PUBLIC HEALTH REPORTS

Public Health Reports
1–7

DOI: 10.1177/00333549241302621
journals.sagepub.com/home/phr

Sage

Bringing Pandemic Science to the Classroom: Building Public Health Capacity at a Rural Kentucky High School

Sahar Alameh, PhD[1]; Anna G. Hoover, PhD[2]; James W. Keck, MD, MPH[3]; Scott M. Berry, PhD, MBA[4]; Sagan Goodpaster, PhD[1]; Savannah Tucker, MPH[4]; and Ashley Goodin, MA[5]

Abstract

In response to the COVID-19 pandemic, a multidisciplinary team at the University of Kentucky developed an interdisciplinary science, technology, engineering, and mathematics and environmental health unit—the Wastewater Assessment for Coronavirus in Kentucky: Implementing Enhanced Surveillance Technology (WACKIEST) Unit—for high school students in summer 2022. This case study outlines the WACKIEST Unit, which focused on wastewater surveillance and COVID-19, the obstacles faced during development and recruitment, and implementation of the WACKIEST Unit in conjunction with a rural wastewater surveillance initiative. The unit was implemented in spring 2023 at a rural high school in Kentucky, spanning 12 days and engaging 190 students. Lessons emphasized the importance of wastewater testing in public health decision-making, particularly in the context of COVID-19. A mobile laboratory provided students with hands-on experience in conducting preliminary analyses of wastewater, and a field trip to the local wastewater treatment plant allowed them to observe real-world wastewater management practices. At the unit's conclusion, students created a public health report aligned with the Evidence-Informed Decision Making in Public Health model, reinforcing the goal of fostering community health resilience. The initiative's success—measured by the unit's completion and positive feedback from students and teachers—supports the creation of online modules for broader dissemination. This case study demonstrates how adaptable interdisciplinary approaches can integrate real-world scientific issues into secondary education, offering valuable insights for future efforts in public health education.

Keywords

public health capacity, wastewater surveillance, COVID-19 education, rural health education, science curriculum development

The COVID-19 pandemic is an unparalleled global health crisis with dramatic effects on the field of education.[1] Not only did the pandemic change how we view learning,[2] but it also highlighted the critical need for cultivating public health awareness in schools.[3] The pandemic underscored the importance of scientific literacy,[3,4] emphasizing the need to understand basic science concepts for informed decision-making in a health crisis.[5] The pandemic highlighted how scientific evidence evolves, demonstrating the need for public adaptability to changing guidelines based on new research.[6] Additionally, the pandemic showcased the process of scientific inquiry and the nature of science, reinforcing the importance of a society well versed in how science works to effectively respond to emerging global challenges.[6,7] The pandemic served as a reminder of the necessity of ensuring adequate levels of scientific literacy among the general population, who must make sense of and act on highly technical information in a short time frame. Critically, scientific literacy has been found to protect against COVID-19 conspiracy theories, further confirming the need to build this protective capacity to ensure

[1] Department of STEM Education, College of Education, University of Kentucky, Lexington, KY, USA
[2] Department of Epidemiology & Environmental Health, College of Public Health, University of Kentucky, Lexington, KY, USA
[3] Department of Family and Community Medicine, University of Kentucky, Lexington, KY, USA
[4] Department of Mechanical and Aerospace Engineering, University of Kentucky, Lexington, KY, USA
[5] Adair County High School, Columbia, KY, USA

Corresponding Author:
Sahar Alameh, PhD, University of Kentucky, College of Education, Department of STEM Education, Taylor Education Building, 597 S Upper St, Lexington, KY 40508, USA.
Email: sahar@uky.edu

evidence-based decisions. As public health researchers and practitioners develop health communication campaigns to combat misinformation and disinformation,[8,9] classrooms provide an ideal setting for teaching key public health concepts that can protect against erroneous information.[10,11]

