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Implementation of an Online Poster Symposium for a Large-Enrollment, Natural Science, General Education, Asynchronous Course

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Asynchronous online courses are popular because they offer benefits to both students and instructors. Students benefit from the convenience, flexibility, affordability, freedom of geography, and access to information. Instructors and institutions benefit by having a broad geographical reach, scalability, and cost-savings of no physical classroom. A challenge with asynchronous online courses is providing students with engaging, collaborative and interactive experiences. Here, we describe how an online poster symposium can be used as a unique educational experience and assessment tool in a large-enrollment (e.g., 500 students), asynchronous, natural science, general education (GE) course. The course, Introduction to Environmental Science (ENR2100), was delivered using distance education (DE) technology over a 15-week semester. In ENR2100 students learn a variety of topics including freshwater resources, surface water, aquifers, groundwater hydrology, ecohydrology, coastal and ocean circulation, drinking water, water purification, wastewater treatment, irrigation, urban and agricultural runoff, sediment and contaminant transport, water cycle, water policy, water pollution, and water quality. Here we present a is a long-term study that takes place from 2017 to 2022 (before and after COVID-19) and involved 5,625 students over 8 semesters. Scaffolding was used to break up the poster project into smaller, more manageable assignments, which students completed throughout the semester. Instructions, examples, how-to videos, book chapters and rubrics were used to accommodate Students' different levels of knowledge. Poster assignments were designed to teach students how to find and critically evaluate sources of information, recognize the changing nature of scientific knowledge, methods, models and tools, understand the application of scientific data and technological developments, and evaluate the social and ethical implications of natural science discoveries. At the end of the semester students participated in an asynchronous online poster symposium. Each student delivered a 5-min poster presentation using an online learning management system and completed peer reviews of their classmates' posters using a rubric. This poster project met the learning objectives of our natural science, general education course and taught students important written, visual and verbal communication skills. Students were surveyed to determine, which parts of the course were most effective

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for instruction and learning. Students ranked poster assignments first, followed closely by lectures videos. Approximately 87% of students were confident that they could produce a scientific poster in the future and 80% of students recommended virtual poster symposiums for online courses.

Keywords: online, general education, scientific posters, asynchronous, natural science, STEM—science technology engineering mathematics, large enrollment, virtual poster session

INTRODUCTION

General Education (GE) Natural Science Courses introduce students to different disciplines and topics within the natural sciences and provide an overview of fundamental concepts, methods of inquiry, principals, and theories. These courses are designed to engage students (majors and non-majors) in empirical and theoretical study, help students understand the relationship between fundamental and applied sciences, enable students to recognize the potential impacts of scientific and technological discoveries, and prepare students to be scientifically competent and engaged citizens. Expected learning outcomes for GE Natural Science Courses includes scientific literacy, finding and critically evaluating sources of information, recognizing the changing nature of scientific knowledge, methods, models and tools, understanding the application of scientific data and technological developments, and evaluating the social and ethical implications of natural science discoveries.

This paper describes how an online poster symposium can be used as a unique educational experience and assessment tool in a large-enrollment (e.g., 500 + students), distant education (DE), asynchronous, natural science, GE course. The title of the GE course is "Introduction to Environmental Science" (ENR2100) and it is a 3-credit Natural Science GE course. All undergraduate students at The Ohio State University (Ohio State) are required to take coursework in the Natural Sciences. ENR2100 covers a variety of topics in environmental science including hydrological processes. We spend 6 weeks (approximately 40% of the semester) focused on water science. The water science topics that we cover include surface water, aquifers, groundwater hydrology, ecohydrology, distribution and movement of water, the water cycle, the interaction of water with biological, ecological and geological systems, precipitation, streamflow, coastal and ocean circulation, soil erosion and sediment, agricultural runoff, irrigation, urban runoff, soil water, water purification, water pollution, water policy, and wastewater treatment.

As a GE course, ENR2100 is a prerequisite for many upper-level water science courses at Ohio State. As a prerequisite, ENR2100 challenges students to learn and develop skills that are important to a scientist (e.g., find, download and read journal articles, use reference management software, use Microsoft PowerPoint, write an abstract, create a figure and table, conduct peer review). Prerequisites also help students become more comfortable with the subject matter (e.g., water science) and helps build confidence so that students can be successful in their upper-level water science courses and labs. Many upper-level water science courses at Ohio State require students to give oral presentations and/or poster presentations. The posters assignments students complete in ENR2100 are intended to give them valuable experience so that can be successful in their future water science coursework.

Each year, we have approximately 200 undergraduate students who take ENR2100 in order to fulfill a course requirement for their B.S. degree in Biology, Chemistry, Earth Science, Ecology, Engineering, Environmental Science, Geography, or Public Health. Many of these students plan to go into careers in water science. In the School of Environment and Natural Resources (the home school of the authors), ENR2100 is a required course for students earning an Environmental Science, Water Science B.S. degree. Approximately 30% of our student poster presentations (150–250 posters per semester) are focused on water science. Our virtual poster symposium offers a unique opportunity for these students, who come from different colleges and departments, but have similar career goals to interact with one another and plant the seeds for future collaborations. Many of our past students have gone onto careers in engineering hydrology, hydroecology, hydrogeology, natural resource management, water treatment, or water policy. The class poster project is designed to broaden the skills, knowledge and understanding of the natural sciences for these students, as well as the other students who are enrolled in ENR2100.

Distance education (DE) is one of the fastest growing trends in higher education, particularly since 2020 with the impacts of COVID-19 on all colleges and universities (Barnett, 2014; Greenland and Moore, 2014; Ginder et al., 2018; De Brey et al., 2021; Stevens et al., 2021; U.S. Department of Education, 2021, National Center for Education Statistics Trend Generator). The U.S. Department of Education estimated that in, 2019 over 7.3-million students were enrolled in DE courses at degree-granting post-secondary institutions in the United States and this number is expected to grow in the future (National Center for Education Statistics, 2018; De Brey et al., 2021, IPEDS Data). In the United States, during the fall of 2020, approximately 73% of all students were enrolled in distant education courses in postsecondary institutions (U.S. Department of Education, 2021, National Center for Education Statistics Trend Generator; National Center for Education Statistics, 2018, IPEDS Data). DE can increase student access to college because it is more affordable than traditional education (e.g., no need to live on campus, no transportation costs), provides greater flexibility (e.g., lectures, assignments, exams can be completed from anywhere), allows courses to be self-paced (e.g., asynchronous courses), and accommodates Students' busy lives (e.g., family, work, extracurricular activities) (Akdemir and Koszalka, 2008; Means et al., 2009; Tucker and Morris, 2012; Barnett, 2014; Broadbent and Poon, 2015; Andrade and Alden-Rivers, 2019;

Müller and Mildenberger, 2021). These are the major reasons why DE has become so popular among students, faculty, and administrators at institutions of higher education.

