



Using Wikipedia Assignments to Teach Critical Thinking and Scientific Writing in STEM Courses

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While many instructors have reservations against Wikipedia use in academic settings, editing Wikipedia teaches students valuable writing, editing, and critical thinking skills. Wikipedia assignments align with the community of inquiry framework, which focuses on the elements needed for a successful online learning experience. We report on a faculty mentoring network, created by WikiProject Limnology and Oceanography, which helped 14 instructors with little to no prior experience implement a Wikipedia assignment in their classes. We found that Wikipedia assignments increase students' motivation to produce high quality work and enhance their awareness of reliable scientific sources. Wikipedia assignments can be comparable to other writing assignments in length and complexity, but have a far wider audience than a traditional research paper. Participants in our mentoring network reported challenges with implementing this new type of assignment, and here, we share resources and solutions to those reported barriers.

Keywords: community of inquiry, limnology, oceanography, faculty mentoring network, science communication, digital skills, online education, information literacy

INTRODUCTION

While academia and Wikipedia have historically had an uneasy relationship, Wikipedia assignments offer an opportunity to bridge the gap between scholarly information and the public (Jemielniak and Aibar, 2016; Konieczny, 2021). Students can play a critical role in this process by adding missing information to articles and thereby improving a freely-accessible resource. In particular, students can directly improve the quantity and quality of information about water-related and other science, technology, engineering, and math (STEM) topics on Wikipedia (Kincaid et al., 2020, Stachelek et al., 2020). Wikipedia assignments also offer opportunities for instructors to foster collaboration between students and subject-matter experts (Radtke and Munsell, 2010) and to have class discussions about the reliability and quality of various online sources of information. Finally, editing Wikipedia helps students experience a direct transfer of information from academic,

often paywalled, sources to a more public distribution of information (Callis et al., 2009). These assignments provide a unique philosophical perspective on the scope and nature of peer-review, both within the scientific community and more broadly, and can work well in a variety of instruction modalities. When writing assignments are completed in isolation with no audience beyond the instructor or fellow students in the course, students may not feel a strong incentive to produce quality written work. At the same time, education research supports the idea that writing is both a critical skill and a way to construct knowledge and deepen understanding about scientific topics (NGSS Lead States, 2013). Structuring writing assignments so that students know their work will reach a broader audience could incentivize students to focus on clarity and comprehensiveness (Apollonio et al., 2018).

Editing or creating new Wikipedia articles is an innovative way to teach critical thinking and scientific writing in online, in-person, or hybrid (including elements of both online and in-person) course formats. Assignments where students either edit existing articles or create new articles on Wikipedia teach students to write clearly and effectively for a broad audience (Vetter et al., 2019). These assignments also motivate students to engage in a writing assignment with immediate and measurable societal impact. Moreover, the quality of the resulting Wikipedia articles helps instructors assess student learning about a particular course topic. Wikipedia assignments can be structured so that collaboration and interaction with colleagues are intended learning outcomes (Koziura et al., 2020). For example, students can jointly edit and improve an article, peer review each other's articles, and/or incorporate expert reviewer feedback as part of the Wikipedia assignment structure (Shane-Simpson and Brooks, 2016). A focus on group learning aligns with many institutional priorities for novel and active learning and peer engagement. Moreover, Wikipedia assignments provide an alternative to academic service-learning projects, with a more global focus on the intended audience, as well as a mechanism for community engagement on a virtual platform (Vetter et al., 2019). These assignments also provide students with opportunities to work with experts beyond their academic institution, a powerful motivator to complete quality work and an opportunity to gain varied insights on a topic.

In addition to meeting specific or requisite learning objectives, Wikipedia assignments provide a creative approach for accomplishing more co-curricular goals of ethical literacy. While digital literacy, information equity, and ethics might not necessarily be core competencies or explicit course objectives, they are nonetheless important topics for students to learn in an increasingly digital world (Coffin Murray and Pérez, 2014). Importantly, Wikipedia assignments help break the "ritualization" of student literature search practices (Bhatt and Mackenzie, 2019), as students are confronted with an assignment that breaks the mold of the typical term paper. Wikipedia assignments also help students become more savvy consumers of online information, an increasingly critical skill (Brossard, 2013). Additionally, Wikipedia editing assignments align with the principles of open pedagogy (Koziura et al., 2020), where students not only produce open information, but also

have to consider open access principles and the accessibility of science communication.

In this article, we describe outcomes and resources generated from a multi-institution faculty mentoring network led by members of WikiProject Limnology and Oceanography¹ during the 2020–2021 academic year, during which most of the mentored instructors were teaching courses with either hybrid or online delivery. The intent of the faculty mentoring network was to provide resources and support to faculty implementing a Wikipedia assignment for the first or second time in their science courses related to aquatic systems. This support included reviews of student Wikipedia drafts by subject area experts that were recruited for this purpose by members of WikiProject Limnology and Oceanography. We report some of the successes and challenges that faculty experienced in carrying out Wikipedia assignments and suggest resources and strategies to support instructors who are interested in doing a Wikipedia assignment in their STEM course.