The Wastewater Assessment for Coronavirus in Kentucky: Implementing Enhanced Surveillance Technology (WACKIEST) initiative is a critical effort to advance the surveillance of SARS-CoV-2 in Kentucky, with an emphasis on rural communities where access to COVID-19 testing is limited.[12,13] The initiative had 2 objectives: (1) developing next-generation technology to streamline wastewater testing for widespread use and (2) implementing a SARS-CoV-2 wastewater surveillance network in rural Kentucky. Through a partnership with the University of Kentucky's science, technology, engineering, and mathematics (STEM) education department, our team added science education tailored to the local context.[14] This effort led to the development of the WACKIEST Unit, an instructional module designed to integrate public health lessons with science education in a way that addresses the unique challenges and opportunities in these communities.

Purpose

We describe the development, recruitment, and implementation of the first year of an interdisciplinary STEM unit related to viruses, COVID-19, and wastewater at a rural high school in Kentucky. We examine the barriers in implementation that delayed initial implementation, the challenges encountered, and the solutions devised. We also discuss considerations for others looking to adopt similar approaches, and we outline plans for future improvements.

Methods

Development of the WACKIEST Unit

In early 2021 and shortly after the onset of the COVID-19 pandemic, our initiative aimed to effectively integrate pandemic-related activities into science classrooms. Our approach aligned with broader educational trends that incorporated socioscientific issues such as the pandemic into STEM curricula.[15,16] Collaborating with a group of experts, we focused on developing instructional material that not only included scientific knowledge about COVID-19 but also aimed to foster a deeper understanding of public health among students. We started by examining the Kentucky Academic Standards for Science,[17] which are adopted from the Next Generation Science Standards 18 (NGSS).[18] The NGSS are research-based standards that structure science education to engage students from kindergarten through 12th grade and prepare them for future challenges.[18] This examination served as the foundation of our interdisciplinary collaboration, which involved members from the College of Education, College of Engineering, College of Medicine, College of Public Health, and various community partners.

We developed a STEM unit focused on wastewater surveillance and COVID-19, with the goal of promoting public health awareness. The unit comprised 6 lessons tailored for high school students in socioeconomically disadvantaged areas of rural Kentucky. The unit lessons and activities were contextualized with real data and local examples, ensuring that topics, particularly wastewater management, were directly related to the community with which the students were familiar.

The WACKIEST Unit: Sequencing and Integrating Lessons

Testing wastewater for SARS-CoV-2 presence was the unit's overarching theme. To align this theme with the typical science classroom curriculum, we identified key content from selected science standards. We sequenced lessons to align with this focus. Building on relevant and current evidence related to viruses, wastewater testing, public health, and environmental education, we used inquiry-driven questions to guide the curriculum. We used this approach to give students the opportunity to investigate and build their knowledge through science and engineering practices, such as developing and using models and analyzing and interpreting data. We aimed to engage and empower students to take ownership of their learning by fostering coherence from their viewpoints. Coherence emerges when students perceive their scientific endeavors as contributing to the exploration of questions and challenges that their classroom community is dedicated to addressing, rather than simply following instructions from textbooks or teachers.[19] To cultivate this type of coherence, we used an instructional model known as storylines.[19] The storyline approach incorporates design principles aimed at involving students in real-life events and problems and encouraging them to generate their own inquiries. Teachers, supported by curriculum materials, can use these inquiries to guide the progression of their sense making.[19]

Content Progression and Hands-on Learning

The content progression for the unit begins with a general introduction in lesson 1 on viruses and the characteristics of life, which includes discussions on living and nonliving concepts (Figure 1). Lesson 2 introduces coronaviruses, with an emphasis on COVID-19, and compares it with seasonal influenza. The storyline continues with lesson 3 on how viruses spread in populations by modeling and illustrating viral replication. Lesson 4 is an introduction to wastewater, wastewater testing, and water quality. The unit includes activities that allow for hands-on learning opportunities, such as testing water quality and analyzing real wastewater testing data (lesson 4), touring a community wastewater treatment plant and exploring careers in STEM (lesson 5),