Online courses can be asynchronous (self-paced participation) or synchronous (real-time participation) and while there are pros and cons for each style of instruction, this paper is focused on asynchronous online learning. Asynchronous DE courses can be particularly challenging for both the instructor and student. For instructors, it can be difficult to design and teach engaging course content that provides for active learning and meaningful student-student and student-instructor interactions in an asynchronous setting. For students, self-paced courses can be challenging if course content is not accessible, activities and assignments are poorly organized, and engagement is not properly structured to foster enriching educational experiences.

Expectations and experiences for teaching and learning in an asynchronous course are likely different because participation and engagement in a self-paced course will look different to what is traditionally observed in a synchronous course (Broadbent and Poon, 2015; Müller and Mildenberger, 2021; Stevens et al., 2021). Similarly, student and instructor expectations and experiences in DE vs. in-person courses are also different (Waschull, 2001; Akdemir and Koszalka, 2008; Means et al., 2009, 2013; Broadbent and Poon, 2015; Caliskan et al., 2017; Daniel and Kamioka, 2017; Stevens et al., 2021). Therefore, in an asynchronous DE course it is important for instructors to anticipate student needs, create accessible content, ensure that learners understand content and are able to apply what they learned, and design active learning experiences that are structured in a way to connect students across different time zones, countries, schedules, obligations (e.g., family, work), learning styles, and technologies (Means et al., 2009, 2013; Barnett, 2014; Daniel and Kamioka, 2017; Andrade and Alden-Rivers, 2019; Orr et al., 2020; Müller and Mildenberger, 2021; Stevens et al., 2021).

College general education (GE) curriculum is designed to explore a breadth of topics, teach essential skills, introduce fundamental ideas and concepts, and develop knowledge, perception and understanding. GE courses are particularly well suited for DE because GE courses are required by all students enrolled in traditional 4-year programs at accredited academic institutions. Typically, students of all majors are required to complete a core set of GE courses in arts, humanities, social sciences and natural sciences in order to graduate. The ability to take GE courses online offers students an affordable and flexible option to complete their coursework. Post-COVID, countless colleges and universities have transitioned GE courses to both asynchronous and synchronous DE options (U.S. Department of Education, 2021, National Center for Education Statistics Trend Generator).

Students enrolled in our asynchronously taught online ENR2100 courses consisted of approximately 18% freshman, 34% sophomores, 26% juniors, and 22% seniors (**Table 1**; total number students = 5,625). The approximate distribution of students from the various colleges at Ohio State were as follows: 29% from the College of Arts and Sciences, 42% College of Business, 2% College of Education and Human Ecology, 5% College of Engineering, 7% College of Food, Agriculture and Environmental Sciences, 8% Exploration and 7% Other. Approximately 78% of students (n = 5,625) took ENR2100 to fulfill a GE requirement and 22% took the course to fulfill a course for their major, minor or as a free elective.

TABLE 1 | Student enrollment by class rank in ENR2100, introduction to environmental science.

Semester ENR2100 taught	Number of students enrolled in ENR2100 by rank				
	Freshman	Sophomore	Junior	Senior	Total
Sp17	67	168	148	135	518
Sp18	53	172	135	174	534
Sp19	76	186	150	144	556
Sp20	85	216	244	196	741
Sp20	125	168	81	39	413
Au20	253	275	179	126	833
Sp21	138	232	160	134	664
Au21	146	220	173	123	662
Sp22	100	237	201	166	704
Total %	1,043 18%	1,874 34%	1,471 26%	1,237 22%	5,625 100%

All courses listed in table were taught as asynchronous, distant education courses. ENR2100 is a 3-credit natural science, general education course taught at The Ohio State University. Spring semester, Sp. Autumn semester, Au. Semesters are 15-weeks. Two-digit year provided (e.g., Sp17 means course was taught in 2017 during the Spring semester). Of these 5,625 students, approximately 78% took ENR2100 to fulfill Natural Science GE credits.

We used poster assignments to provide an online classroom environment and activities that were grounded in the constructivist theory of education, where learners construct new knowledge and understanding through experience and incorporating new information with their prior knowledge (Richardson, 2003). ENR2100 has 2 Goals and 6 Expected Learning Outcomes (ELOs) that are provided in **Table 2**. Poster assignments were designed to be linked to Goal 1 and ELO 1.3 (**Table 2**), as well as Goal 2 and ELO 2.2 and ELO 2.3. Scientific posters allow students to engage in higher order learning during their analysis, synthesis and evaluation of scientific research, they are able to demonstrate that they have achieved specific course learning outcomes, they create a scholarly and professional product, and they develop skills for effective written, oral and visual communication.

Here we demonstrate how academic units that confer degrees in hydrology (e.g., Earth Sciences, Environmental Science, Geological Sciences, Natural Resources) could utilize a student poster symposium in the DE courses that they teach. We show how student scientific posters can be used as a particularly effective writing assignment that includes an interactive online poster symposium and peer review. We also describe how online technology (e.g., learning management systems) permits an instructor to incorporate a scientific poster symposium in an asynchronous, large-enrollment, natural science course. The methods presented here can be easily adapted for synchronous DE courses as well as upper-level undergraduate and graduate DE courses and courses that are taught in-person.

TABLE 2 | Course goals and expected learning outcomes (ELOs) for introduction to environmental science (ENR2100).

GOAL 1. Successful students will engage in theoretical and empirical study within the natural sciences, gaining an appreciation of the modern principles, theories, methods, and modes of inquiry used generally across the natural sciences.		
	ELO 1.1	Successful students are able to explain basic facts, principles, theories and methods of modern natural sciences; describe and analyze the process of scientific inquiry.
	ELO 1.2	Successful students are able to identify how key events in the development of science contribute to the ongoing and changing nature of scientific knowledge and methods.
X	ELO 1.3	Successful students are able to employ the processes of science through exploration, discovery, and collaboration to interact directly with the natural world when feasible, using appropriate tools, models, and analysis of data.
GOAL 2: Successful students will discern the relationship between the theoretical and applied sciences, while appreciating the implications of scientific discoveries and the potential impacts of science and technology.		
	ELO 2.1	Successful students are able to analyze the inter-dependence and potential impacts of scientific and technological developments.
X	ELO 2.2	Successful students are able to evaluate social and ethical implications of natural scientific discoveries.
X	ELO 2.3	Successful students are able to critically evaluate and responsibly use information from the natural sciences.

Poster assignments linked to ELOs shown with X.