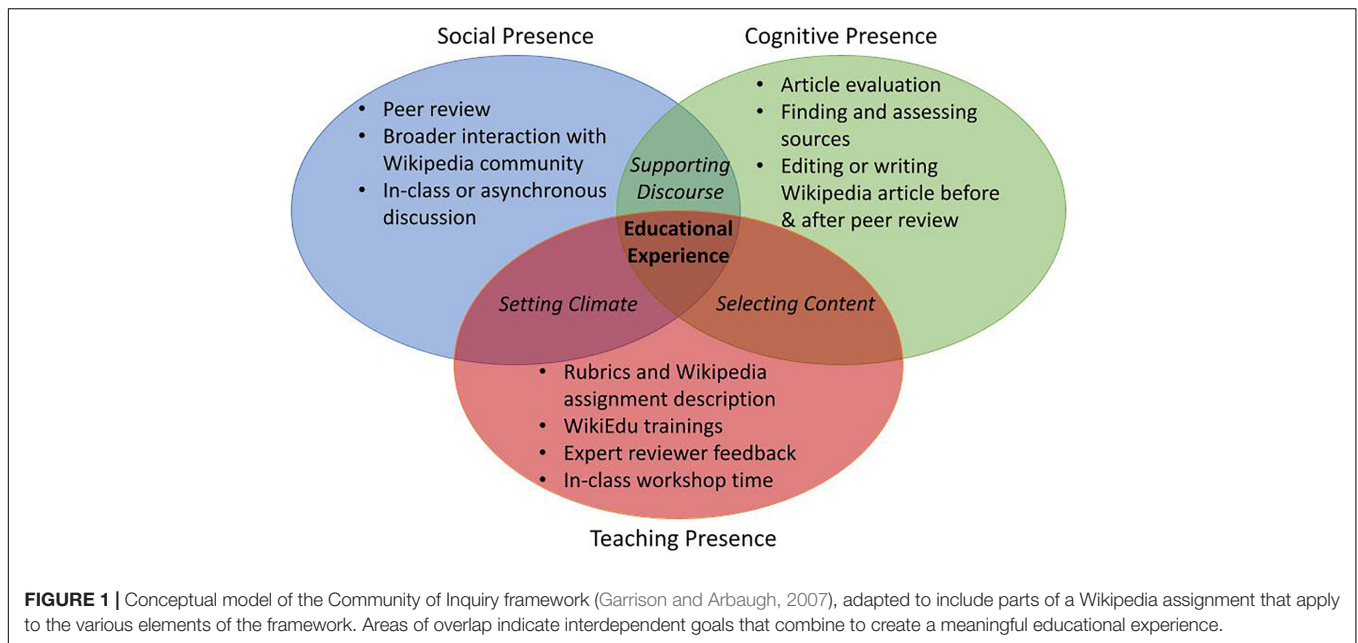
WIKIPEDIA ASSIGNMENT ALIGNMENT WITH THE COMMUNITY OF INQUIRY FRAMEWORK

A Wikipedia assignment maps onto the Community of Inquiry framework developed for online learning and therefore aligns with constructivist theories of learning (Garrison and Arbaugh, 2007). Briefly, the Community of Inquiry framework posits that three overlapping elements are needed for a successful online educational experience: social presence, cognitive presence, and teaching presence (Garrison et al., 2001). Different portions of Wikipedia editing or writing assignments map on to each of these three elements (**Figure 1**). First, social presence is the ability of learners to project their whole and authentic selves in an online learning environment. In a Wikipedia assignment, this element is achieved through students' ability to work informally in a virtual draft environment, called the "sandbox" (**Supplementary Material:**) (WP L&O The Sandbox²), on the Wikipedia site. In this space, students can select topics of interest and interact with peers through offering feedback or working collaboratively on a single topic. Second, cognitive presence is the way that learners construct understanding through continued cycles of reflection and communication. Wikipedia assignments can be structured to go through iterative phases of feedback as student work develops and are scaffolded to facilitate this construction of knowledge. Finally, teaching presence is defined as the ways that courses are designed and instruction is delivered to facilitate student understanding. As mentioned previously, Wikipedia assignments can be tailored with different levels of student–teacher interaction individually or in groups. The free platform, WikiEdu,³ also delivers asynchronous online modules on how to edit Wikipedia and provides instructor support for Wikipedia assignments.

¹https://en.wikipedia.org/wiki/Wikipedia:WikiProject_Limnology_and_Oceanography

²https://en.wikipedia.org/wiki/Wikipedia:About_the_sandbox

³<https://wikiedu.org/>



In addition to mapping onto an established pedagogical framework for online learning, Wikipedia assignments help meet specific learning objectives in STEM courses, such as critical thinking and evaluation. For example, Wikipedia has standards about what types of sources can be referenced.⁴ Learning about appropriate referencing can be both a lesson objective and an aspect of assessment on the finished project by including training about this topic. Additionally, Wikipedia assignments require reconciling potentially conflicting sources of published information and deciding how to present them. For example, several students in a course taught by one of the authors identified substantial discrepancies among sources of lake depth data. Ultimately, the search for a scientific “truth” led students to further question: *How can we rationalize this? What “facts” should be given on the page when there is conflicting information? How do we report conflicting information while staying within the Wikipedia guidelines for unbiased reporting?* Recognizing that conflicting evidence may exist in the scientific literature and critically evaluating which sources are reliable to provide encyclopedic information are possible learning outcomes that Wikipedia assignments can help to both teach and assess.

In addition to facilitating critical thinking, Wikipedia assignments can help students gain understanding of and confidence in the iterative scientific writing process (Rayner et al., 2014). As students move through drafts to the final stages of a Wikipedia assignment, they transition from first learning through writing to then writing to communicate. Removal of scientific “jargon,” linking to existing pages, and simplifying text can help the students better understand complex information. By emphasizing quality over quantity of content added, instructors work with students to identify the essential information to focus on what readers *need to know*, rather than what readers *could know*. Wikipedia pages (like all encyclopedia entries) should be thought of as points of entry to concepts, so it is important to

make sure the essential information is prioritized. This style of writing is more technical and concise, and also less narrative, than students might experience when writing in their other courses. Many undergraduate students will never publish a research paper or manuscript, but they will likely need to create some form of written content for a general audience in the course of their careers. Learning to write for different audiences, such as subject-matter experts and the public, is crucial, and is accomplished with Wikipedia-based assignments. Finally, Wikipedia assignments can include valuable training on editing writing when students must modify text in response to feedback from a variety of readers. Learning to understand what is meant from feedback and how to respond to and give respectful and constructive critical feedback is a valuable scientific skill that forms the basis of peer review.

THE ADAPTABILITY OF WIKIPEDIA ASSIGNMENTS TO VARIED LEARNING ENVIRONMENTS AND LEARNING OBJECTIVES

A key strength of a Wikipedia assignment is its flexibility, which can be adapted for use in a wide range of learning environments and to address a variety of learning objectives. This adaptability was exemplified by the 15 courses that were supported through our 2020–2021 faculty mentoring network, which were diverse in subject, class demographics, and delivery method.

The 15 supported courses were offered at 14 institutions across North America, ranging from small liberal arts colleges to large, research-intensive, doctorate-granting institutions. Three of the 13 American institutions are identified as minority serving institutions by the Rutgers Graduate School of Education, 2020. While all 15 courses addressed topics related to the environmental sciences and ecology, they ranged from broad

⁴https://en.wikipedia.org/wiki/Wikipedia:List_of_guidelines

survey courses in limnology, aquatic ecology, and the aquatic environment, to more specialized courses such as stream ecology and ecotoxicology. Most courses focused entirely on aquatic sciences and emphasized inland waters, while others (e.g., Climate Change, Ecotoxicology) spanned several ecosystem types. The majority of the courses were primarily scientifically focused, although two included aspects of environmental management and one was a science course designed for non-science majors. While all courses were geared to upper-year undergraduate or graduate students, several included a mix of students at both academic stages. Class sizes ranged from seven to 30 students, with an average size of 18 students per class, and students worked individually, in pairs, or in small groups of up to four students to complete their Wikipedia assignments. Due to the on-going COVID-19 pandemic, most courses were offered virtually, while some were offered only in-person and others followed a hybrid model that included elements of both virtual and in-person instruction. In all cases, the instructors who participated in our faculty mentoring network were able to tailor their Wikipedia assignment to their learning environment, for example, by curating a list of topical Wikipedia articles for their students, focusing on ecosystems near their institution, or adjusting the amount of student interaction that was required during the assignment.

