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Fighting for the CURE: Antibiotic Discovery and Storytelling during the Time of COVID

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Abstract

Students' experiences shape their learning and understanding of content, which will allow them to make meaning with it. Science classes can provide opportunities for living experiences and acting as a mechanism for learning, but lectures and discussions, along with "cookbook laboratory experiments" lack opportunities for meaningful experiences, which causes content to become harder for students to grasp. The development and implementation of course-based undergraduate research experiences (CUREs) open diverse student populations to research-type experiences involving content that can change their lives. This CURE program utilized antibiotic discovery to non-major, pre-nursing students during the Spring 2020 semester at the beginning of the COVID19 pandemic. Before moving swiftly to emergency remote learning, the students had completed over half of their tasks, particularly isolating and purifying their samples. In order to continue this antibiotic discovery CURE, meetings went virtual and the instructor became the student hands. Organisms were characterized using standard microbiological tests, and the student experience was saved overall, though the impact of the pandemic on the research, as expressed through student reflections, influenced students' perceptions of their learning. Though unconventional, the modified research process saved the CURE and provided students with experiences to connect their work to their lives.

Keywords: Storytelling, CURE, reflective learning, experiential learning

Introduction

When content relates to their lives and creates experiences, students take a greater interest in learning and making meaning with it (Taylor, 2007; Mezirow, 1990). Storytelling acts as one way to help encourage students to engage with the content while allowing them the opportunity to create new knowledge and find ways to express that knowledge to others (Alterio, 2003). Students need to want to engage and learn, but faculty have to engage students and help them engage the content (Race, 2011). Lecturing, discussions, and prompts tend to miss this desired impact, as do the standard "cookbook laboratory experiments" generally implemented into introductory science laboratory courses (Clark, et al., 2000). Researchers have shown that undergraduate research in Science, Technology, Engineering, and Mathematics (STEM) fields enhances student engagement and persistence in STEM fields, but those research experiences tend to focus on science majors, most often upper classmen pursuing independent projects (Hanauer et al., 2017; Lopatto, 2004). Undergraduate Research Experiences (UREs), like these independent projects or inclusion in faculty research programs, have shown significant gains in helping students interact with scientific principles, but require substantial investments in resources, including materials and faculty time to operate them (Linn et al., 2015). Additionally, UREs typically can only involve a few students at a time, thereby leading to significant competition for the top students and cannot be scaled to bring these benefits to more students, and even diverse populations at the same institutions. This research, in contrast, embraces the course-based undergraduate research experience (CURE) to engage nursing students in an introductory microbiology laboratory course in antibiotic discovery with the intent to transform students' perceptions of science and antibiotics as noted through student assessments in the course, particularly those focused on storytelling.

Relevant Literature

CUREs vs. UREs

As mentioned above, UREs involve a few students at an institution who participate in more focused research activities with a Primary Investigator (PI), often the faculty member leading the research, and have a strong mentoring component from other members of the research team as well as the PI (Linn et al., 2015). Students in these programs tend to already be highly interested in science and may have developed that interest early in life (Russell et al., 2007). Additionally, many students who participate in such programs have the tendency to go on to graduate education within the sciences (Lopatto, 2004). Programs tend to reach across demographic groups, genders and particular majors, but most students participating are already high scoring and successful students (Lopatto, 2004; Russell et al., 2007). The question for many faculty members has been how to provide these benefits to more students, which lead to the development and implementation of CURE programs.

In contrast to the UREs, CUREs expand research opportunities and scientific method exploration to a large number of students with usually less focus on individual mentorship because of the increased student to faculty ratio (Linn et al., 2015). CURE programs, as defined by Auchincloss, et al. (2014), provide students with the opportunity to use scientific principles, discover new insights, work on relevant topics, participate in collaboration, and build on previous knowledge within these research projects. CUREs tend to be hypothesis driven and help students work through the steps of the scientific method (Dolan, 2016). CUREs also improve students' perceptions about science, persistence in science, and leading potentially to careers in science (Auchincloss et al., 2014; Dolan, 2016; Linn et al., 2015; Hanauer et al., 2017). The ability to participate in a CURE provides students with experiences related to content, which improves student learning.

Conceptual Framework for the Antibiotic Discovery CURE

For the CURE framework, this course model was based off two international antibiotic discovery curriculum programs, the Small World Initiative and the Tiny Earth Program. The program was being implemented for the first time at The Pennsylvania State University – Penn State Schuylkill (hereby referred to as Penn State Schuylkill) during Spring 2020. Within this course, one group of students participates as Small World students, while the other group participates as Tiny Earth students, though the programs have very similar purposes and techniques. The Small World Initiative, as noted by Dolan (2016), is one of three national curriculum programs using a common experiment system.[1] Both programs have students obtain soil samples to isolate and characterize potential antibiotic producing bacteria as laboratory experiments.

