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Rapid Pivot of CURE Wet Lab to Online with the Help of Instructor Communities

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The pivot to remote and hybrid learning during the Covid-19 pandemic presented a challenge for many in academia. Most institutions were not prepared to support this rapid change, and instructors were left with the burden of converting a traditional face-to-face course into multiple modalities with very limited preparation time. When institutional support is lacking, we posit that instructor communities of practice can help provide the resources needed to meet the instructional demands. Tiny Earth, a course-based-undergraduate research experience (CURE) and international network of instructors and students, responded to the instructional challenges of the pandemic by leveraging its large community of instructors to create several smaller working groups to form focused communities of practice. Using the pedagogical principles of backward design and scientific teaching, one working group, the Tiny Earth Pivot Group (Pivot Group) generated a course map of remote learning activities and simulated learning resources to fulfill the Tiny Earth learning objectives and maintain the essential tenets of a CURE. Additional working groups were created to disseminate the resources collated and created by the Pivot Group to the greater community. In terms of Tiny Earth, the community structure provided the means for instructors to rapidly pivot their course materials to multiple modalities while upholding the student CURE experience. Harnessing the hallmarks of communities of practice—collective workpower toward common purpose, diversity of perspectives, and ongoing evolution—coupled with high-structured course design allows instructors flexibility and adaptability in meeting the changing modalities of higher education.

KEYWORDS online teaching, hybrid teaching, remote blended learning, wet lab, digital curriculum, course-based undergraduate research experience (CURE), scientific teaching, microbiology instruction, instructor community of practice

PERSPECTIVE

Hybrid learning is here to stay. Multiple teaching modalities dominated instruction in 2020–21 due to the Covid-19 pandemic: fully online, hybrid, at-home experiential labs, and everything in between, and sometimes including parallel face-to-face options. Most institutions were not prepared to support this rapid change, so the burden of work landed on individual instructors to pivot their courses rapidly to multiple modalities (1). Unfortunately, many instructors were also unprepared for using the digital tools as well as the pedagogical implications for remote learning and inclusion; in one study, 60.5% of instructors cited a need for additional professional development to respond to Covid-19. In addition, the problem is exacerbated for women; when asked whether institutions were providing adequate support during the Covid-19 pivot to remote learning, 62.5% of men reported feeling supported by their institution, while only 38.7% of women felt their institutions provided adequate support (2).

When institutions fall short and the instructional choices become overwhelming, instructor communities of practice can help. Members of a Community of Practice (CoP) share a concern as a result of a common experience, and they learn how to refine the experience based on regular interactions and follow a domain-community-practice structure as described by Wenger (3). Briefly, a CoP can provide the framework for a group of instructors teaching the same curriculum facing similar challenges (the domain) to meet regularly to discuss and share ideas (the community). As a result of engaging as a community within a domain, the CoP develops shared resources, materials, and artifacts for the practitioners within the practice. An effective CoP can provide the members of that community with space for open dialog and ideation, equitable contribution, and evolving outcomes. The shared purpose and experiences of a

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CoP benefit from the diversity of ideas and perspectives within the group (4).

Applying sound pedagogical principles to instructional design can provide a framework that focuses the community on students and learning. Well-established approaches like backward design (5) and scientific teaching (6, 7) readily lead to high-impact practices such as active learning, high-structured courses, and transparency in objectives that have shown again and again to be the most effective ways to engage students in learning, foster belonging in science, and encourage persistence of diverse students in STEM (8, 9). An added benefit of using these approaches is that they also translate readily to remote learning contexts and are more important in blended-learning contexts (10). These approaches also provide a lens through which to look when making decisions about which teaching technologies are most appropriate for those contexts. These types of frameworks (i.e., keeping student and learning outcomes at the center) work well in communities of practice because they provide a shared language for course design, into which the community members' diverse ideas can be shared, considered, expanded, and vetted in an equitable way.

Here we show how communities of practice coupled with high-structure course design approaches can support the rapid uptake of digital tools and sound pedagogies that afford efficiencies in course design, instructional decision-making, and implementation. This is especially the case for introductory courses where the concepts and content do not vary wildly. In the case of gateway courses at larger colleges or universities, it may make sense to build community within high-enrollment course teams, within a department program, or across multiple life-science departments with similar missions. In the case of wet-lab courses or extensive research courses, it may make more sense to forge a community across institutions but within the discipline, such as through a professional society, or by course type, such as a course-based undergraduate research experience (CURE) with a wet lab.