The 14 instructors that participated in our faculty mentoring network in 2020–2021 were also diverse with respect to their career stage and prior teaching experience. Participants included senior-level tenured faculty, as well as faculty within the first five years of their appointments. Most participating instructors had not previously used Wikipedia-based activities in their courses, but prior teaching experience ranged widely; while some instructors had taught at the post-secondary level for many years, at least one instructor was teaching a post-secondary course as the senior instructor for the first time.

Wikipedia assignments can also be easily tailored to address a wide range of learning objectives, and can be adapted to the learning level of the students by adding (or removing) elements or complexity (see **Table 1** for examples). For instance, an assignment can be made more advanced by increasing the amount of text that is required, or can be made less advanced by instead focusing on adding media or missing citations to an existing article. In all courses supported through our network, students either edited an existing Wikipedia article or wrote a new article to meet the learning objectives specific to their course. Although the learning objectives varied widely among the supported courses, we identified a number from the course syllabi that were shared by multiple courses:

1. *Developing scientific and technical writing skills.* Effectively writing scientific and technical documents, such as journal articles, protocols, and reports, requires a specific writing style characterized by clarity, brevity, and neutrality. This writing style is also used by the community of Wikipedians (i.e., volunteer editors of Wikipedia articles) who follow the Wikipedia Manual of Style⁵. By writing and editing

Wikipedia articles, students were therefore able to practice and develop their scientific and technical writing skills.

2. *Communicating scientific knowledge to the public.* Wikipedia is the most common source of introductory information on a topic, and has the potential to share scientific knowledge more equitably than traditional methods of dissemination, such as journal articles or reports. Therefore, Wikipedia can be a tool to improve public knowledge on a range of scientific topics (Brossard, 2013; Kincaid et al., 2020). Articles are held to a high standard of public accessibility and readability by the community of Wikipedians. Course assignments supported the development of plain-language communication skills as students interpreted complex scientific concepts for the public, and explained them in accessible language that met the standards of Wikipedia.
3. *Thinking critically.* Successful completion of Wikipedia editing or writing assignments requires students to critically review and evaluate information from multiple sources, and to resolve any inconsistencies. This can require an evaluation of diverse sources of information and decision-making regarding what information to include. This provided the opportunity for students to critically review, assess, and evaluate existing and new information in their assigned Wikipedia articles.
4. *Researching and resourcing information.* Students were tasked with identifying appropriate references and information to back up their Wikipedia contribution. They also reviewed any existing article text, assessed the suitability of its references, and removed or replaced any inappropriate or out-of-date references. Although the citation styles used by Wikipedia tend to be more journalistic in form, as opposed to the formal citation styles used in academic writing, the importance of locating and citing appropriate sources to back up statements of fact remains the same as in an academic paper. Wikipedia assignments also provided an opportunity for students to evaluate information equity and access to scientific information; for example, the value to the public of open source information versus information stored behind paywalls.
5. *Developing digital skills.* It is critical that students learn how to find, evaluate, and communicate information online. Wikipedia editing and writing assignments allowed students to develop these skills while also navigating online training modules, resources, and comment pages that were facilitated by the WikiEdu support team.
6. *Developing an awareness of diversity and representation in science.* Minoritized individuals are under-represented both in terms of the numbers of editors actively contributing to Wikipedia (Koerner, 2019), and the number of articles about them (Wagner et al., 2016; Gupta and Trehan, 2021). In articles on STEM topics, minoritized individuals are even less equitably represented (Salam, 2019). Several courses explicitly focused on increasing the awareness and representation of minoritized scientists during their Wikipedia editing assignment by writing

⁵https://en.wikipedia.org/wiki/Wikipedia:Manual_of_Style

biographies of notable scientists from under-represented groups, while others focused on including references that were written by members of under-represented groups. For example, students updated Wikipedia pages about lakes to include Indigenous place names that had been given to those lakes prior to colonization (e.g., Green Lake in Wisconsin, United States⁶), and added sections that discussed the broader significance of waterbodies (e.g., the cultural history of the Chilocotin River in western Canada⁷).

into existing or planned courses. We note some common instructor challenges and offer resources to help overcome those challenges, based on our experience both as instructors of courses that have used Wikipedia assignments and as members of WikiProject Limnology and Oceanography (**Table 2** and **Supplementary Material**). In particular, we share resources we have developed to introduce instructors to Wikipedia assignments, including two handouts on how to manage Wikipedia assignments (**Supplementary Material: WP L&O Managing Assignments**, **Supplementary Material: WP L&O Resources for Wiki Assignments**), a handout about selecting articles to edit (**Supplementary Material: WP L&O Selecting Articles**), and a handout on maintaining student engagement (**Supplementary Material: WP L&O Student Engagement**). We also include handouts that address specific technical questions about using Wikipedia in the classroom, such as how to draft articles in the sandbox (**Supplementary Material: WP L&O The Sandbox**), how to add images to Wikipedia (**Supplementary Material: WP L&O Adding Images**), what a sample schedule for a Wikipedia assignment might look like (**Supplementary Material: Wikipedia Term Assignment Schedule**), a guide for expert reviewers of student work on Wikipedia (**Supplementary Material: WP L&O Reviewer Guide**), and an example of a

FINDINGS: INSTRUCTOR-REPORTED SUCCESSES, CHALLENGES, AND RESOURCES

While there are compelling reasons to include Wikipedia assignments in STEM courses, we recognize that instructors may face challenges with incorporating novel assignments

⁶[https://en.wikipedia.org/w/index.php?title=Green_Lake_\(Wisconsin&oldid=%20992398001#History](https://en.wikipedia.org/w/index.php?title=Green_Lake_(Wisconsin&oldid=%20992398001#History)

⁷https://en.wikipedia.org/w/index.php?title=Chilcotin_River&oldid=1017983811#Cultural_Significance

TABLE 1 | Learning objectives shared by multiple courses participating in the faculty mentoring network, and elements of a Wikipedia assignment that can be used to support those learning objectives.