MATERIALS AND METHODS

General Education Natural Science Course and Students

The poster assignment was implemented in the course Introduction to Environmental Science (ENR2100), which is taught at The Ohio State University as (1) an entirely online, asynchronous course or (2) an in-person, synchronous course. The work presented in this paper is focused entirely on asynchronous online courses. ENR2100 is a 3-credit General Education Natural Science Course for undergraduate students. ENR2100 is designed to give students an introduction to environmental science, the ecological foundation of environmental systems, the ecological impacts of environmental degradation by humans, and strategies for sustainable management of environment and natural resources.

The course was taught using the Canvas Learning Management System (Canvas LMS)[1]. There were no required sessions when students had to be logged into Canvas at a scheduled time. ENR2100 was taught over a 15-week semester (autumn or spring) and divided into 15 weekly modules. Student questions were answered by email, Canvas discussion boards, or during office hours that were conducted online using Zoom[2].

Students were expected to keep pace with weekly deadlines (e.g., Fridays at 11:59 p.m.) but were permitted to schedule their efforts freely within the 7-day time frame. Students were instructed and expected to spend 3 h per week on direct instruction (i.e., watching lecture videos and taking notes) and an additional 6 h per week working on out-of-class work (e.g., studying, readings, poster assignments). Of these 6 h, students were instructed to spend approximately 3 h per week working on their poster assignments. Students were able to submit assignments online from anywhere and thus enrollment in ENR2100 consisted of both domestic and international students. A total of 9 asynchronous online ENR2100 courses have been taught at Ohio State over the past 6 years to 5,625 students. Class sizes each semester ranged from approximately 400 to 825 students, with an average class size of 625 students.

Poster Assignment Timeline and Asynchronous Online Poster Event

The first asynchronous online poster symposium took place in 2017 and since then we have hosted a total of nine online poster events during the autumn and spring semesters at Ohio State. Multiple asynchronous online poster events were also successfully held during the COVID-19 pandemic. Each online poster symposium was scheduled and organized within Canvas LMS and open for about 1-week to allow for student participation from all over the globe. Each poster symposium consisted of between 400 and 825 individual posters, with the average poster event consisting of 625 individual poster presentations. Students also completed poster peer reviews during the online poster symposium, with each student completing 2 reviews, for a total of 800–1,650 individual poster peer reviews per symposium.

A Student's overall poster project was scaffolded into 6 smaller assignments, which students completed throughout the semester. Detailed instructions, How-To videos and examples were also provided for each assignment (**Table 3** and **Supplementary Material**). Starting in 2019 a free open textbook "Scientific Posters: A Learner's Guide" was used to help students complete their poster assignments (**Table 3**)[3]. The six poster assignments were worth 25% of a Student's overall course grade. Early assignments were worth fewer points (e.g., Poster Assignment 1 was worth 10 points) compared to assignments that students completed later in the semester (e.g., Poster Assignment 5 was worth 40 points). A detailed grading rubric was provided to students for each poster assignment (**Supplementary Figures 1–3**).

Students were surveyed in order to evaluate the quality of instruction and learning with regards to scientific posters, to determine if poster assignments were meeting learning objectives, to understand if a virtual poster symposium was a rewarding educational experience for students, and to gauge student comfort with and preference for using technology in our course (**Figure 1**). Survey data for ENR2100 was collected over 8 semesters for 9 course sections of ENR2100. A total of 3,167 students from six distinct asynchronous, online ENR2100 courses participated in the survey. All student responses were

[1]https://carmen.osu.edu

[2]https://osu.zoom.us/

[3]https://ohiostate.pressbooks.pub/scientificposterguide/

TABLE 3 | Free resources (i.e., books, how-to videos, downloadable files) for instructors and students.

Free educational resource	Type	Link
Environmental ScienceBites, Volume 1	Open book	https://ohiostate.pressbooks.pub/sciencebites/
Environmental ScienceBites Volume 2	Open book	https://ohiostate.pressbooks.pub/sciencebitesvolume2/
Scientific posters: A learner's guide	Open book	https://ohiostate.pressbooks.pub/scientificposterguide/
Using web of science to find journal articles	Video	https://youtu.be/s8Poqum6s8M
Tips for reading a journal article	Video	https://youtu.be/Bn023GXHwug
Creating an original figure for a poster	Video	https://youtu.be/EqEVHN67s4A
Giving a poster presentation	Video	https://youtu.be/zlt7PwEyjMA
Virtual poster symposium in canvas	Video	https://youtu.be/49GDNepo4uI
PowerPoint poster templates	Files	https://u.osu.edu/introenvironmentalscience/course-assignments/environmental-science-project/scientific-poster/

These resources are intended to help instructors organize and host a virtual poster symposium and manage online poster peer reviews. Resources are also provided for students so that they understand how to produce an organized, high-quality poster and give a professional and informative presentation. All resources are completely free.

anonymous. Enrollment in each of the six courses ranged from 400 to 725 students. Students completed the survey at the end of the semester (i.e., Week 15), after they had completed their poster assignments and participated in the online poster symposium. Surveys were conducted within Canvas during the following semesters: Spring 2017, 2018, 2019, 2020, 2021 and Autumn 2020 and 2021 (**Table 1**).

RESULTS

Poster Assignments and Virtual Poster Symposium

All students at Ohio State are given free access to Microsoft Office products (i.e., PowerPoint, Excel), therefore, students used this software to create their scientific posters. At the beginning of the semester, Microsoft PowerPoint poster templates (36-inches × 48-inches) were provided to all students on Canvas. Students were instructed to download and use one of the poster templates to create their poster (**Table 3**). Poster templates were already formatted (e.g., proper font type, font size, color, organization) and contained detailed instructions about designing a high-quality scientific poster (e.g., how to properly insert a figure or table, scaling, resolution, cropping, moving objects). Each student enrolled in ENR2100 was required to create their own poster (e.g., if 500 students were enrolled in ENR2100, then we had 500 individual poster presentations).

Students worked on their poster presentations throughout the semester and received regular feedback from the instructor and teaching assistants (**Figure 2**). The online poster symposium itself was held at the end of the semester over a period of 6 days during week 14 (a semester is 15 weeks long). During the first 3 weeks of the semester, students were introduced to scientific posters, learned about primary and secondary sources, learned how to utilize library resources to find and download journal articles, newspaper articles, documentaries and books, shown examples of scientific posters and asked to select a topic that is related to environmental science (**Figure 2**). Students were given the ability to choose their poster topic. To ensure that posters were focused, students were instructed to concentrate their poster on one species, one environmental issue, and one location. Students were instructed that in terms of location, the area should be limited to a maximum size of about 100 km × 100 km. Students selected a wide range of environmental topics for their posters. Poster themes included, but were not limited to air pollution, biodiversity, climate change, ecology, food production, mining natural resources, natural resource management, renewable energy, urban design, water pollution, water resources, waste management, wildlife management.