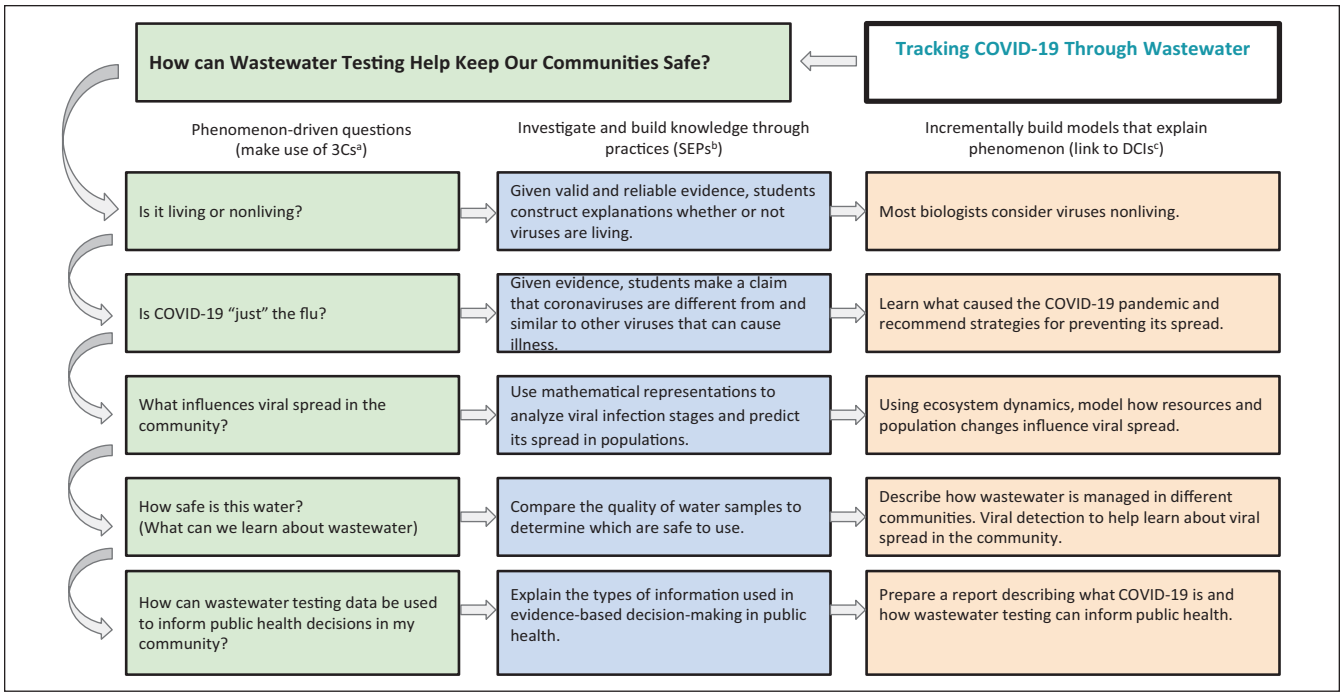

Figure 1. A storyline of the Wastewater Assessment for Coronavirus in Kentucky: Implementing Enhanced Surveillance Technology (WACKIEST) Unit, developed in summer 2022 by a multidisciplinary team of experts at the University of Kentucky for high school students in rural settings.

[a] Cross-cutting concepts (3Cs) in the Next Generation Science Standards (NGSS) refer to the ways that scientists and engineers advance their thinking.[14]

[b] Science and engineering practices (SEPs) in the NGSS include practices of science and engineering that are essential for all students to learn.[14]

[c] Disciplinary core ideas (DCIs) in the NGSS refer to the fundamental ideas that are necessary for understanding a given science discipline.[14]