This paper provides a perspective on how communities of instructors across multiple institutions can co-create and disseminate high-structured curricula that allow for the rapid, evolving, and sustained pivoting of complicated course structures (such as wet labs) to remote learning. We also provide an example of how such a community pivoted a well-established CURE, Tiny Earth, to online and at-home formats while shoring up a teaching community of practice around a new and evolving digital curriculum.

A TIME OF TRANSITION

Tiny Earth is a CURE developed in 2012 by Professor Jo Handelsman and has the simultaneous goals of discovering new antibiotics from soil bacteria and increasing the persistence of diverse students in STEM (11). Briefly, students collect soil samples from a location of their choice and in turn formulate and test hypotheses about the antibiotic potential of bacteria living in the soil sample. Once students select bacteria from serially diluted soil samples, they screen for antibiotic production against a suite of safe relatives of known pathogens and refine their original hypothesis with regard to their research projects (12). At the end of the semester, students enter data about their antibiotic-producing isolates into the Tiny Earth Database (https://data.tinyearth.wisc.edu/public_data), a public database to disseminate results. The wet-lab course is affordable and easy to implement in an array of courses, ranging from nonbiology to biology majors, introductory biology to microbiology, and lower- to upper-division courses. Therefore, Tiny Earth can be and is taught at a variety of institution types including 2-year colleges (14%), 4-year colleges (56%), research universities (11%), and other educational establishments (e.g., high schools, 19%) (11). There are currently more than 700 Tiny Earth Partner Instructors (TEPIs) who have been trained to teach the curriculum around the globe (11).

At the beginning of the Covid-19 pandemic in March 2020, it became clear to the TEPIs that online, hybrid, and at-home learning would dominate instructional modes in the 2020–21 academic year. Knowing that TEPIs implement the curriculum at diverse institutions, in diverse courses, and now in diverse modalities, how could Tiny Earth meet the community's varied needs and still deliver a quality course to students learning during the pandemic? In addition to being a robust CURE, Tiny Earth is an international network of instructors who identify as one large community of practice, with the focus of delivering the Tiny Earth curriculum comprised of smaller, agile communities of practice (i.e., working groups or committees) who manifest the program's strategic priorities (11). The Covid-19 pandemic and social unrest of 2020 provided the landscape for Tiny Earth to quickly mobilize and convene new and existing communities of practice. These included the formation of a Tiny Earth Curriculum Pivot Group (Pivot Group) to pivot the Tiny Earth curriculum to meet the instructor and student needs in the classroom due to the Covid-19 pandemic, and other working groups and committees such as the TEPI Workshop Committee, the Tiny Earth Symposium Committee, and a TEPI Training Leadership Team to disseminate the pivot curriculum to the greater TEPI community.

RAPIDLY PIVOTING A CURE CURRICULUM TO ONLINE, AT-HOME, AND IN BETWEEN

The Tiny Earth curriculum is designed using scientific teaching principles including active learning, assessment, and diversity (7) and uses a "backward design" approach to course design by starting with learning objectives first, followed by assessments and activities (5). Each of the 12 Tiny Earth lab sections has a set of learning objectives for which student-centered materials for in-person activities and assessments were mapped out. To address the imminent need for online and at-home teaching material, the Pivot Group retrofitted a course map, a curricular alignment tool that allows instructors to visualize the backward design of their entire course (13), with Tiny Earth learning objectives that mirrored online and at-home materials to current resources used in the in-person, lab-based course. Remote activities, including online and at-home materials, were crowdsourced from members of the greater TEPI community. With the course maps, the Pivot Group aimed to develop and align learning objectives that are hallmarks of a CURE, including scientific practices, discovery, relevance, iteration, ownership, and authenticity (14, 15). An example of a course map can be found in Table 1. In addition, the Pivot Group simultaneously developed adaptations to the learning objectives that promoted antiracism, justice, equity, diversity, and inclusion (AJEDI) in response to social unrest and are outside the scope of this paper (16). In the end, the course map provided a tangible framework for the working group to collaborate, apply backward design principles, and create a foundation for the implementation of multiple high-structure learning environments.

Examination of the extended course map revealed gaps in remote materials for specific learning objectives. To fill these gaps and to provide continuity for students with the material during the semester, online and at-home resources were adapted, adopted, or created to simulate the work typically done by students in the laboratory. For example, the adoption of an at-home serial dilution exercise using basic craft supplies (17) for use by the Tiny Earth community provided a hands-on activity for students to learn this microbiology skill. The Pivot Group also gathered case studies and recorded videos to reinforce the corresponding learning objectives, including antibiotic discovery, structure, and antibiotic resistance. In addition, the Pivot Group created content to aid students in traversing the curriculum virtually, with the help of a fictional student called "Taylor the Tiny Earthling," as they complete the lab work for the course. This resource included background information, demonstration videos of protocols (for an example created by Tiny Earth, please visit https://youtu.be/4KlKQT9YGL8), results from the lab, and points where students would analyze the results and then choose the next assay to perform. Ultimately, the goal was for students to design their own experiments, work through how to purify an antibiotic-producing bacterium from an environmental sample, and identify it using various microbiological assays. This online resource can now readily be updated and used for years to come by the Tiny Earth community as prelab activities for students who are in the laboratory for the semester or as a remote resource if needed in the future.