During Week 3 of the semester, students completed Poster Assignment 1, which was a 10-point quiz designed to examine their understanding of scientific posters and scientific communication, their ability to find, download and read journal articles, and their proficiency to critically evaluate and use primary and secondary sources of information (**Figure 2**). The quiz was open-book and students were permitted to use online resources and our class' free open textbook "Scientific Posters: A Learner's Guide" (**Table 3**, see text footnote 3). Students were given multiple attempts and the highest score between attempts was kept. Quizzes were graded and students were provided with written feedback to ensure that they understood fundamental concepts and skills required to write and present an impactful scientific poster.

In Week 5, students completed Poster Assignment 2, which was worth 10-points (**Figure 2**). For this assignment, they were asked to pick their poster topic (i.e., one species, one environmental issue, one location), write a poster abstract and provided 10 references that they would use in their poster. Students are given examples and suggestions but are free to pick their poster topic as long as the research is related to the field of environmental science. Seven references were required to be primary source journal articles, the other 3 could be journal articles or secondary sources. This assignment was open-book and completed on Canvas as an untimed quiz. Poster Assignment 2 was graded using a rubric, and individual feedback was provided to each student regarding their poster topic, 10 references and abstract.

In Week 8, students completed Poster Assignment 3, which was worth 15-points (**Figure 2**). For this assignment, students were required to complete two sections of their scientific poster (e.g., Introduction and Materials and Methods) Students used one of the poster templates (**Table 3**) that were provided on Canvas to complete Poster Assignment 3. The poster templates contained detailed instructions (e.g., writing text, creating figures

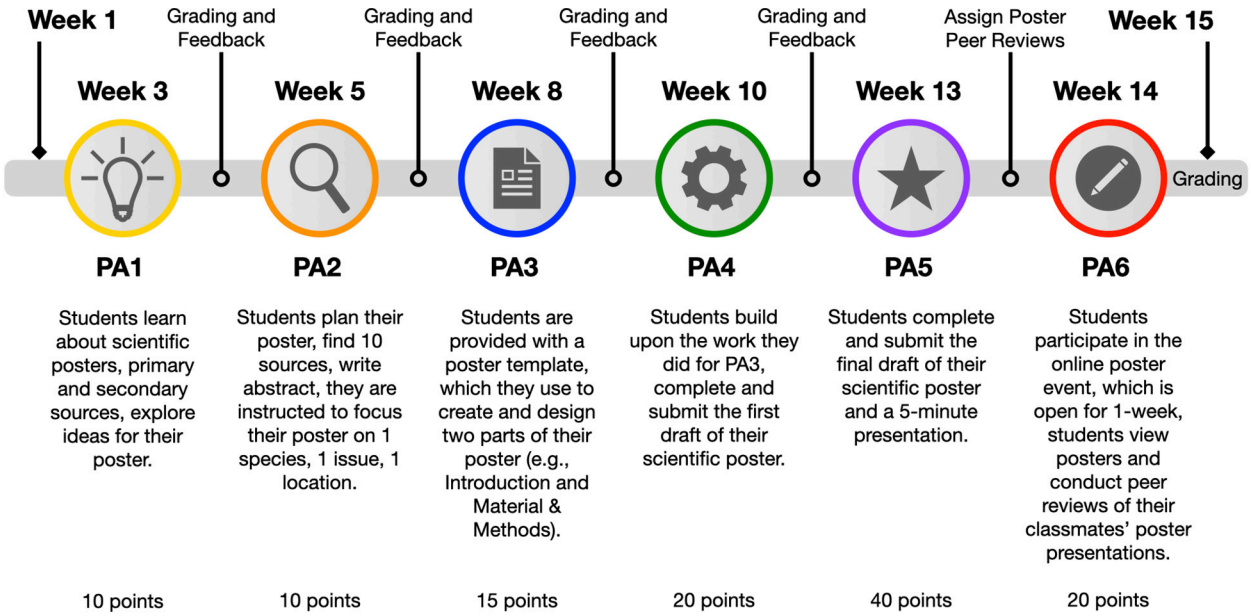

FIGURE 1 | Students were surveyed about their experience with poster assignments and asynchronous online poster event. Students responded to each question by selecting 1 of 5 responses: strongly agree (blue), agree (green), neutral (yellow), disagree (orange), strongly disagree (red). A total of 3,167 students from six different asynchronous, online courses participated in surveys. Class sizes ranged from approximately 400 students to 725 students. Students completed surveys at the end of the semester (i.e., Week 15) after they had completed all poster assignments. Surveys data collected during the following semesters: Spring 2018, 2019, 2020, 2021 and Autumn 2020 and 2021. All student responses were anonymous.

and tables) and were already formatted (e.g., organization, font style, font size, color) to help students produce an organized and professional poster. Students submitted their poster as a PowerPoint file (or PDF file) on Canvas. All student poster files uploaded to Canvas were automatically screened for original content by Turnitin software[4]. Students were encouraged and permitted to utilize Turnitin software prior to each poster assignment submission to ensure that their work was original. Posters were graded by the instructor and teaching assistants using a grading rubric (**Supplementary Material**) and feedback was provided to each student *via* Canvas.

Students continued to work on their posters through week 10 of the semester using the feedback they received from the instructor and teaching assistants on Canvas. At the end of Week 10, students submitted one PDF file, which was the first draft of their poster. Their first draft contained Title, Name, University Address, Abstract, Introduction, Materials and Methods, Results, Discussion, 10 References, 4–6 Figures and/or Tables, and Figure Captions. Students uploaded their poster file to Canvas, and it was automatically screened for original content by Turnitin software (see text footnote 4). Posters were graded by the instructor and teaching assistants using a grading rubric (**Supplementary Material**) and addition feedback was provided to each student using Canvas.

Students continued to work on their posters through week 13 of the semester using the feedback they received from the instructor and teaching assistants on Canvas. At the end of week 13, each student was required to upload their final poster (PDF file) and presentation (5-min audio or video recording) to Canvas within a discussion board (**Figure 2**). Canvas automatically screened for original content using Turnitin software (see text footnote 4) and randomly generated and assigned poster peer reviews for each student. Each student was randomly assigned two posters for peer review. Students were able to see the posters they were assigned to review on Canvas in their "To-Do List" and complete the reviews through Canvas discussion board using a rubric and guided instructions.

Our asynchronous, online poster symposium started on Sunday at 12:00 a.m. of Week 14 and was open to all students for a total of 6 days (**Figure 2**). Students were permitted to login to Canvas at any time and as many times they liked during Week 14 to view the posters and poster presentations posted to the discussion board and complete their assigned peer reviews. Students completed their peer reviews through Canvas and were provided with instructions and a rubric, which they used to complete their peer reviews (**Supplementary Material**). In total, each online poster symposium consisted of approximately 400–825 poster presentations and 800–1,650 peer reviews. Poster grades and peer reviews were provided to each student using Canvas during week 15, which was the final week of the semester.