Learning Objectives	Supporting Elements of a Wikipedia Assignment
<i>Developing scientific and technical writing skills</i>	<ul style="list-style-type: none"> - Revise an existing Wikipedia article to better meet Wikipedia's core content policies (https://en.wikipedia.org/wiki/Wikipedia:Core_content_policies) - Add a section to an existing Wikipedia article - Develop a new Wikipedia article - Incorporate feedback from peer reviews into a drafted Wikipedia article following the iterative model of scientific writing
<i>Communicating scientific knowledge to the public</i>	<ul style="list-style-type: none"> - Select and add data, images, or other supporting information to a Wikipedia article - Discuss open access information and information accessibility with peers - Increase information equity by prioritizing open access information and resources when adding to Wikipedia - Translate complex information into plain-language text that is intended for the public
<i>Thinking critically</i>	<ul style="list-style-type: none"> - Evaluate a Wikipedia article for its content, accuracy, and completeness - Evaluate a Wikipedia article for the suitability of its supporting information and citations - Read source material, evaluate, and synthesize when writing or adding to a Wikipedia article - Review work by peers and provide constructive feedback and suggestions for improvement
<i>Researching and resourcing information</i>	<ul style="list-style-type: none"> - Cross-link to other Wikipedia articles where appropriate - Add supporting information and citations to existing Wikipedia articles - Increase information equity by prioritizing open access information and resources when adding to Wikipedia - Conduct research on a topic, synthesize information, and craft original text for a Wikipedia article
<i>Developing digital skills</i>	<ul style="list-style-type: none"> - Learn how to access the scientific literature and use library resources - Navigate the WikiEdu dashboard and training modules - Interact with WikiEdu support staff, instructors, and peers via the online message board system - Create and add content using the online Wikipedia "what you see is what you get" content editor
<i>Developing an awareness of diversity and representation in science</i>	<ul style="list-style-type: none"> - Discuss how the representation of minoritized individuals and groups affects who gets heard, what viewpoints are prioritized, and what ways of knowing are elevated/ignored - Assess the supporting information and citations used in a Wikipedia article, and add resources by minoritized individuals and groups - Add text to an existing Wikipedia article to make it more inclusive or representative - Write an article, or add to an article, about a scientist who is a member of a minoritized group

The supporting elements for each objective are arranged from the shortest-duration activities to the longest, and can be selected or adjusted as needed to meet the specific learning objectives of a course or the learning level of the students.

TABLE 2 | Challenges reported by instructors, with resources to overcome those challenges and specific citations or links to access those resources.

Assignment Phase	Instructor Challenge	Resources and Solutions	Citations/Links
Early	Lack of familiarity with editing Wikipedia	WikiProject Limnology & Oceanography instructional video WikiEdu platform with educational modules and technical support	<ul style="list-style-type: none"> • https://www.youtube.com/watch?v=_Nin4RENHU4 (Alternate Wikipedia Link: https://en.wikipedia.org/wiki/File:Motivational_V3-FINAL.webm) • https://wikiedu.org/ • Instructor Training: https://dashboard.wikiedu.org/training/instructors • Supplementary Material: WP L&O Managing Assignments • Supplementary Material: WP L&O Resources for Wiki Assignments
Early	Finding appropriate articles to edit	WikiProjects Wikipedia Article Finder	<ul style="list-style-type: none"> • Relevant WikiProjects: <ul style="list-style-type: none"> ◦ https://en.wikipedia.org/wiki/Wikipedia:WikiProject_Limnology_and_Oceanography ◦ https://en.wikipedia.org/wiki/Wikipedia:WikiProject_Lakes ◦ https://en.wikipedia.org/wiki/Wikipedia:WikiProject_Women_scientists ◦ https://en.wikipedia.org/wiki/Wikipedia:WikiProject_Rivers ◦ https://en.wikipedia.org/wiki/Wikipedia:WikiProject_Fishes ◦ https://en.wikipedia.org/wiki/Wikipedia:WikiProject_Algae ◦ https://en.wikipedia.org/wiki/Wikipedia:WikiProject_Ecology • https://dashboard.wikiedu.org/article_finder • Supplementary Material: WP L&O Selecting Articles
During	Initiating and maintaining student engagement	WikiProject Limnology & Oceanography motivational video Breaking overall assignment into sub-projects	<ul style="list-style-type: none"> • https://www.youtube.com/watch?v=6ny9Z7CDWq8 (Alternate Wikipedia Link: https://en.wikipedia.org/wiki/File:Motivational_V3-FINAL.webm) • Paper suggesting best practices: Vetter et al., 2019 • Supplementary Material: WP L&O Student Engagement
During	Uneven computing skills and access to internet	If possible, carving out in lab/class "workshop" time for students to work on project Breaking Wikipedia assignment into a group project	<ul style="list-style-type: none"> • Printable handouts with Wikipedia editing instructions: https://wikiedu.org/for-instructors/#instructors • Case studies on how instructors have adapted and modified Wikipedia assignments to meet their students' needs: https://commons.wikimedia.org/wiki/File:Case_Studies,_How_instructors_are_teaching_with_Wikipedia_(Wiki_Education_Foundation).pdf
During	Wikipedia culture: jargon, edits to student work, negative interactions with other Wikipedia editors	Dedicated discussion or FAQ time on Wikipedia culture and policies, particularly harassment policies WikiPage Templates indicating that editors are students Wiki Education Expert support Drafting in the sandbox	<ul style="list-style-type: none"> • https://en.wikipedia.org/wiki/Wikipedia:Harassment • https://en.wikipedia.org/wiki/Template:Dashboard.wikiedu.org_assignment • https://en.wikipedia.org/wiki/Wikipedia:Five_pillars • https://en.wikipedia.org/wiki/Wikipedia:Policies_and_guidelines • https://en.wikipedia.org/wiki/Wikipedia:Editing_policy • Supplementary Material: WP L&O The Sandbox • Supplementary Material: WP L&O Adding Images • Article about women's experiences with Wikipedia editing: Menking et al., 2019
During	Timing/pacing of assignment	WikiEdu recommended timelines Example assignment schedule	<ul style="list-style-type: none"> • https://wikiedu.org/ • Supplementary Material: Wikipedia Term Assignment Schedule
End	Varying quality of peer reviews & peer review participation	Make peer review part of the final grade Include a rubric for expectations for peer review assignment	<ul style="list-style-type: none"> • Modifiable, generic peer review rubric: https://serc.carleton.edu/details/files/96845.html • Supplementary Material: WP L&O reviewer guide
End	Assessing student work	Existing rubrics Coordinating expert peer review Identifying student changes using article history or WikiEdu tools	<ul style="list-style-type: none"> • https://qubeshub.org/community/groups/coursesource/publications?id=2615&tab_active=about&v=1 • https://commons.wikimedia.org/wiki/File:Wiki_Education_Classroom_Program_example_grading_rubric.pdf • https://upload.wikimedia.org/wikipedia/commons/9/92/Instructor_Basics_How_to_Use_Wikipedia_as_a_Teaching_Tool.pdf • Supplementary Material: Wikipedia Evaluation and Editing
End	Deciding whether to publish revisions to Wikipedia	Allow time in course sequencing for students to receive reviews and feedback from larger Wikipedia community Do not make grading contingent on edits being accepted	<ul style="list-style-type: none"> • https://en.wikipedia.org/wiki/Help:Editing • Article about best practices: Shane-Simpson and Brooks, 2016

Challenges are grouped by assignment phase; early (before the course begins or in the beginning stages of the assignment), during (when the students are actively working on the assignment), and end (at the end of the course or assignment as the instructor is assessing the assignment).