RAPIDLY DISSEMINATING THE DIGITAL AND AT-HOME CURRICULUM

Workshops and webinars

Communities of practice allow for peers to share their knowledge in a purposeful manner and engage on a regular basis (3). Each year, the TEPIs and students have the opportunity to participate in a biannual in-person symposium, which was moved to an online gathering in 2020 (https://tinyearth.wisc.edu/events/). The goal of the conference is to enable TEPIs and their students to come together and share their work and learn from each other's practices, a goal that was upheld during the pivot to being virtual. During the conference, TEPIs indicated through informal survey their desire to collaborate, share, and learn from one another to meet the changing needs of their students. Thus, TEPIs required venues to convene and continue to share their knowledge and practices. This need led to the development of virtual workshops and webinars that acted as a learning space for faculty to brainstorm, share ideas, and learn tips/tools to implement Tiny Earth successfully at their respective institutions. To coordinate these events, a Workshop and Webinar Committee, an additional community of practice, was established.

The goal of the TEPI Workshop and Webinar Committee was two-pronged: (i) help instructors navigate the changes to their mode of instruction in response to the Covid-19 pandemic with support from each other and (ii) develop strategies that could still deliver the Tiny Earth experience to students through the different modalities. The TEPI Workshop Committee solicited topics from the instructors via surveys and created a schedule of workshops to be delivered biweekly. TEPIs served as the hosts for the webinars or workshops based on their interests and expertise. Tiny Earth Headquarters hosted the workshops via Zoom, an online video conferencing platform to allow instructors worldwide to join the discussions. Workshop facilitators showcased digital assets and other tools helpful in implementing the new modalities of the Tiny Earth curriculum in their classrooms and engaged the TEPI participants in discussions about how to integrate the materials into their teaching context. As part of the workshop series, committee members regularly engaged in virtual office hours as open forums for troubleshooting discussions or as a place to share ideas. Similarly, a working group of Tiny Earth TEPIs and staff from headquarters formed to pivot the new-TEPI training online and incorporate the new digital content created by the Pivot Group through interactive sessions and breakout working groups. In total, 380 Tiny Earth instructors attended these events. For TEPIs who were unable to attend due to time zone differences or other commitments, workshops and webinars were recorded and made available on the Tiny Earth Instructor website and Canvas site.

Digital repositories and assets: Canvas, Google Drive, and Zoom

Communities of practice build capacity by developing tools and assets that can be shared among their members to improve their practice (3). An outcome of the work to pivot to online was creating digital repositories and assets that would be accessible to the TEPI community. First, the Pivot Group used Google Drive to collaborate and share materials. Later, the working group adopted the Canvas

TABLE 1
Examples of activities and assessments in Tiny Earth, a course-based undergraduate research experience (CURE), adapted for face-to-face, at home, and online modalities[a]