Student Learning Experience

Students were asked three questions about their experience completing their poster assignments as part of an asynchronous, online course. Student responses to these questions are shown in **Figure 1**. When students were asked if they were provided

[4]https://turnitin.com

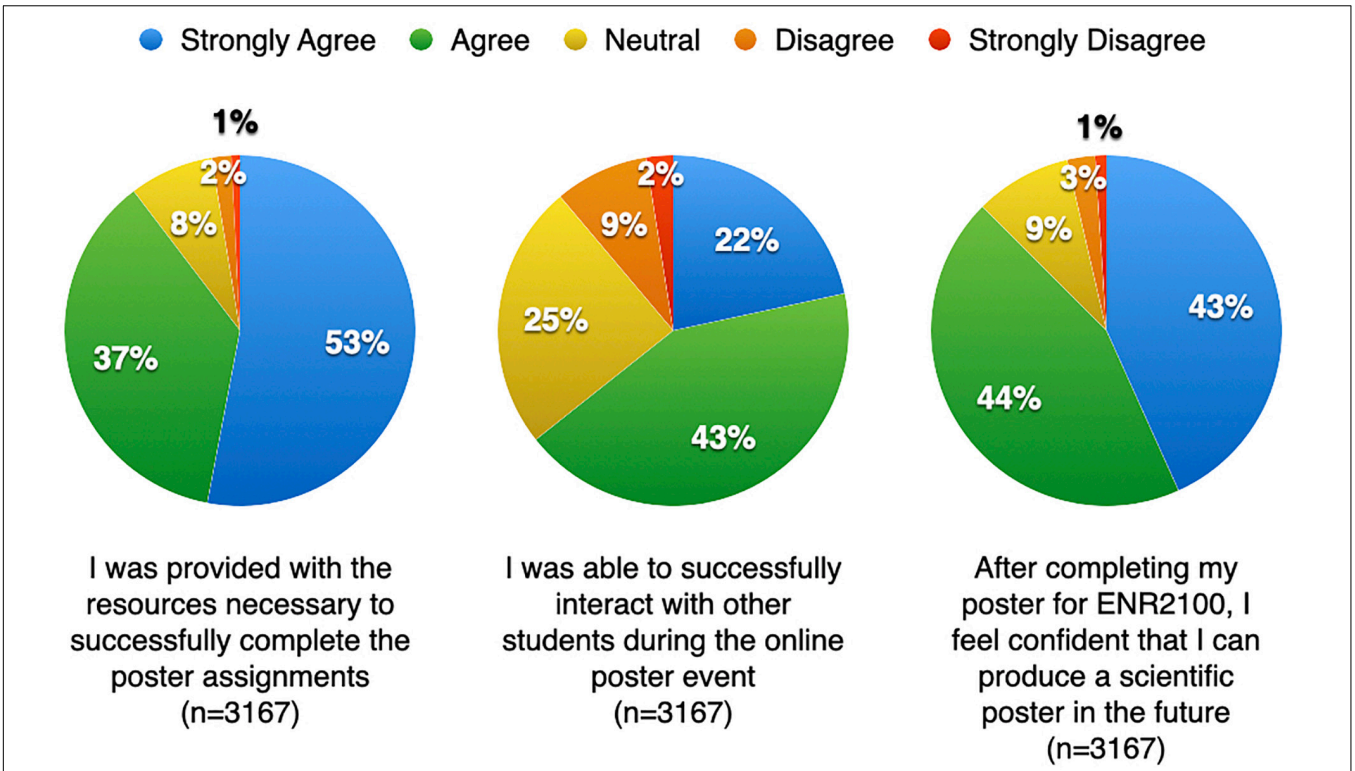

FIGURE 2 | Timeline of poster assignments. Students completed a total of 6 poster assignments during a 15-week semester. PA1 and PA2 were a short-answer quizzes. Students submitted a poster PDF file for PA3 and PA4. Students submitted a poster PDF file and 5-min audio (or video) presentation for PA5. For PA6, each students completed 2 poster peer reviews during the online poster symposium. The online poster symposium was open for 6 days during Week 14 of the semester. All poster assignments were open book. Students were given 7–21 days to complete each poster assignment. Students completed and submitted all poster assignments using Canvas Learning (https://carmen.osu.edu). Poster files submitted for PA3, PA4, and PA5 were uploaded to Canvas and automatically screened for original content by Turnitin software (https://turnitin.com). Each poster assignment was graded using a rubric and feedback was provided to each student through Canvas. The point value for each poster assignment is provided at the bottom. PA, Poster Assignment.

with the resources necessary to successfully complete their poster assignments, student responses were as follows: 90% (2,839 of 3,167) strongly agreed or agreed, 8% (246 of 3,167) neutral, and 2% (82 of 3,167) disagreed or strongly disagreed (**Figure 1**). When students were asked if they were able to successfully interact with other students during the Virtual Poster Symposium, student responses were as follows: 68% (2,154 of 3,167) strongly agreed or agreed, 22% (697 of 3,167) neutral, and 10% (316 of 3,167) disagreed or strongly disagreed (**Figure 1**). When students were asked if they were confident that they could produce a scientific poster in the future, student responses were as follows: 87% (2,755 of 3,167) strongly agreed or agreed, 9% (285 of 3,167) neutral, and 4% (127 of 3,167) disagreed or strongly disagreed (**Figure 1**).

At the end of the semester, students were also surveyed within Canvas to determine which parts of the course were most effective for instruction and learning. Students were asked to rank five modes of content for our course based on which they learned the most: Poster Assignments, Lecture Videos, Lecture Slides, Quiz Materials, Additional Resources (**Figure 3**). A total of 1,788 students from three distinct asynchronous, online courses participated in the rankings during the Autumn 2020, Spring 2021, and Autumn 2021 semesters. Enrollment ranged from 500 to 700 students. Rankings were completed at the end of the semester (i.e., Week 15) by students after they had completed all lectures, quizzes and poster assignments. All student responses were anonymous.

Figure 3 shows that Poster Assignments were most frequently ranked #1 (595 first-place votes) by 1,788 students when asked to identify the part of the course where they learned the most. The number of 1st-place votes (**Figure 3**) were as follows: Poster Assignments (595 votes), Lecture Videos (507 votes), Lecture Slides (332 votes), Quiz Materials (320 votes), and Additional Resources (88 votes). The number of 2nd-place votes (**Figure 3**) were as follows: Lecture Slides (496 votes), Lecture Videos (475 votes), Quiz Materials (481 votes), Poster Assignments (253 votes), and Additional Resources (108 votes).

Students (n = 1,788) from these same three asynchronous, online courses were asked the following three questions at the end of the semester as part of an anonymous online survey:

1. Would you encourage other online courses to consider similar scientific poster assignments and virtual poster symposium?
2. Did presenting your poster in an audio or video clip add to your understanding of your poster topic?