Wikipedia assignment description and rubric (**Supplementary Material: Wikipedia Evaluation and Editing**). We also share data from courses taught in Fall 2020 and Spring 2021 to provide quantitative context about Wikipedia assignments (**Figure 2**).

While we focus on universal challenges that instructors could encounter when using a Wikipedia assignment, we want to also highlight that Wikipedia assignments can take many forms. As a minimal example, an instructor could assign students a Wikipedia article related to course content to read and evaluate and then discuss strengths and weaknesses of the article during a class period or via an asynchronous discussion board. A more involved assignment could include a subsequent step where students do research about the article topic and suggest edits or improvements to the article. A third assignment level could require students to edit an existing Wikipedia article, with varying levels of editing required, based on instructor discretion. These edits could range from adding a handful of references or sentences or adding informative images, to adding new sections or paragraphs, creating new diagrams or other imagery, and including multiple references to substantially improve an existing article. Finally, the most time-consuming option is to have students create a new Wikipedia article on a topic not currently covered by Wikipedia, which is most likely appropriate for advanced undergraduate or graduate students. Depending on the instructor's preference, students can keep their edits in their "sandbox," a space on Wikipedia for drafting edits that is still public-facing, or students can be asked to publish their edits to the Wikipedia article so that they are live. Additionally, students can either work alone or in pairs or groups to complete the assignment. The WikiEdu platform allows for a range of possibilities for designing a Wikipedia assignment (see **Figure 2** for examples). As an example, assignments can range in effort from a group assignment where students work together to make small changes to an article (**Figure 2A**) to an individual assignment where students work alone to make substantial additions to an article (**Figure 2B**). Based on our teaching experiences, editing an existing Wikipedia article or creating a new article are both equivalent to assigning a term paper, in terms of the effort required by students to complete the assignment. Wikipedia assignments can therefore be adapted to meet the learning objectives of a course and the needs of the instructor(s) and students.

Notably, Wikipedia assignments combine the skill-building of a writing assignment with the societal impact of a science communication or outreach assignment. For the courses taught by instructors in our faculty mentoring network, students added an average of 670 words to a Wikipedia article, with a maximum course average of 1,590 words added per student (**Figure 3**). Students added an average of seven references to the articles they edited, with a maximum of 20 references added (**Figure 3**). While it is tempting to compare these values to similar word or citation counts for a more standard written assignment, it is important to note that due to the concise nature of encyclopedic writing, quality of edits should be prioritized over quantity. While the number of words or citations might be comparable to a typical written assignment, Wikipedia assignments can have outsized effects on how student work is seen and valued. For example,

in the courses taught by instructors in our faculty mentoring network, the average article edited by students received nearly 8500 views in the 2 months following the course (roughly 140 views per day). Article views ranged from 67 to nearly 78,000 per student article, encompassing a far broader impact than a typical paper that is seen only by the instructor and perhaps fellow students in the course. Writing for an audience beyond the members of a course can provide an incentive for students to produce high-quality work.

In addition to these quantitative measures of Wikipedia assignment impact, instructors reported qualitative measures of student engagement and learning outcomes. For example, one instructor said that students "had more positive feedback on this assignment and were more motivated than on assignments where only the professor would have seen their final product." Another instructor reported that, based on a question asked in their course evaluations, students agreed that the Wikipedia assignment improved their ability to communicate scientific topics to the public. Instructors reported that students were attracted to the idea of the Wikipedia assignment having a broader impact, saying "it was surprisingly clear to them how valuable this effort was in a larger societal context. In particular, they really caught on to the idea that we have unique access to scientific information both in terms of the library and our understanding of it and that we have an obligation to share that understanding." Students also noted that while they may never author a scientific publication, they have now made a societal contribution by improving a Wikipedia article. In their course evaluation, a student concurred, saying "I think this project was an amazing opportunity to practice those research skills but gave us students way more of a reward than just a research paper to turn in. We actually created a whole Wikipedia page; I mean it still seems unreal!" Instructors also reported that the Wikipedia assignment fostered discussions about information equity, with one student sharing in their course evaluation, "The Wikipedia project gave me a better understanding of the work that goes behind sharing information with the public and how much time that takes. I had not really appreciated the position I was in as a student, having access to articles and information that the public does not have." Finally, the Wikipedia assignment led to nuanced discussions and understanding of what constitutes a reliable source, with one student sharing in their course evaluations: "I always thought that Wikipedia was this lawless website who let anyone join and edit pages but after all the modules I had to complete I quickly understood that Wikipedia was not as horrific as my teachers had described growing up." Overall, based on student and instructor feedback, Wikipedia assignments help students gain a more nuanced understanding about the responsibility of authorship and the reliability of sources, particularly Wikipedia.

LESSONS LEARNED FROM THE 2020-2021 FACULTY MENTORING NETWORK

The instructors who participated in our 2020-2021 faculty mentoring network reported a number of lessons learned that can

A Lumber River

The Lumber River, sometimes referred to as the Lumber River, is a 133-mile-long (214 km) river in south-central North Carolina in the Flat Coastal Plain. European settlers first called the river *Drowning Creek*, which is the name of its headwater. The waterway known as the Lumber River extends downstream from the Scotland County-Hoke County border to the North Carolina-South Carolina border. Soon after crossing into South Carolina, the Lumber River flows into the Little Pee Dee River, which flows into the Pee Dee River, or Great Pee Dee River. Finally, the combined waters flow into Winyah Bay and the Atlantic Ocean.

In 1989, the river was designated as a "Natural and Scenic River" by the North Carolina General Assembly. In addition, it is the only blackwater river in North Carolina to be designated as a National Wild and Scenic River by the Department of the Interior. In 2010, the Lumber River was voted one of North Carolina's Ten Natural Wonders. The result of an on-line contest held by *Lure* for Tomorrow, a coalition dedicated to supporting the preservation of North Carolina's land and water resources.^[1]

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- 2.1 Lumber River State Park
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History

Ancient indigenous peoples

Evidence from archeological excavations along the Lumber River has shown that successive cultures of indigenous Native Americans inhabited this area for thousands of years. A number of archeological sites have been excavated on high ground along the river. While many have been disturbed by the agricultural practices of the post-Columbian era, numerous artifacts and some fossils have been recovered. These include a diagonal canoe made by indigenous people and estimated to be over 1,025 years old. This ancient canoe is on display at the Native American Resource Center at the University of North Carolina at Pembroke.

Much of the archeological work in the Lumber River region has been done in Robeson County. A total of 429 archeological sites have been recorded in this area. The sites contain components from various archeological periods: Paleo-Indian, Archaic Woodland, Mississippian and Historic (after European encounter). Iroquoian, Siouan, and Carolina Algonquian speaking peoples were among the historic tribes who lived in the coastal and inland regions prior to European encounter. Archeologists have identified 47 sites of potential importance, 20 of which are eligible for inclusion in the National Register of Historic Places.