Figure 2. The mobile laboratory at a high school in south-central Kentucky, demonstrating on-site pathogen analysis capabilities and providing hands-on learning experiences for students as part of the WACKIEST Unit—Wastewater Assessment for Coronavirus in Kentucky: Implementing Enhanced Surveillance Technology. The 2-week unit in public health and STEM (science, technology, engineering, and math), developed in summer 2022 by a multidisciplinary team of experts at the University of Kentucky, provided hands-on learning experiences and demonstrated on-site pathogen analysis capabilities to enhance students' understanding of public health.

and developing a public health report (lesson 6). A distinctive feature of the unit is the inclusion of a mobile laboratory housed in a molecular biology laboratory in a Ford Transit van (Figure 2). This mobile laboratory is capable of performing pathogen analysis of wastewater within 1 to 2 hours in remote or rural locations. The unit incorporates a simplified testing protocol derived from the original procedure, which is tailored for high school students to conduct preliminary analyses of contrived wastewater.

Unit Review and Refinement

Content experts from various disciplines reviewed the content for each lesson for accuracy and alignment with NGSS. The education team revised the lessons based on this feedback to ensure that they were accurate, current, and aligned with NGSS standards. In addition, 4 in-service middle and high school teachers who were experienced in NGSS reviewed the unit using the EQuIP rubric (Educators Evaluating the Quality of Instructional Products).[20] This rubric provided a structured framework for offering criterion-based feedback, which was instrumental in refining the lessons. The review process concluded in June 2022. We obtained institutional review board approval from the University of Kentucky and began the recruitment process.

Recruitment Plans and Implementation Challenges

One of our plans for effective implementation of the WACKIEST Unit was to collaborate with partners from the wider public health system,[21] such as wastewater management and public schools, to promote awareness about COVID-19 and wastewater testing technology in rural populations. Such partnerships can be particularly important in nonmetropolitan communities where public health resources are stretched in ways that can constrain local agencies' health communication efforts.[22] Despite thorough planning, our recruitment and implementation plans faced some barriers, which are detailed hereinafter.

School/teacher recruitment. Our study initially targeted schools in 6 counties of rural eastern Kentucky where the team was conducting wastewater surveillance. However, the initial response from schools in these counties was limited. Some administrators showed reluctance, concerned that their teachers already had too much to handle in the postpandemic period. Three schools initially consented to participate in the pilot study but later postponed or declined. As a result, our team broadened the scope to include any middle school and/or high school in rural Kentucky. Expanding our focus to encompass any middle school and/or high school in rural Kentucky substantially improved our school recruitment efforts.

Time constraints. The postpandemic academic environment presented unique challenges related to time. Teachers and students, already burdened with catching up on education gaps caused by the pandemic, found accommodation of additional content to be challenging. These challenges led to scheduling conflicts and strained the capacity to integrate a new unit into an existing curriculum. To minimize teachers' time commitment, we offered to coteach some of the lessons, and we facilitated the unit activities. Doing so not only eased time constraints but also offered students direct interaction with experts.

Natural disasters. In 2022, a series of floods in Eastern Kentucky disrupted communities and damaged educational infrastructure, which had a substantial effect on schools that had initially shown interest in participating. The aftermath of the flood also highlighted the vulnerability of rural education systems to natural disasters, which influenced our strategies in managing time constraints and recruitment efforts. Interestingly, the 2023-2026 National Health Security Strategy[23] emphasizes the need to plan for concurrent health emergencies. Our experiences of simultaneously building a pandemic-focused curriculum while adapting to flood-related disruptions in our initial partner counties reinforced the need for building adaptive capacity into educational approaches. Our experience also underscored the need for integrating real-life events into the science curriculum to better prepare students for emerging challenges.