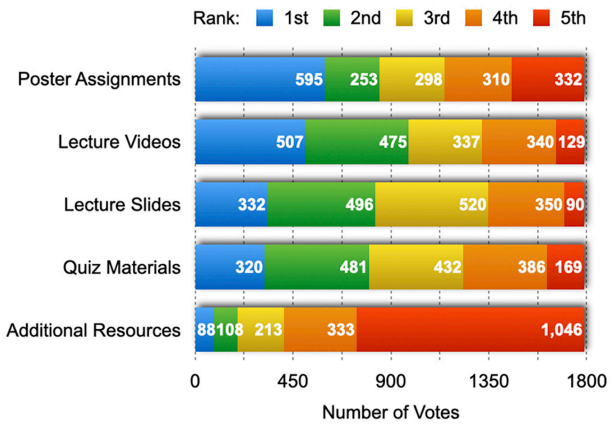

FIGURE 3 | Students ranked five course components (Poster Assignments, Lecture Videos, Lecture Slides, Quiz Materials, Additional Resources) based on which component they learned the most (1st) to least (5th). Total number of votes that each component received is shown as blue (1st-place), green (2nd-place), yellow (3rd place), orange (4th-place), red (5th-place). A total of 1,788 students from three different asynchronous, online courses participated. Students completed rankings at the end (i.e., Week 15) of the Autumn 2020, Spring 2021, and Autumn 2021 semesters after they had completed all lectures, quizzes and poster assignments. All student responses were anonymous.

3. Do you have any comments, ideas or suggestions about the Poster Assignments or the Virtual Poster Symposium?

Approximately 80% of students answered "Yes" to question 1 and 90% answered "Yes" to question 2. The Top 5 Comments to question 3 are provided in **Table 3**.

DISCUSSION

Goals and Learning Outcomes

Poster presentations are an especially effective assignment for teaching science literacy and information literacy in a Natural Science GE course for several reasons. First, presenting a poster to a mixed audience of student peers, teaching assistants, and instructors encourages students to prepare for and effectively communicate with a real audience (Sisak, 1997; Hobson, 2008; Brownell et al., 2013; Feliú-Mójer, 2015; Pedwell et al., 2017). In order to produce a high-quality poster and give an impactful presentation, students must learn how to find, read, evaluate and effectively use information. Faced with the prospect of presenting their work to dozens of their peers, students will confront questions by an audience as integral to the assignment more so than is possible when the only audience is an instructor who grades their work (Huxham et al., 2012; Menke, 2014; Rouser, 2017). Science and information literacy empowers students to become engaged citizens in local, national and global communities, which is a major learning objective for Natural Science GE courses.

Second, the genre of the scientific poster is both more easily comprehensible and imitable by early students than other types of professional scientific outlets (e.g., peer-reviewed journals, professional meetings). The fully fledged research paper or lab report are particular forms of communication, which require detailed instruction and guidance. A meaningful research paper may likewise require more substantial work and time than students are able to commit in a general education course (Huxham et al., 2012). Research papers and lab reports are typically reserved for upper-level courses and labs taken by students (e.g., majors and minors) who have the educational background and training for this level of difficulty. Posters, by contrast, make intuitive sense as a method for abstracting crucial information about a topic, and even introductory posters can function as useful educational tools (Menke, 2014; Navarro et al., 2021). In our Natural Science GE courses, we have observed that all students (e.g., science major, non-science major, freshman, sophomores, junior, senior; **Table 1**) are able to produce organized and professional-looking posters and give polished and informative presentations. We did observe that students who did well on early poster assignments (e.g., Poster Assignments 1–3) and used TA feedback to improve subsequent poster assignments, were much more likely to produce a high-quality poster presentation at the end of the semester. We also noted that students who were more engaged in our online course (as judged by Canvas analytics, which permitted us to see the number of page views, number of downloads, number of discussion posts, number of emails) were more likely to do well on their poster assignments.

Third, research posters encourage multiform representation (e.g., tables, graphs, maps, photographs) and, as research shows, encountering ideas in multiple forms increases the likelihood that students will gain a conceptual understanding and learn to apply what they learn to understand and solve real-world problems (Miller, 2014; Rodríguez-Estrada and Davis, 2015; Rouser, 2017; Murchie and Diomede, 2020; Perra and Brinkman, 2021). Effective communication both requires and inculcates understanding of the science about which students communicate (Brownell et al., 2013; Feliú-Mójer, 2015). Stiller-Reeve et al. (2016), note that climate science and geoscience are increasingly interdisciplinary, and it is therefore important for scientists to write clearly and communicate effectively. They argue that the key to improving the writing and communication skills is to target early career scientists through peer learning (Stiller-Reeve et al., 2016). They show how an online writing program called ClimateSnack can be used to connect young scientists online who can then share manuscripts, receive peer feedback and improve their writing before its published (Stiller-Reeve et al., 2016). To be clear, it is not a choice between teaching students to understand the findings of science, on the one hand, and on the other hand, focusing on the skills of communicating those ideas, facts, theorems, experimental models, and so forth. Effective communication both requires and inculcates understanding of the science about which students are communicating to their audience.

Fourth, the poster presentation assignment makes it feasible to incorporate effective writing and communication instruction in a course with hundreds of students (Hobson, 2008; Navarro et al., 2021). Here we used our virtual poster symposium to serve

as interactive online space for students to communicate with their peers by taking part in collaborative learning and discussion (Knapp, 2018). Knapp (2018), found that virtual poster sessions mimic the interaction patterns of in-person conference poster sessions. Teaching scientific literacy and communication is crucial, both for those who plan to become scientists and for those pursuing other professions (Hobson, 2008; Feliú-Mójer, 2015). It promotes deeper learning and understanding of the methods and findings of scientific endeavors, while also promoting enjoyment and ongoing engagement within the practices of research. Perhaps most important, poster presentations train students to participate in conversations about scientific findings, as well as the implications of those findings in society, politics, healthcare and other areas of life. These are important learning objectives for Natural Science GE courses.

We would like to point out that our students created their posters based on research presented in published journal articles. Our students did not conduct the research themselves, mainly because it would be challenging for an undergraduate student to complete laboratory and/or field-based research as part of a 3-credit, 15-week, Natural Science GE course. Students did not have the training, time, funding, and resources to conduct such work. Rather, the main objectives for this poster project were to accomplish the goals and learning outcomes for a Natural Science GE Course: teach scientific literacy and scientific communication, promote a deeper learning and understanding of the methods and findings of natural science research, describe and analyze the process of scientific inquiry, engage in theoretical and empirical study within the natural sciences, and evaluate the social and ethical implications of natural science discoveries. For an online undergraduate honors course or an online graduate-level course, original student data could definitely be presented during an asynchronous online poster symposium similar to what we describe here.