Eighteenth century

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Early English surveyors named the river "Drowning Creek." In 1749, British colonial records identified the river as a branch of the Little Pee Dee River. In 1809, the North Carolina state legislature changed the name of the river to Lumber, most likely to symbolize the thriving lumber industry in the area, and its use of the river for transporting logs. They wanted a name more positive than Drowning Creek.

Nineteenth century

In the late 18th and the 19th centuries, the lumbering and naval stores industries were critical to the region's economy. The Lumber River became a vital route for transporting 100-foot logs downriver to the sawpits of Georgetown, South Carolina. Lumber from South Carolina was important for the timber industry and associated production of turpentine. The visible remaining bridge abutments, train bridges, and stock pilings are reminders of the critical importance of lumbering and naval stores industries to the area as a whole.

Recreation

In the 21st century, the Lumber River is a highly prized recreation corridor in North Carolina. Active outdoor recreation and festivals are among the most popular activities, including canoeing, boating, fishing, hunting, picnicking, camping, nature study, swimming, biking, jogging, crafts, and fossil and artifact hunting.

Lumber River State Park

The Lumber and some of its adjoining banks are part of the Lumber River State Park, which comprises 9,874 acres of land and 115 miles of waterway. The park's recreational activities are currently at Princess Ann Access in the south and the Chalk Banks access to the north (near the town of Wagraw).^[2]

There are 24 boat launches along the Lumber River that serve as access points to Lumber River State Park. The entire length of the river is open to fishing. The common game fish are black crappie, largemouth bass, catfish and redbreast sunfish. All anglers must have a valid fishing license and follow the regulations of the North Carolina Wildlife Resources Commission. Nine primitive camping sites are located at the Princess Ann section of the park, between Drumm and Fair Bluff. These campsites are meant to be used by no more than six people at a time. Each site has a picnic table and grill, lantern holder, trash can, and fire ring. There are several hiking trails and picnic areas at Princess Ann as well as the many municipal and county parks that are located on the Lumber River.^[3]

Fourteen individual campsites are available at the Chalk Banks Access Area in Scotland County for family camping. Each site has a table, lantern holder, trash can and fire pit. Canoe in campsites are also available.

Local wildlife

The Lumber River has many different types of organisms in and around it, including the *Semiothisa lumbra*, which is a species endemic to the sandhills region that the Lumber River flows through.^[4] The *Semiothisa lumbra* is also known as the sandhills bug. The sandhills bug is not the only unique organism that lives around the Lumber River. Other organisms such as *Megalania proaca*, a giant water skipper and *Leucostictus borealis*, the red-collared wood pecker are

See also

- Lumber River State Park

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B Eklutna Glacier

Eklutna Glacier is a land terminating glacier in Chugach State Park and the Chugach Mountains near Anchorage, Alaska.^[1] Runoff from Eklutna Glacier contributes to Eklutna Lake, the main source of drinking water for the Anchorage community as well as hydroelectric power via the Eklutna Hydroelectric Project.^{[2][3]} However, Eklutna Glacier is shrinking in response to climate change which will inevitably affect downstream water resources.^[4] Eklutna Glacier is also known by the Dena'ina name: *Iidu Bena Li*.^[5]

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Geology

Eklutna Glacier is a 10 km long, 29 square km, valley glacier originating from the Pleistocene epoch. The glacier has two branches that converge about 2.7 km above the glacier terminus. The Main Branch is characterized by a large, low-sloping basin compared to the smaller and steeper West Branch. Glacier elevation ranges from 580 m above sea level at the terminus to a maximum of 2190 m, according to 2010 statistics.^[6] The steep valley walls surrounding each of the glacier contain peaks over 2500 m. Whiteout Glacier neighbors Eklutna Glacier at the southern edge of the main branch.^[7] Glacial melt heads the West Fork Eklutna River which flows north to Eklutna Lake, which was created by a natural damming at the northwest end of the glacially carved Eklutna River Valley by a recessional moraine.^{[2][8]}

Climate Change

Like many Alaskan glaciers, Eklutna Glacier is shrinking due to climate warming.^[9] Eklutna Glacier is located within the maritime Cook Inlet climate zone.^[10] Land terminating, lower elevation glaciers in maritime climates are losing mass at higher rates than continental glaciers.^[10] Field observations of Eklutna Glacier between 1979 and 2015 found a terminus retreat of 1.6 km.^[7] However, surface thinning accounts for most of the mass loss, with an average rate of -0.85 m per year of surface elevation change between 2010 and 2015 compared to -0.6 m per year from 1957 to 2010. Eklutna Glacier has an overall negative mass balance, meaning more melt is occurring than snow accumulation.^[4] As climate warming continues to cause ice melt, the glacier will continue decreasing in mass and eventually recede so much that it will no longer release meltwater. This will cause significant changes in streamflow for the downstream water resources of Eklutna Lake that depend on extra inflow from Eklutna Glacier.^[4]

History

Eklutna Glacier and neighboring Whiteout Glacier were used as a military training site between the 1950- and mid 1970s. Soldiers based out of Fort Richardson practiced skills for arctic warfare including tactical cross country skiing, rappelling into crevasses, and glacier travel safety. Training in Alaska's harsh winters served to prepare soldiers for any cold winter that might arise in Eurasian battle grounds.^[11]

Research

Observations of Eklutna Glacier terminus retreat have occurred since the early 1900s, and research of the glacier's dynamics have since become more robust.^[12] A USGS study in cooperation with the Municipality of Anchorage investigated glacial runoff and sediment contribution to the Eklutna Lake basin during the years 1985 to 1988. Glacial field work has been employed since the late 1990s by various agencies and research groups, focusing on accumulation and ablation measurements. This includes digging snow pits, setting stakes for ablation and accumulation measurements, climatological station deployment, and laser altimetry.^[13]

Recreation

The Eklutna Traverse is a popular mountaineering and glacier navigating route that connects Eklutna Glacier, Whiteout Glacier, and Eagle Glacier. The retreat and thinning of Eklutna Glacier has made the once easy walk up the glacier terminus much more hazardous. Glacier skills and experience are advised for this technical traverse. The Mountaineering Club of Alaska maintains three historic huts along the Eklutna Traverse that can be used by travelers, including Pichler's Perch, built in 1964, on the northeast side of Eklutna Glacier near the terminus.^[11]

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FIGURE 2 | Examples of student edits to Wikipedia in two of the courses taught by members of the Wikipedia Limnology & Oceanography faculty mentoring network that highlight the range of possible student edits and Wikipedia assignment complexity. Shaded text highlights student additions to each article, with different color shading indicating different student editors. The article on the Lumber River (A) was edited by two students, who jointly added 217 words and 2 references to the article, while the article on the Eklutna Glacier (B) was edited by one student, who added 2183 words and 19 references to the article.

be applied in future Wikipedia assignments to improve instructor and student experiences, not only in post-secondary courses in the aquatic sciences but in STEM courses more broadly. Herein we outline some of those key lessons that were shared by course instructors who participated in the faculty mentoring network, from both their and their students' perspectives.