Responding to Challenges

The process of responding to challenges was multifaceted. Ongoing dialogue among the interdisciplinary research team and iterative feedback mechanisms involving our project partners, including school teachers, primarily drove the identification of these challenges. These discussions were formal and informal, occurring throughout the implementation phase of the project. The research team held regular debriefing sessions to reflect on project progress and to discuss preliminary observations. These sessions provided a platform for identifying immediate challenges and strategizing adjustments to our approach. Furthermore, feedback from teachers who were directly involved in delivering the activities played a crucial role. Their insight into student engagement and understanding was invaluable for identifying pedagogic and content-specific challenges. In addressing each barrier, we also found that solutions to one challenge often helped mitigate other challenges, leading to a more effective overall problem-solving approach. Following our recruitment efforts that started in 2022, we ultimately achieved a successful implementation at the first school in spring 2023.

Outcomes

WACKIEST Unit Implementation

The unit implementation took place in spring 2023 at a rural high school in south-central Kentucky. A total of 791 students are enrolled in the school, and a substantial percentage of students are economically disadvantaged; about 14% of students are in a racial and ethnic minority group. The WACKIEST Unit spanned 12 school days, with each lesson structured to take 1 or 2 days. Supervised by 3 high school biology teachers, the unit engaged 190 students across 9 biology sections.

Implementation Overview

Implementation of the WACKIEST Unit involved multiple strategic components designed to maximize the educational impact and ensure a seamless integration into the existing school curriculum.

Team support. Implementation of the WACKIEST Unit was characterized by high involvement from the WACKIEST team, which comprised project scientists, field technicians, and STEM educators. The WACKIEST team played a crucial role in supporting teachers and students. University researchers provided lesson plans and materials and cotaught activities, including the use of the mobile laboratory (Figure 2), which enriched the student experience and reduced the work burden on teachers.

Teacher training. In preparation for the unit, the WACKIEST team facilitated a full-day professional development workshop

Figure 3. High school students from south-central Kentucky visiting a community wastewater treatment plant during a spring 2023 field trip as part of the WACKIEST Unit—Wastewater Assessment for Coronavirus in Kentucky: Implementing Enhanced Surveillance Technology. This visit, organized by a multidisciplinary team from the University of Kentucky, illustrated real-world applications of wastewater management and public health, connecting classroom learning with community-based environmental science practices.

Figure 4. Participants in the Girls' Science Day 2024 camp hosted by Mzuzu University in Malawi, Africa, engaging with the WACKIEST Unit—Wastewater Assessment for Coronavirus in Kentucky: Implementing Enhanced Surveillance Technology. This adaptation of the unit, designed by a multidisciplinary team at the University of Kentucky, focuses on wastewater-based epidemiology, sanitation, and career promotion in STEM (science, technology, engineering, and math). Culturally relevant activities were aimed at empowering young female students in low-resource rural settings to connect scientific concepts with their community's public health needs.

for teachers on the university campus. This workshop was essential in equipping teachers with the content knowledge and pedagogical strategies needed to deliver the unit effectively. Teachers also had the opportunity to tour the WACKIEST laboratory and the mobile laboratory, which allowed them to familiarize themselves with the equipment and procedures that would be used in the classroom.

Community partnerships. Another key component of the implementation was the collaboration with local community wastewater treatment plants. The WACKIEST team worked closely with these facilities to customize the lessons on wastewater testing, ensuring that they reflected the processes and challenges faced by the community. As part of this collaboration, students participated in field trips to wastewater treatment plants (Figure 3), where they observed real-world applications of their classroom learning. This partnership exposed students to potential STEM careers in their communities, such as those within wastewater treatment plants and with the US Environmental Protection Agency.

Public health focus. The unit's lessons were designed to underscore the importance of wastewater testing in public health decision-making, especially in the context of COVID-19. The culmination of the unit was a project that required students to create a public health report by applying the knowledge that they had acquired to real-world scenarios. This project was crucial in helping students understand how scientific data, such as data obtained from wastewater testing, inform public health policies and actions. The unit aligned with the Evidence-Informed Decision Making in Public Health model,[24] which emphasizes the role of scientific evidence in shaping effective public health strategies. By engaging students in this process, the unit not only enhanced its understanding of public health but also contributed to the WACKIEST Unit's broader goal of fostering community health resilience through education.