The Small World Initiative started as the Microbes to Molecules course in 2013 under the direction of Dr. Jo Handelsman at Yale University and then expanded to include other institutions, thereby becoming the Small World Initiative (Caruso et al., 2016; Davis et al., 2017). The Small World Initiative encourages students to pursue science and engage in scientific field-based research revolving around "crowdsourcing antibiotic discovery" (Davis et al., 2017). The curriculum involves having students isolate bacteria from nearby soil sampling sites, determine potential antibiotic producers from the isolates by testing against safe-ESKAPE (non-disease causing) organisms, and extract compounds from their chosen, isolated organisms (Davis et al., 2017). From Yale and a handful of institutions, the Small World Initiative has grown over the last 8 years to include over 300 institutions across fifteen countries (Small World Initiative, 2021). Barral et al. (2014) were among the early implementers of the program and explained that during the pilot phase with 25 schools, the assessment of the program examined student perceptions about the science learned, students' experiences about participating in research and how they viewed field-based laboratory work. Their methods at that point involved the use of pre- and post- surveys (Barral et al., 2014). Assessment of the program has noted improvement in these areas

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[1] Dolan's work was written before Tiny Earth was founded and as related to the Small World Initiative would most likely also fit into this category.

beyond those experienced in traditional "cookbook" type laboratory courses. Barral et al. (2016) also explain that this CURE implementation has the ability to improve student experiences and in particular, they note that women and minority groups have a greater growth in these categories. In their study, Caruso et al. (2016) found that students participating in the program had higher grades than control groups who were involved in traditional laboratory courses. Their work also showed an improvement within critical thinking skills (Caruso et al., 2016). The instructor was trained under the protocols of the Small World Initiative at the University of Connecticut—Storrs during the summer of 2017 during a weeklong intensive training.

The Tiny Earth Program officially started in summer 2018 at the University of Wisconsin Madison and the Wisconsin Institute of Discovery. It is the transformed version of the Microbes to Molecules course from Yale and is once again under the leadership of Dr. Handelsman (Tiny Earth Project, 2021). Similar to the Small World Initiative, the Tiny Earth Program seeks to inspire students to careers in science by involving them in original laboratory research as part of "studentsourcing antibiotic discovery" (Tiny Earth Project, 2021). Additionally, the Tiny Earth Program has begun work to create and house a database for chemical samples from student-isolated microbes and continue to examine the types of compounds found. Furthermore, as Bueso-Bordils et al. (2020) note, the Tiny Earth Program also helps students explore microbial biodiversity within these soil ecosystems as the search for antibiotic producing bacteria continues, while instructors are able to highlight the discovery component to students. In a twist to the American implementation of the course, the work of Bueso-Bordils et al. (2020) explored the use of Tiny Earth to also engage both university aged students and a pre-university set in the work, while providing the university students additional knowledge of antibiotic resistance in bacteria, skills in teamwork, lab work and model teaching. The instructor maintains a membership as a Tiny Earth Instructor, since its development.

Conceptual Framework for Assessments in the Course

Beyond the implementation of the CURE, this project focused on the ability to connect experience with learning. The pedagogical framework for this project integrates transformative learning from Mezirow (1990) with aspects of storytelling from Alterio (2003). As Mezirow (1990) notes,

> To make meaning means to make sense of an experience; we make an interpretation of it. When we subsequently use this interpretation to guide decision making or action, then making meaning becomes learning. We learn differently when we are learning to perform than when we are learning to understand what is being communicated to us. (p. 1)

The act of doing provides the experience and provides for an opportunity to reflect upon what has happened. The reflection then allows for the information gained from experience to be utilized in another part of life. This concept of learning provides the learner with the ability to change their perceptions, and in turn, their lives (Mezirow, 1990).

Transformative learning, as Taylor (2009) explains, has particular hallmarks in its execution. These elements are the experience of the individual, a critical reflection on the experience, and dialogue about the experience, along with a holistic orientation to the process, an awareness of the context being provided, and an authentic implementation (or practice) from teacher to learner. Though the elements are distilled from transformational educational experiences, each of these elements is not a strategy in and of itself for changing how students learn. Instead, the experiences implemented, as the transformative process, require each element to work with the others (Taylor, 2009). Though experience is central to process, for without it, the rest degrades, providing the mechanism for reflection and dialogue needs to exist within a trusting relationship between teacher and learner circumstances and have a context that the learner can relate to.

Within this CURE, the experience, of course, was the procedures related to the antibiotic discovery procedures from the Small World Initiative and the Tiny Earth Program, but the application and reflection on that experience was given special outlet. In many CUREs, the notebook and potentially a few discussion questions may provide that outlet, but within this CURE implementation, students experiences were to be connected with a reflective element, storytelling.