Several instructors noted that, for both instructors and students with no prior experience editing Wikipedia, the assignment involved a steep learning curve. Within the first few weeks of the assignment, students were required to set up a Wikipedia account, complete a number of training modules through the WikiEdu dashboard, and begin the process of selecting an article or topic to work on. As a result, some instructors and students reported that the assignment felt

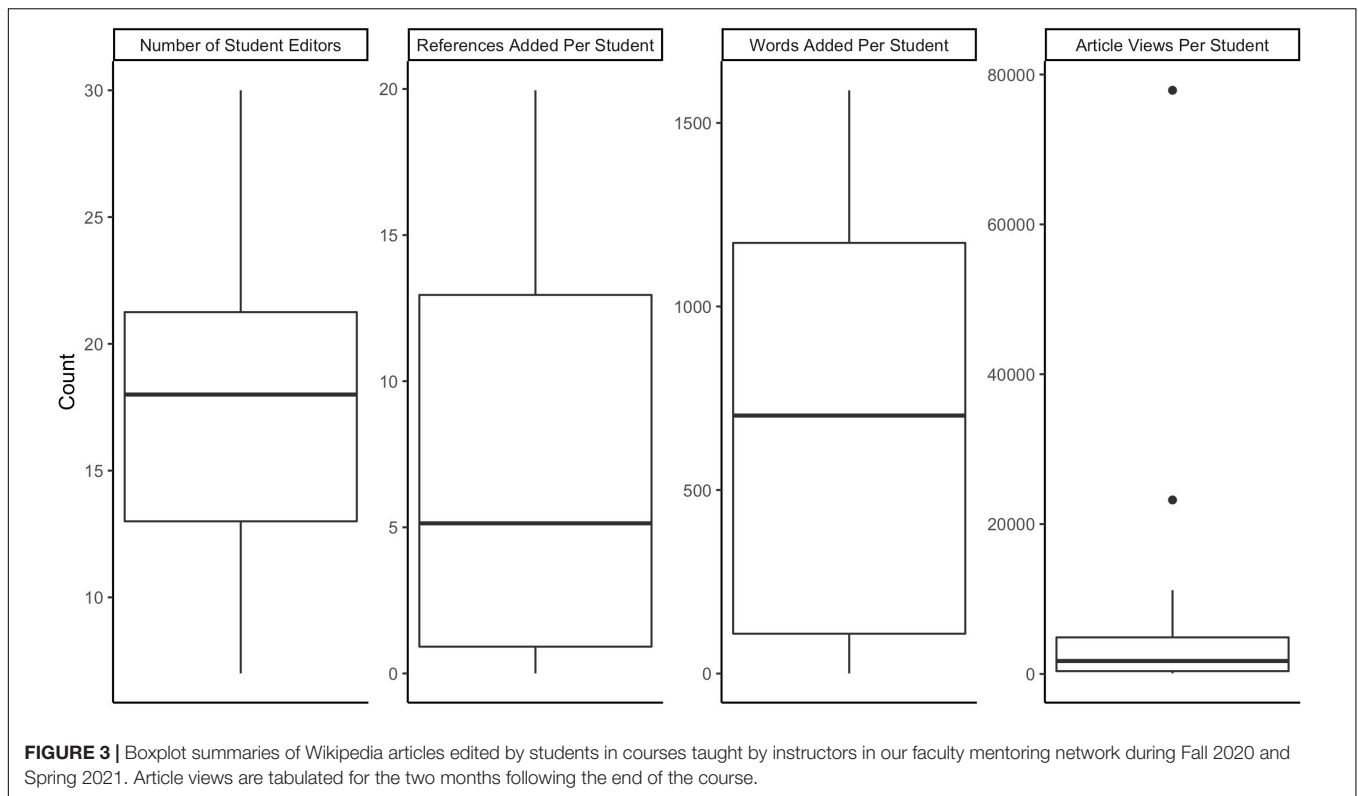
intimidating at first, and noted that it was easy for students who felt this way to fall behind in the WikiEdu training modules, causing further feelings of intimidation. Instructors emphasized that extra effort was required in the first few weeks of the assignment to ensure that students completed the training modules, and that assigning marks to the completion of training modules was a good incentive. Those instructors who had previously used Wikipedia and the WikiEdu dashboard in their courses also recognized that their confidence in teaching with Wikipedia increased in subsequent semesters, making it easier to run the assignment and manage student progress.

Students in the 15 courses that were supported by the faculty mentoring network created 22 new Wikipedia articles and edited 173 existing articles, with each student adding an average of

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nearly 700 words (**Figure 3**). This represents a large amount of work that must be reviewed by the course instructor, with students in each class sometimes working on a wide range of articles and topics. Since the end goal for the assignment is often for the student's work to be publicly posted on Wikipedia, there is a large burden on the instructor to catch any errors and provide informed, high-quality feedback on a diverse set of articles. One way to offset this workload is to pair students with expert reviewers (graduate students, technicians, faculty members, or research scientists) who can provide feedback on articles in their area of expertise, although sufficient time must be allocated in the assignment schedule for the feedback to be incorporated into the article.

The instructors who participated in our faculty mentoring network all noted that a supportive community was critical to the success of their Wikipedia assignments. Instructors were able to find community support during the 2020–2021 academic year through their participation in the WikiEdu platform, our faculty mentoring network, and an expert review process that was facilitated by the WikiProject Limnology & Oceanography team. Participation in the WikiEdu platform included access to a WikiEdu staff member who could provide technical support for the Wikipedia website and training modules, while participation in the faculty mentoring network included access to resources (e.g., those included as **Supplementary Material**) and a team of colleagues who could provide support for subject-specific and classroom-specific questions. The expert review process facilitated a review of student Wikipedia articles by STEM practitioners and provided access to a broader community

for both instructors and students. While instructors received help with reviewing and providing feedback on their students' Wikipedia articles, which could span a wide range of topics, students received feedback from someone with expertise in their particular article topic which increased their confidence in the final version of their work. Participating in and interacting with a supportive community therefore improved the overall experience of both the instructors who implemented Wikipedia assignments in their courses and their students, based on feedback we received from instructors.