Instruction, Grading, and Student Feedback

Management of Poster Assignments

Careful planning and organization is required by the instructor to make tasks easy to understand and to ensure that expectations are clear for students. Integrating rubrics throughout the course aids in this endeavor so that students know how their work will be graded, ensure that grading is accurate and fair, helps to provide students with timely feedback, and reduces grading errors and to avoid student mistakes (**Table 3** and **Supplementary Material**). An online Learning Management System (LMS), like Canvas, is essential for the management and implementation of an online poster symposium, especially in a large enrollment DE course that is being taught asynchronously. In addition, the Canvas LMS allows for frequent instructor-student communications (e.g., email, discussion posts, assignment comments) and convenient anytime, anywhere access to scientific posters for both students and instructors. Joyner et al. (2020) did observe what they described as a "synchronicity paradox" in online education where students wanted synchronicity to form peer communities, but yet the chief appeal of online education was the asynchronicity. The solution, they argue, it to provide synchronous activities centered around existing patterns of interactions such as lecture co-watching, study groups that select from and meet during specific time slots (Joyner et al., 2020). For our class, we will sometimes group posters according to topic (e.g., water science, climate change, renewable energy) because we found this to be an effective way to encouraged peer-to-peer interactions among students with similar educational interests and career goals (e.g., water science) but who may be from different colleges and departments.

During poster development and composition, the defined scope and structure of the assignment lends itself to a step-by-step process with repeated early feedback (**Figure 2**). Students proceed through a quiz, a bibliography, an abstract, and two preliminary drafts of their poster (**Figure 2**). Likewise, grading can be accomplished more effectively with the same or fewer resources because instructors can see the work in real-time and clarify questions by communicating with students directly. The instructors' and teaching assistants' (TAs) assessments can also be supplemented by peer-review, which increases the effectiveness of the assignment by deepening its resemblance to the actual work of scientists.

While it may be apparent that a scaffolded poster project can simplify the grading process, especially when compared to other written assignments (i.e., research papers), it is not to say that grading posters does not demand a significant dedication of time as well. An assignment of this type requires the compilation and combination of multiple grades for an individual student (e.g., feedback from instructor, teaching assistant, peers) in order to calculate a final grade. The time-demands of these processes are exacerbated when course enrollment is several hundred students and compiled student grades are derived from multiple types of assessments.

Poster Feedback and Grading

In terms of instructor-student ratio, we found that 1 teaching assistant can effectively handle the grading and poster feedback for 40–50 students, meaning that students receive their poster grade and feedback within 7–10 days of submitting an assignment. To allow for smoother workflow and timely and detailed feedback, our teaching assistants utilize rubrics (**Supplementary Material**) for grading Poster Assignments 2–6 (**Figure 2**). Rubrics allowed teaching assistants to consistently assess assignments from student to student. We found that assigning the same TA to the same group of 40–50 students for the entire semester worked best for poster grading and providing feedback. Our TAs preferred grading the same 40–50 students throughout the semester and we found that when same TA worked with the same 40–50 students throughout the semester, that poster grading and feedback was much more likely to be completed and that poster feedback was more detailed and constructive. Students also preferred working with the same TA throughout the semester (as opposed to using a different TA throughout the semester) because they were able to build a working relationship with the TA and become more conformable communicating and interacting with one TA. If students wanted to interact with a different TA, they could easily do so during

weekly TA Office Hours that were held over Zoom. We would like to point out that Poster Assignment 1 isn't graded by hand because it is set up as a self-grading, multiple-choice quiz.

All poster submissions, grading, feedback and communication (e.g., instructor-student) was accomplished online using the Canvas LMS. Teaching assistants were able to use Canvas to directly annotate poster files (e.g., add comments, highlight, mark up, draw), grade posters using rubrics and provide detailed comments to students (**Table 3** and **Supplementary Material**). Students were able to see grading rubrics before they started each assignment, presenting expectations and components of each poster assignment. Students were also able to receive timely and detailed feedback through the rubric so that they could improve their work before continuing onto the next poster assignment. Students who had a question could email the instructor using Canvas or post a question within the Canvas discussion board for the instructor to answer.

These strategies allowed teaching assistants to provide students with specific and timely information for each poster assignment, so that students were able to quickly identify and correct mistakes before continuing to the next poster assignment. By scaffolding poster assignments, the instructor was better able to ensure student success because instruction and learning was broken up into manageable tasks. In addition, with the completion of each poster assignment, students built a stronger foundation on which to build their poster. With each step in the process students acquired new skills and new understandings that helped advance them toward their ultimate goal of producing a high-quality poster and presentation.

In addition to poster grading and student feedback, poster peer reviews must be accounted for when hosting an online poster symposium. The "Virtual Poster Symposium in Canvas" video (link to video provided in **Table 3**) provides detailed instructions on how to assign, manage and conduct online poster peer reviews using Canvas. With the traditional pencil-paper peer-review, a workflow is created where student reviews need to be sorted not only by the reviewer but also the instructor. This process places the reviews in the hands of the instructor for an extended period of time, increasing the time between which the student delivers their presentation to when the student receives feedback. This may result in students receiving feedback days or even weeks after their presentation by which time the feedback may be less useful to the learner. Therefore, it is important to provide meaningful and timely feedback to students during the relatively short period of time (i.e., 15 weeks) that they are enrolled in the course. A turnaround time of around 7–10 days, from the time a student submitted their poster to the time the instructor provided feedback, seemed to work best for student success. If grading and feedback couldn't be provided within 10 days, we extended the deadline of the next poster assignment by 1 week. If we didn't extend the deadline, students weren't able to complete their work on time. This is why its important to have an adequate number of teaching assistants to assist with grading and feedback (e.g., 1 TA per 40 students). The Canvas LMS can automatically facilitate many of these logistical tasks that would have traditionally been done by the instructor with pencil-paper peer-reviews, therefore dramatically reducing the time frame of the peer-review process. These tasks include automatically and randomly assigning students their peers to review, reminding students to complete peer-reviews by automatically placing on item on the Student's Canvas "To-Do List," providing immediate access to the peer's work, providing an online space to conduct and submit peer-reviews, sharing back to poster presenters their peer's feedback immediately after reviews are completed (**Table 3**).

Poster Resources and Student Accommodations

Over the past 8 years, we have developed several educational resources that have been particularly effective at helping our students design and give professional poster presentations (**Table 3**). Detailed instructions, examples and How-To videos are also provided to students before they begin an assignment (**Table 3**, videos and **Supplementary Material**). In 2019, we published a free open textbook (**Table 3**, Scientific Posters: A Learners Guide) that we now use for our poster assignments. This book has been particularly helpful to our students. In addition, we published two open textbooks with chapters that were written by our ENR2100 undergraduate students (**Table 3**, Environmental ScienceBites, Volume 1 and Environmental ScienceBites, Volume 2). These two open textbooks have provided our students with examples of writing, figures and tables that they could use to guide them as they created their own scientific posters. These materials are freely available and provided in **Table 3**. Anytime a student has a question about a particular part of a scientific poster we can direct them to a book chapter, poster example or instructional video to answer their question (**Table 3**). These resources are also convenient for students because they are free and can be retrieved online on demand.