Conclusion and Future Plans

Access to resources such as the mobile laboratory, strong partnerships with local community organizations (eg, wastewater treatment plants), and the support of teachers were all key factors in the successful implementation of the WACKIEST Unit. These strategies enhanced educational outcomes and fostered meaningful connections between students and their communities, making science education relevant and impactful.

Since spring 2023, our unit has been implemented in 2 additional schools, and we are translating materials into Spanish. We have also adapted activities for a Girls' Science Day camp in Malawi, Africa, focusing on wastewater, sanitation, and promotion of STEM careers (Figure 4). Implementation of the WACKIEST Unit identified 3 elements that were critical to the program's success: resource adaptability, tailored educational content, and interdisciplinary collaboration.

A major takeaway from our experience is the importance of adaptability in educational resources. The lack of access to specialized equipment, such as our mobile laboratory, in most schools led us to create a simplified testing protocol suitable for high school environments. We have also documented this protocol through images and videos from our mobile laboratory, making these resources available for teachers and students. Building strong partnerships with local communities while tailoring educational content to meet the needs of each community has proven invaluable. As we move forward, we plan to enhance our partnerships with more school districts—rural and urban—to make our unit applicable to various community contexts, fostering a broader and more inclusive community of learning.

The interdisciplinary approach that we adopted has been indispensable. By bringing together diverse expertise and viewpoints, we were able to design, implement, and assess our unit effectively, setting a standard for future educational projects. In the future, we plan to develop interactive online modules, including laboratory simulations based on our wastewater testing protocol, to connect theoretical knowledge with real-world applications. These modules will be designed for middle and high school students and will include real-time data to further enrich students' learning experiences. Such innovations will improve our ability to scale the curriculum beyond Kentucky to reach additional schools and settings worldwide.

Acknowledgments

The authors acknowledge the contributions of the educators, community partners, and students who piloted the curriculum and participated in and supported this project. Their insights and expertise were invaluable in shaping the implementation and evaluation of the educational unit.

Declaration of Conflicting Interests

The authors declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: Scott Berry has an ownership interest in Salus Discovery, LLC, which has licensed some of the technology described in this article.

Funding

The authors disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This work was supported by the National Institutes of Health RADx-rad Initiative (grant U01 DA053903-01).

