). All but 2 of the HU mentors and 1 of the WSHS students who committed to the program completed it. Table 3 summarizes the number of students, mentors, community attendees at the April event, and posters each year.

The curriculum was not formally evaluated; the UW and HU team discussed how to improve the program based on the weekly feedback from WSHS students and HU mentors. Major changes included: adding more user-friendly monitors and increasing the quantity of monitors, formalizing the weekly collaboration between lead HU mentors and the UW graduate student, increasing the pre-program mentor training, and reducing the amount of slides while increasing activities. Perspectives on the program from HU mentors, WSHS students, the HU faculty, and the UW team are provided in Table 4, by the authors from these groups. The UW graduate student collected these data anecdotally through semi-structured conversations with other authors. All authors reviewed the summary table to ensure their perspectives were captured accurately.

Of the 12 HU mentors, 10 graduated college (one is still enrolled). At least four mentors enrolled in graduate programs (three in STEM fields and one in education). At least four mentors entered workplaces (three in STEM fields and one in higher education). Of the 10 WSHS students, nine graduated high school (a rate higher than the WSHS graduation rate[18]). At least six students enrolled in higher education (at least two in STEM programs).

Challenges and Solutions

The distance between UW and HU/WSHS, and lack of shared experience, was challenging. Weekly video meetings between the UW graduate student and HU lead mentors, with others from UW and HU sometimes joining, was helpful. Patience with trust-building and gradually increasing interaction between WSHS students and the UW team was important. Relationship-building between the HU team and WSHS students at the beginning of each year was essential and took time, leading to concern about grant timelines. This was addressed by separating the educational and research aims of the grant.

It was challenging to motivate formal assessments (e.g. graded assignments), making it difficult to formally evaluate the curriculum and track learning. To assess WSHS student learning, HU mentors used informal quizzes and open discussion. Increased communication with the UW team helped the UW team better understand learning needs and improve the program accordingly.

During year 3, WSHS sports schedules changed and conflicted with EnvironMentors. High school sports are extremely important to this community. Fewer WSHS students signed up for the program, so the team decided to increase support per student.

The HU team had difficulty communicating with WSHS students over email or phone, so they switched to social media, which was more successful.

Next Steps

Several teachers, air quality personnel, and environmental educators have expressed interest in adapting this curriculum in their own school and community settings. As a result of this project, HU obtained a new EPA grant focused on tribal air sensor loan programs. HU EnvironMentors are now working with high school students to develop a community lending program for low-cost air sensors provided by EPA Region 10.

The curriculum is now a permanent part of HU EnvironMentors, and they continue adapting it to better fit the needs of each group of students. The team does not plan to formally evaluate the curriculum, as formal assessments were not a good fit for the program, and a strength of the curriculum is the ability to use it dynamically. The achievement of the program is reflected in the research posters, and in student and mentor retention and success.

Conclusions

This model was developed for a rural, agricultural community in the Yakama Nation reservation, and emphasized collaborations. This curriculum could be adapted for use with middle and high school students in many different communities.

Hands-on engagement with air monitors, a high mentor to student ratio, and frequent meetings were key to learning. Support with data cleaning and analysis is important, either from mentors or other partners. Collaboration with the community’s air quality agency allows students to explore comparisons to regulatory monitors and see examples of how research connects with real-world programs. Increasing activities involving family, friends, and community members would broaden engagement around air quality. This curriculum is based on use of optical particle counters, which encompasses many available low-cost

PM sensors. This program lends itself well to highlighting local case studies and data, and should be adapted to focus on air pollution sources and issues most relevant locally.

This program's achievement is attributed to strong partnerships. The ability to adapt and improve the program according to student and community needs and ideas depends on open communication, which requires a foundation of relationship-building. Dynamic, responsive programming supports non-extractive scientific work and relies on community partnerships.

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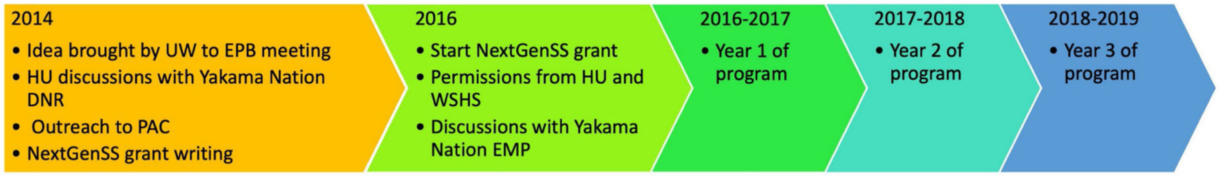