Some of our students receive accommodations (e.g., accessible media, assistive technology, deadline modifications) and we found that running our virtual poster symposium asynchronously through the Canvas LMS allowed us to provide accommodations to all our students. Arcila Hernández et al. (2022) came to a similar conclusion when examining poster sessions at professional science conferences from March 2020 to March 2021. They recommended incorporating an asynchronous virtual poster session into in-person poster sessions to improve accessibility, provide greater flexibility, increase engagement, and allow for a greater diversity of feedback (Arcila Hernández et al., 2022).

Some students did find it difficult to create and design their scientific posters. We observed that students who had little to no previous experience using Microsoft PowerPoint found it more difficult to create and design their scientific poster compared to students who had previous experience using PowerPoint (**Table 4**). To help these students we provided free 36-inch × 48-inch PowerPoint poster templates that all students were able to download and use (**Table 3**). We also provided poster examples, instructional videos and book chapters about creating and designing scientific posters (**Table 3**). The other issue we observed for our students was the type of computer they used to create their poster (**Table 4**). Not surprising, students who used a laptop or desktop computer were better able to complete their poster assignment compared to students who used a tablet.

TABLE 4 | Top 5 student responses to the end-of-semester survey question "Do you have any comments, ideas or suggestions about the Poster Assignments?" A total of 1,788 students from three different asynchronous, online courses participated.

Top 5 Student comments regarding poster assignments
1. Students appreciate seeing examples of scientific posters to help them design their own posters. Providing large-format (e.g., 36-inch × 48-inch) PowerPoint poster templates helps students produce professional-looking posters.
2. It is important for the instructor and/or teaching assistants to provide frequent and detailed feedback between poster assignments.
3. Students liked being able to pick their own poster topic because it allowed them to focus on a topic that was important and interesting to them.
4. Students who had little to no previous experience using Microsoft PowerPoint found it more difficult to create a scientific poster compared to students who had previous experience with the PowerPoint software. Laptop and desktop computers, with their larger screens and higher processing power, are better for working on large-format (e.g., 36-inches × 48-inches) posters compared to tablets.
5. Primary source journal articles can be difficult for students to understand.

Students completed rankings at the end (i.e., Week 15) of the Autumn 2020, Spring 2021, and Autumn 2021 semesters after they had completed poster assignments. All student responses were anonymous.

The larger screens and higher processing power of laptop and desktop computers made for a much better experience when working on large-format (e.g., 36-inches × 48-inches) posters. **Supplementary Table 1** provides additional recommendations for poster assignments based on our long-term study.

Asynchronous virtual poster symposiums were part of our classes both before and after the -19 pandemic (**Table 1**). We observed a 30% increase in enrollment in our DE course after COVID-19 (**Table 1**), which resulted in 30% more poster presentations and 30% more peer reviews. In terms of using the Canvas LMS to run and manage the virtual poster symposium (e.g., instructions, poster submissions, video, audio, grading, peer review) nothing changed after the COVID pandemic. We did have to hire more teaching assistants to help with the increased numbers (e.g., to hold Zoom office hours, provide poster feedback and assist with grading). The other difference that we observed after the COVID pandemic, was that students became more independent and proficient when using technology. Students were better prepared to record audio, record video, use Microsoft PowerPoint and Excel, and use databases to find and download journal articles. As a result, we observed that posters were more detailed and organized, figures and tables were higher quality, video and audio recordings became more polished and professional. We also observed that online student interactions were often more frequent and meaningful (e.g., back and forth discussions between students) and peer reviews were more detailed, specific to the research presented in the poster, clear and constructive. Instructors and teaching assistants also experienced a significant decrease (about 50%) in the number of emails from students who had questions related to technology.

Student Educational Experience

Our scientific poster project was designed to provide students with an engaging and rewarding educational experience in a Natural Science GE course that had a large enrollment of diverse students and was being taught as an asynchronous DE course. To obtain and analyze evidence of student learning with scientific posters we conducted student surveys (**Figures 1**, **3**). These data indicated that students were provided with the resources necessary to complete their scientific poster (**Figure 1**). Students viewed the poster assignments as valuable and impactful parts of the course (**Figure 3**) and approximately 90% of our students stated that they gained an understanding and appreciation for theoretical and empirical studies within the natural sciences. After completing the poster assignments, students were confident that they could successfully produce a scientific poster in the future (**Figure 1**) and approximately 80% of our students would encourage other online courses to utilize scientific poster presentations. Holt et al. (2020) received similar positive feedback from students (n = 66) who participated in their virtual poster session for an upper-level ecology course. They identified several key benefits of an online poster session including enhanced instructor-student engagement, flexibility of the remote venue, and the ability to interact with peers in an otherwise isolated COVID world (Holt et al., 2020). Students who completed the poster assignments for our class were successfully able to:

1. Explain facts, principles, theories and methods of natural sciences.
2. Find, critically evaluate and responsibly use information from natural sciences.
3. Evaluate the social and ethical implications of natural science discoveries.
4. Explain the changing nature of scientific knowledge and methods.
5. Demonstrate how peer-review is an integral part of the scientific process to maintain high standards of quality and provides credibility to research.
6. Become better writers and speakers by focusing their attention on particular details and considering the input of an actual audience.

In conclusion, an online poster symposium can be used as a unique educational experience and assessment tool for an online, asynchronous courses. Here we described a study that takes place from 2017 to 2022 (pre- and post-COVID) and involves 5,625 students over 8 semesters. We demonstrate how online poster presentations and peer review can be used in an asynchronously taught online Natural Science, General Education course. The methods, tools and resources provided here (**Table 3** and **Supplementary Material**) can be adapted to fit other online courses that are being taught asynchronously or synchronously. Furthermore, we have demonstrated that by using a Learning Management System like Canvas, instructors can effectively manage the organization, student feedback and grading of

poster assignments, even in large-enrollment online courses. Students found the poster assignments and the online poster event to be engaging, collaborative and offer interactive peer-to-peer experiences. Based on instructor and student feedback, we recommend the implementation of an online poster symposium to be used as a rewarding learning experience for students enrolled in DE courses that are being taught asynchronously or synchronously.

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 author.

AUTHOR CONTRIBUTIONS

BL, EW, and KS: conceptualization, methodology, resources, review and editing, and project administration. BL: writing original draft and funding acquisition. All authors have read and agreed to the published version of the manuscript.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feduc.2022.906995/full#supplementary-material

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