Learning objectives	Key concepts	Recommended activities and assessments by modality		
		Face-to-face	**At home**	**Online**
Identify soil properties and correlate them with microbial abundance.	Soil is a complex matrix comprised of organic matter, inorganic matter, and living organisms. Microorganisms are ubiquitous and diverse in soil.	Collect soil sample from an environment of your choice following the protocol and guidelines in the Tiny Earth manual. Complete the lab worksheet (soil data collection form).	Assemble your at-home soil collection kit based on the guide posted in our course management system, including the pH strips that arrived in your Tiny Earth kit at the start of the semester. Collect a soil sample from an environment of your choice following the protocol and guidelines in the Tiny Earth manual. Complete the lab worksheet and soil data collection form in the Tiny Earth manual **except** (1) Ignore water content on sheet and (2) categorize texture and organic content using USDA's Guide to Texture by Feel.	Watch the Tiny Earth soil collection video (https://youtu.be/4KIKQT9YGL8) and complete the "Taylor, The Tiny Earthling" Interactive Module which involves following the fictional student, Taylor, on their soil collection. In the course management system, choose the soil sample that is most similar to your sample and complete the quiz on soil characteristics and microbial diversity.
Isolate microorganisms from a soil sample. Describe microbial diversity, abundance, and morphology.	Microorganisms are ubiquitous and live in diverse and dynamic ecosystems. Microorganisms and their environment interact with and modify each other.	Complete the soil dilution and bacterial plating protocols in the Tiny Earth manual. Complete the lab worksheet (observe soil dilutions, observe bacteria on a plate, and assess biodiversity).	Assemble your at-home soil dilution and growth media kits based on the guide posted in our course management system. Complete the lab worksheet (observe soil dilutions) and plate the soil onto the growth media. Seal the plates and set at room temp for 2 days away from children and pets. After 2 days, complete the lab worksheet (observe bacteria on a plate and assess biodiversity). DO NOT open the plates. Dispose immediately in the trash.	Watch the Tiny Earth soil dilution (https://youtu.be/yG7N7bqp7tk) and plating videos (https://youtu.be/SDjxzALPqb8). Each member of your group will read one of three publications on bacterial morphology on bacterial morphology. In your group's videoconferencing breakout room during class time, each of you will share the main findings from your assigned paper and one question. As a group, post on the course management system three bacterial morphologies you would expect to see in our local soil.
Generate a testable hypothesis. Design and execute an experiment to test it.	Understanding in science is derived from a process of observation, experimentation, gathering evidence, interpreting results, and communicating findings. Writing a testable hypothesis is central to designing an expt.	Work with a partner to generate a hypothesis about the bacteria from your soil sample. Design an expt to test your hypothesis. Do the expt, collect your results, and write up your findings format described in the course syllabus.	Work with a partner to generate a hypothesis about the bacteria from your soil sample. Propose an expt that would test your hypothesis. Describe the materials and methods, what data you would collect. In lieu of doing the expt, because we cannot open the plates, we will be doing our actual testing using the Tiny Earth Public	Work with a partner to propose a hypothesis about the data you find in the Tiny Earth Public Database (https://data.tinyearth.wisc.edu/public_data). Design an expt to test it, analyze the relevant data, and write up your findings in the lab report format described in the course syllabus.

(Continued on next page)

TABLE1 (Continued)

Learning objectives	Key concepts	Recommended activities and assessments by modality		
		Face-to-face	At home	Online
			Database. Propose another hypothesis about the data you find in the database. Design an expt to test it, analyze the relevant data, and write up your findings in the lab report format described in the course syllabus.	

[a]Sample adapted from Section 2, More Than Just "Dirt" (12) by the Tiny Earth Curriculum Pivot Group. Note that the learning objectives and key concepts remain constant and are met by each of the recommended adaptations by modality.

learning management system whereby instructors could copy course materials directly into their learning management systems. The TEPI Workshop Committee also used Canvas to post materials and recorded webinars and workshops for instructors who were unable to meet synchronously. Zoom made it possible for the community to gather in a way that it had not in the past. As the year progressed, these materials were all gathered under the umbrella of a new, password-protected instructor website. Together, these tools make it possible for a large community to engage robustly across institutions, instructional modalities, and time zones (18).

Lessons learned and next steps

Communities of Practice are communities of people first and foremost. Building relationships and trust and functioning as a social entity are the core of a community (3). During a time when everyone was adapting to a rapidly changing landscape in teaching, events like the workshops facilitated connections between the TEPI community and created a space for the community to support one another. These events served as a place where instructors could reflect on students' changing needs and abilities in the new learning environment. It allowed instructors to discuss and align the digital and at-home Tiny Earth course materials for all students (remote, hybrid, and in-person) and ensure strategies to foster inclusivity and equity among students in their adaptation of the Tiny Earth research course.

Together, TEPIs were able to quickly collate resources by leveraging the strengths of members of the community and tapping into the shared Tiny Earth vision of working as a cohesive network, even though instructors hail from all types of institutions and parts of the world. Using scientific teaching practices, like backward design, to create a robust course map with materials that instructors could use in various settings also illuminated areas in which the current curriculum could use further refinement and revision to meet the needs created by a rapidly changing educational landscape. Tiny Earth will continue to redeploy these TEPI communities of practice to take a closer look at the entire Tiny Earth curriculum and evaluate the effects. Our perspective is that others may use these practices as well in their own educational context and consider future studies to evaluate the effectiveness of these types of working groups and communities using the CoP framework.

Given that remote learning and its multiple incarnations will not be going away anytime soon, we offer the perspective that leveraging communities of instructors who use sound course design practices allows for the rapid, evolving, and sustained evolution of curriculum. Navigating this new and rapidly changing landscape can be overwhelming for the individual science instructor. Using evidence-based practices and enlisting peer instructors with common purpose will make the process more enjoyable for instructors and the curriculum more meaningful for students.

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Apply to become a TEPI: https://tinyearth.wisc.edu/join.

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