Figure 1:
Timeline of the NextGenSS research project

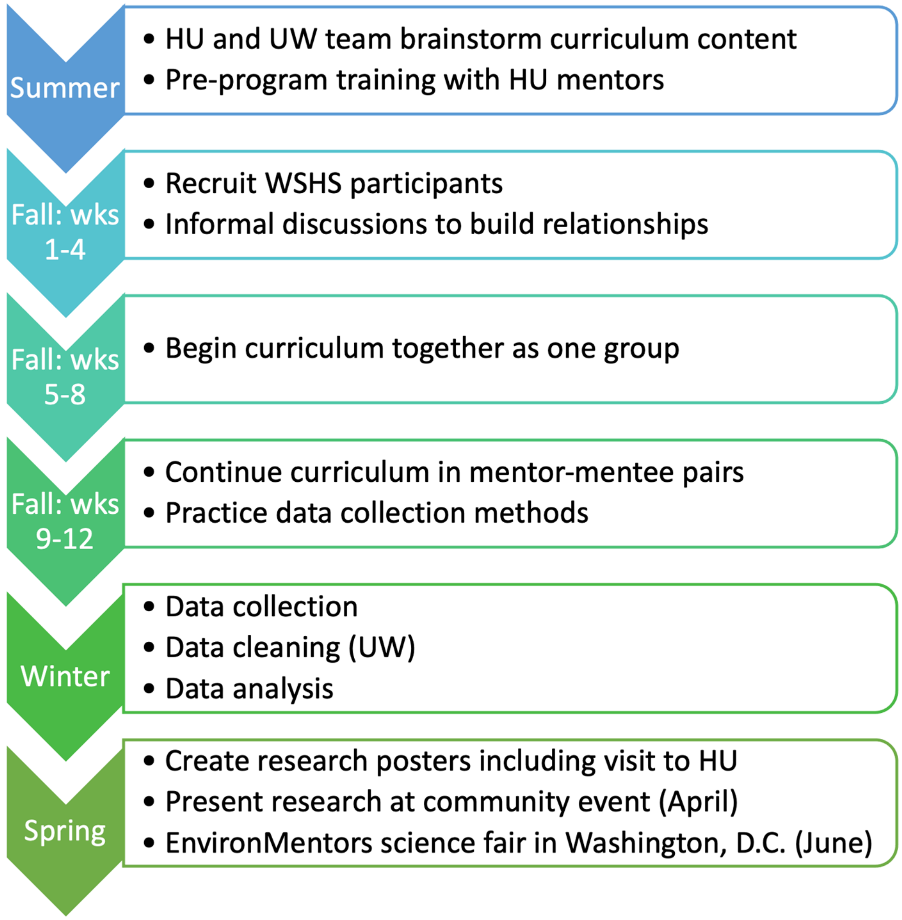

Figure 2:
Timeline of curriculum implementation and student research

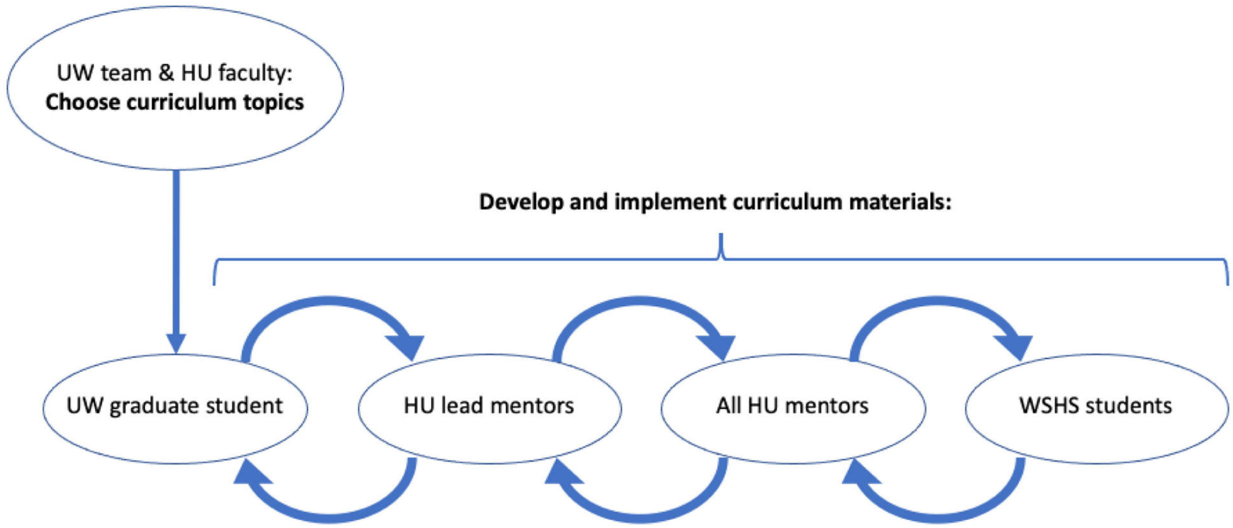

Figure 3:
Flow of information and feedback for curriculum development

Table 1:

Roles and responsibilities for the program

Responsibility	HU faculty	UW faculty & researchers	UW graduate students	HU lead undergraduate student mentors	HU undergraduate student mentors	WSHS students
NextGenSS grant application	X	X				
Lead EnvironMentors program, including maintaining relationship with WSHS and hiring HU undergraduate student mentors	X					
Select low-cost air quality monitors for students to use		X				
Pre-program training for mentors on air quality background and how to use selected air monitors		X	X			
Recruit WSHS student participants	X			X	X	
Develop curriculum	X	X	X	X		
Teach or review material with HU lead mentors	X		X			
Teach or review material with HU mentors				X		
Conduct curriculum with WSHS students	X			X	X	
Provide feedback on the curriculum	X			X	X	X
Develop research project topics	X	X	X	X	X	X
Site air quality monitors				X	X	X
Collect data						X
Data download	X			X	X	X
Data cleaning and analysis suggestions		X	X			
Data analysis	X			X	X	X
Develop posters	X	X	X	X	X	X
Plan community events with PAC	X	X	X	X	X	
Present posters						X

Table 2:

Program learning objectives and associated topics/activities. See the curriculum webpage for the curriculum materials.

Learning Objective	Knowledge/Skill	Topic/Activity
Design a research project through increased knowledge and hands-on learning.	Regulatory air monitoring	Online map of regulatory monitors and Air Quality Index Case study
	Low-cost PM monitors	Purple Air (low-cost sensor) monitor map Monitor components Laser-based particle counter activity
	Particle size	Particle size & deposition in the lung Monitor measurement of particle size
	Sources of PM	Local sources of PM Weather inversion activity Combustion and molecules activity
	PM and health	Air pollution effects on lungs, heart, blood vessels, and brain
	Public opinion	Debate on air quality regulation using public comments
	Forming hypotheses	Dependent and independent variables Project topics and hypotheses Youth Participatory Action Research process activity
	Using PM monitors	Standard Operating Procedures Practice using monitors Site monitors for projects
	Recording data	Practice filling out log sheets Fill out log sheets for projects
Perform data analysis and interpretation on data student has collected .	Reading XY graphs	Review examples of XY graphs Practice drawing XY graphs of expected data from monitoring
	Analyzing data	Data variables Practice downloading data Follow data analysis steps for projects
	Interpreting data	Discussions with mentors on data patterns and trends
Prepare written and graphic materials to present student research.	Data presentation	Workshop with mentors on making tables and graphs Air Quality Index colors on graphs of PM data activity
	Research posters	Examples of research posters Research poster template and project worksheets Create posters with mentors
Present research results to community members and learn from community member feedback and community environmental initiatives.	Research communication	Community science fair
	Environmental initiatives in the community	Visits to: Yakama Forest Products, sustainable logging forest Guest speakers: foresters, wildlife refuge ranger

Table 3:

Numbers of students, mentors, community attendees, and posters each year

	Year 1	Year 2	Year 3
Students	5	5	3
Mentors	4	5	3
Community attendees at the community event	~20	~20	~20
Posters at the community event	4	5	3
Posters at the EnvironMentors national science fair in Washington, D.C.	4	5	3

Table 4:

Perspectives on the educational program by authors from each participating group.

	HU mentors	WSHS students	UW researchers, graduate student, & faculty	HU faculty
Experiential learning	• Hands-on activities best supported learning • Slides were too time consuming	• Activities of conducting research facilitated deeper understanding of the concepts	• Appropriate flexibility and pacing for experiential learning was essential (initially a challenge that required separating educational and research aims)	• Real-world application of the curriculum where “correct” answers are unknown was exciting to students
Communication	• Meetings between WSHS students and the UW team was a positive aspect of the program • Small group sessions facilitated more open communication with students		• The initial challenge of limited engagement with students was ameliorated by video and in-person meetings between the UW team and HU mentors and WSHS students • Meetings allowed for tailoring resources and receiving and incorporating feedback	• The initial challenge of limited ability to communicate with students over email or phone was addressed by using social media
Skill-building	• Trainings between lead mentors and the UW team were helpful, especially on software use • Slides were informative • More training prior to the start of the program was needed, especially on data collection and analysis methods	• The full day session at HU working on posters was helpful • One-on-one training with mentors, especially on Microsoft Office, graphs, and tables was helpful • It was difficult to adapt to changes made		• Training mentors in teaching and research skills, especially data analysis and graphing, was a positive outcome of the program

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		• Some material was too rushed		
Relationship building	• Leadership role experience in mentoring the WSHS students was an important benefit of the program	• Roles, organization, and goals of the program were vague, making it initially more difficult to build relationships with the UW team	• Stronger research relationships with community partners was an important benefit of the program	• Relationship building between high school and undergraduate students was an important benefit of the program
Student success	• Research and teaching skills and experience were positive outcomes gained from the program	• New research knowledge and skills, especially presentation skills, were positive outcomes gained from the program		• The 90% graduation rate for WSHS and HU students reflects well on the program • HU and WSHS student pride in giving back to their community, and a sense of responsibility, were positive aspects of the program