Instructors also realized that it was important to create a schedule for the Wikipedia assignment that allowed enough time for the students to complete all components. Many instructors noted that Wikipedia assignments worked better as a semester-long exercise, which allowed enough time for students to complete the training modules, written assignment, and peer review, along with other course work and deliverables such as exams and lab assignments. One key issue is that, if Wikipedia assignments run the length of the semester, other course work can be crowded out of the schedule. Instructors recommended that, in order to prevent this and to give students the best chance at success at both the Wikipedia assignment and the course overall, good planning and scheduling is critical.

Generally, students viewed Wikipedia editing and article writing assignments more positively than other aspects of their courses. Students seemed to be motivated by the fact that their work would be publicly-available beyond the end of the course, and viewed this as a positive aspect of the assignment relative to a traditional course assignment that would only be

viewed by the instructor. Students also seemed to appreciate the opportunity to research and write about scientific topics that were important to them on a personal level. This was demonstrated in several courses where students were tasked with writing about regional waterbodies that did not have a Wikipedia entry, or that had an inadequate or incomplete entry. In some cases, students communicated with citizen groups that were associated with these waterbodies, or reached out to individuals with longstanding ties to the region, leading to discoveries and the sharing of informal but nevertheless valuable information. Although this information did not necessarily meet the standards for inclusion in a Wikipedia article, students found these interactions to be interesting and rewarding, and the interaction itself provided an alternate way for students to engage with the subject matter. The impacts of a Wikipedia assignment can therefore go beyond the assignment and generate a broader interest in science communication and public engagement for the student.

Instructors reported that their students gained a deeper appreciation of diversity and equity in science through their Wikipedia assignments. Students were given the opportunity, many for the first time, to think critically about whose voices are heard and shared when communicating science. It was noted by several students that Indigenous voices and experiences were excluded from articles about North American waterbodies, while other students endeavored to add the Indigenous names for local waterbodies to the corresponding Wikipedia pages. Students democratized access to science information by prioritizing open access resources rather than resources located behind a paywall, enabling more members of the public to access primary sources of information. Students also served as translators and interpreters of scientific information for the public. In most cases, this involved taking complex scientific concepts and applying their specialized skills and knowledge to communicate these concepts in plain-language. In two separate classes, students served as actual translators as they translated information about waterbodies in China into English, thereby making the information accessible to a broader audience. While this examination of diversity and equity in science communications was a generally positive aspect of the Wikipedia assignments, at least one student avoided adding content to Wikipedia that would have amplified the experiences of an under-represented group due to the potential removal or negative review of their work by other Wikipedians. It is important to note that editors who attempt to reduce bias and increase representation in Wikipedia articles can sometimes receive negative or hostile feedback from other Wikipedians (Menking et al., 2019; Kincaid et al., 2020). **Table 2** provides resources to mitigate negative interactions between student editors and Wikipedians.

Overall, many students reported to their instructors that their opinion of Wikipedia changed over the course of the semester. After completing the WikiEdu training modules, critically reading Wikipedia articles, assessing shortfalls, conducting research and gathering resources, and then crafting their own text or other content, students reported both more favorable and more skeptical views of Wikipedia as an information resource.

Many students were surprised to learn that the community of Wikipedians adheres to a code of conduct and other guidelines when editing or adding to articles, and that posted information is constantly checked and corrected by the community. Other students were more critical of what they found on Wikipedia following the assignment, since they themselves had been able to login and edit articles. Overall, student-reported outcomes at the end of the semester suggest that students had developed a more nuanced opinion of Wikipedia, and were more aware of both its utility as a resource and the need to investigate primary sources for credibility and accuracy.

STUDY LIMITATIONS

In spite of the overall success of this initiative, two methodological constraints of this study of our faculty mentoring network must be considered: (1) the complex effects of COVID-19 on university courses and (2) the inherent limitations of a case study approach.

First, the 2020–2021 faculty mentoring network took place during the first full academic year of the COVID-19 pandemic. After having to pivot to online teaching on very short notice during March 2020, many of the instructors who took part in our faculty mentoring network were delivering their courses entirely online for the first time during the 2020–2021 academic year. At the same time, those instructors who taught in person during the 2020–2021 academic year, or who delivered a hybrid course with elements of both online and in-person instruction, were searching for assignments and learning activities that could be easily moved online if local circumstances surrounding the pandemic changed. Like many STEM instructors, those who participated in our faculty mentoring network were also searching for activities that could meaningfully replace labs, field trips, and other in-person activities that were no longer possible for health and safety reasons. Because of these extenuating circumstances, instructors were perhaps more willing to modify their course syllabi and try an entirely new teaching activity (and one with a fairly challenging learning curve) than during a “normal” academic year.

Second, this was not a formal research study, but rather a case study approach wherein instructor experiences were queried both while they were using Wikipedia in their courses and after their courses had ended. Instructors in both semesters shared their experiences during network team meetings, asked questions or looked for team feedback via email and a Slack channel, and accessed a set of resources that were curated by the WikiProject Limnology and Oceanography team. After each semester had ended, all instructors were asked to complete an exit survey and to share course materials (e.g., syllabi, rubrics, and assignment descriptions) that they had used in their courses. Therefore, the experiences of the 14 instructors who used Wikipedia assignments in their post-secondary aquatic science courses are fairly well-captured in this paper. On the other hand, student experiences are not adequately represented because we did not have *a priori* ethics approval in place to survey

students or request their feedback. Although some instructors have passed along anonymous comments provided by their students during course evaluations, this has been anecdotal and informal. The reliance on instructor-reported student outcomes can be addressed during any future studies by obtaining ethics approval in advance in order to measure student success and satisfaction with Wikipedia assignments.

CONCLUSION

Overall, our 2020–2021 faculty mentoring network was a success, with all instructors reporting positive experiences during their participation in the network and using Wikipedia assignments in their aquatic science courses. Many of the instructors who participated have continued to use Wikipedia editing or article writing assignments in subsequent courses, having found the assignment to be an effective way for their students to achieve meaningful learning outcomes. We encourage instructors to consider implementing a Wikipedia assignment in their post-secondary STEM courses to support the development of critical thinking, ethical literacy, science communication, and scientific writing skills.

DATA AVAILABILITY STATEMENT

The original contributions presented in this study are included in the article/**Supplementary Material**, further inquiries can be directed to the corresponding authors.

AUTHOR CONTRIBUTIONS

EL and JG co-led the drafting and editing of the manuscript and are joint first authors. All other authors contributed ideas and substantial revisions to manuscript drafts. MA, JAB, JEB, VC, JG, EL, TL, CL, EN, AR, AS, and MV participated in the faculty mentoring network, and KB and EG participated as course instructors, with all providing reflections on instructor challenges and successes with Wikipedia assignments. JB, KH, DK, EL, and AS helped found WikiProject Limnology & Oceanography and helped support the faculty mentoring network activities.

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SUPPLEMENTARY MATERIAL

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