ORCID iD

Sahar Alameh, PhD https://orcid.org/0000-0001-7478-8791

References

1. Goldberg SB. *Education in a Pandemic: The Disparate Impacts of COVID-19 on America's Students*. Office of Civil Rights; 2021. Accessed January 28, 2024. https://www2.ed.gov/about/offices/list/ocr/docs/20210608-impacts-of-covid19.pdf
2. Kerres M, Buchner J. Education after the pandemic: what we have (not) learned about learning. *Educ Sci*. 2022;12(5):315. doi:10.3390/educsci12050315
3. Gu C, Feng Y. Influence of public engagement with science on scientific information literacy during the COVID-19 pandemic. *Sci Educ*. 2022;31:619-633. doi:10.1007/s11191-021-00261-8
4. Valladares L. Scientific literacy and social transformation. *Sci Educ*. 2021;30(3):557-587. doi:10.1007/s11191-021-00205-2
5. Arnold JC. An integrated model of decision-making in health contexts: the role of science education in health education. *Int J Sci Educ*. 2018;40(5):519-537. doi:10.1080/09500693.2018.1434721
6. Matuk C, Martin R, Vasudevan V, et al. Students learning about science by investigating an unfolding pandemic. *AERA Open*. 2021;7:233285842110548. doi:10.1177/23328584211054850
7. Callaghan NI, Khaira S, Ouyang A, et al. *Discovery*: virtual implementation of inquiry-based remote learning for secondary STEM students during the COVID-19 pandemic. *Biomed Eng Educ*. 2021;1(1):87-94. doi:10.1007/s43683-020-00014-z
8. Rasmussen J, Lindekilde L, Petersen MB. Public health communication reduces COVID-19 misinformation sharing and boosts self-efficacy. *J Experiment Polit Sci*. Posted online April 22, 2024. doi:10.1017/xps.2024.2
9. Whitehead HS, French CE, Caldwell DM, Letley L, Mounier-Jack S. A systematic review of communication interventions for countering vaccine misinformation. *Vaccine*. 2023;41(5):1018-1034. doi:10.1016/j.vaccine.2022.12.059
10. Osborne J, Pimentel D. Science, misinformation, and the role of education. *Science*. 2022;378(6617):246-248. doi:10.1126/science.abq8093
11. Allchin D, Bergstrom CT, Osborne J. Transforming science education in an age of misinformation. *J College Sci Teach*. 2024;53(1):40-43. doi:1080/0047231X.2023.2292409
12. Banadaki MD, Torabi S, Alexus Rockward, et al. Simple SARS-CoV-2 concentration methods for wastewater surveillance in low resource settings. *Sci Total Environ*. 2024;912:168782. doi:10.1016/j.scitotenv.2023.168782
13. Torabi S, Amirsoleimani A, Dehghan Banadaki M, et al. Stabilization of SARS-CoV-2 RNA in wastewater via rapid RNA extraction. *Sci Total Environ*. 2023;878:162992. doi:10.1016/j.scitotenv.2023.162992
14. Darlington EJ, Violon N, Jourdan D. Implementation of health promotion programmes in schools: an approach to understand the influence of contextual factors on the process? *BMC Public Health*. 2018;18(1):163. doi:10.1186/s12889-017-5011-3
15. Elsner JN, Sadler TD, Zangori L, Friedrichsen PJ, Ke L. Student interest, concerns, and information-seeking behaviors related to COVID-19. *Discip Interdiscip Sci Educ Res*. 2022;4(1):11. doi:10.1186/s43031-022-00053-2
16. Sadler TD, Friedrichsen P, Zangori L, Ke L. Technology-supported professional development for collaborative design of COVID-19 instructional materials. *J Tech Teach Educ*. 2020;28(2):171-177.
17. Kentucky Department of Education. Kentucky academic standards for science. December 2022. Accessed December 18,

2022. https://www.education.ky.gov/curriculum/standards/kyacadstand/Documents/Kentucky_Academic_Standards_for_Science_2022.pdf
18. NGSS Lead States. *Next Generation Science Standards: For States, by States*. National Academies Press; 2013.
19. Reiser BJ, Novak M, McGill TAW, Penuel WR. Storyline units: an instructional model to support coherence from the students' perspective. *J Sci Teacher Educ*. 2021;32(7): 805-829. doi:10.1080/1046560x.2021.1884784
20. Next Generation Science Standards. EQuIP rubric for science. 2014. Accessed December 18, 2022. https://www.nextgenscience.org/resources/equip-rubric-science
21. National Association of County & City Health Officials. *National Public Health Performance Standards: Local Implementation Guide*. National Association of County & City Health Officials; 2013. Accessed January 28, 2024. https://www.naccho.org/uploads/card-images/public-health-infrastructure-and-systems/2013_1209_NPHPS_LocalImplementationGuide.pdf
22. Hoover AG, Zephyr PD. Classifying community organizational health communication networks: local health department recognition of public information-sharing partners across sectors. *J Public Health Manag Pract*. 2021;27(5):513-520. doi:10.1097/PHH.0000000000001265
23. US Department of Health and Human Services. *2023-2026 National Health Security Strategy*. Administration for Strategic Preparedness & Response; 2023. Accessed January 28, 2024. https://aspr.hhs.gov/NHSS/National-Health-Security-Strategy-2023-2026/Documents/nhss-2023-2026-508.pdf
24. National Collaborating Centre for Methods and Tools. A model for evidence-informed decision making in public health. 2009. Accessed August 12, 2024. https://www.nccmt.ca/uploads/media/media/0001/01/0285efc9fa08b3b0fab06b7c940c2f6767087cfc.pdf