Storytelling was chosen as a focus for student assessment, as it could provide a format to not only reflect on the experience provided within the laboratory, but also it fostered the application of that knowledge by having the student explain how the experience would influence their behaviors and careers, along with connecting the current experience with their past experiences. As Alterio (2003) explains, storytelling is one of our oldest forms of learning and communication. Additionally, it provides the ability to express views and share experiences. By using storytelling, students can talk through their concepts, along with their experiences. Storytelling is not as simple as just saying, "Tell me a story…", instead it requires creating a culture of storytelling where the environment is without judgement and can be considered safe for the student to tell the whole story, including those emotional components (Alterio, 20013; McKillop, 2005).

Health Professionals and Storytelling

Health professionals, especially nurses, have to maintain a difficult balance of learning and comprehending complex scientific concepts and then being able to explain parts of those concepts to patients, who come from varying backgrounds, and do so during times of crisis. Bourhis, Roth and McQueen (1989) note that within the healthcare setting that Medical Language (ML) and Everyday Language (EL) use are commonplace and that convergence, the movement between one style to that of another group, is important for communication. Doctors tend to maintain a higher degree of ML use, even with patients, which can lead to communication breakdowns between these groups, though convergence to EL to help patients understand procedures and treatment plans is expected. In contrast, nurses may act as "communication brokers" where they need to rise to the level of ML used by the doctors, while also being able to move quickly to the EL level of their patients, which may also be explained as translating the ML of the doctor to an understandable EL for the patient (Bourhis, Roth & McQueen, 1989, p.341). Nursing students need to learn ways to take the concepts from their courses and make meaning with it, so they can later recall and apply it to their professional lives. Storytelling provides one way for students and other health professionals to help accomplish this task.

Storytelling has been promoted as one way for nurses and nursing students to learn content, but also is viewed as a significant way to learn about patient history (Tevendale & Armstrong, 2015). Tevendale and Armstrong (2015) note that having nurses encourage patient storytelling can provide a way for nurses to learn important parts of patient history that are not commonly expressed or asked about during standard entrance interviews at a healthcare facility. Additionally, Davidhizar and Lonser (2003) explain that storytelling can provide a way for nurses to disseminate knowledge to patients and their families. The use of storytelling has been shown to increase the level of trust generated between patients and their caregivers, which can also translate into increased compliance with healthcare protocols (Haigh & Hardy, 2011). Storytelling of protocols and techniques can help patients feel more at ease with what to do, and more importantly what not to do (Davidhizar & Lonser).

The importance of storytelling within nursing is growing throughout the field, but much of the research on storytelling in nursing focuses on the clinical setting or nursing education courses, however the skills of storytelling and reflection are often ignored in the students' initial courses where the development of these skills could provide meaningful practice before the more impactful major-based courses. Nurse education courses and clinical experiences utilize these methods to help nursing students make meaning of the experiences and content (Davidhizar & Loser; Haigh & Hardy). However, these courses and experiences come later in nurse education. Pre-requisite courses could implement opportunities to learn such skill sets and provide the opportunity to practice storytelling and reflective learning. Some course types, like literature and history, may provide amble opportunity for these skills to be developed but the later application of the content to clinical experience tends to be limited. Prerequisite science courses generally provide the content that will act as a foundation for later experience but the formats tend to be more limited. The implementation of the CURE model opens students to having experience, which also provides the opportunity for students to take their experience and create stories around it.

Methods

This research study was a qualitative, exploratory design as part of a preliminary study on student learning of the concepts incorporated into an introductory microbiology course implementing a CURE on antibiotic and utilizing the mechanism of storytelling for reflective learning. Since this was more exploratory in nature, the design focused on examining student work to determine themes that students deemed as meaningful. Students were assessed on content acquisition through quizzes and comprehension through discussion posts, presentations, and weekly oral journaling. The goal was to examine what students learned by looking at what they explained in their oral journals and then how they connected it to their lives and potential future careers.

Research Participants

This antibiotic discovery CURE project was implemented into MICRB 107, Elementary Microbiology Laboratory classes at Penn State Schuylkill. MICRB 107 is designed as an introductory microbiology laboratory for students who do not plan on further studies within the field of microbiology. The course tends to be utilized as the microbiology course for students designated as pre-major nursing or those who are trying to enter into a registered nursing program, as microbiology courses with laboratories tend to be pre-requisites for such programs. The MICRB course, for example, is a pre-requisite for students seeking entrance to our affiliate, the Joseph F. McCloskey School of Nursing in Pottsville, PA. In Spring 2020, two sections, containing a total of 35 students between sections, were involved in the project.

Given the new curriculum model, the author used this opportunity to investigate student perceptions of the activities performed within laboratory sessions through active reflection on experiences. The Pennsylvania State University Institutional Review Board had approved the study in March of 2020 and students were approached for consent by a member of the research team shortly before our spring break, which also happened to be the end of our in-person learning. The information session informed students that participation in the study would not require any additional work from the students. Additionally, students were informed that their participation in the study would not provide them any direct benefits or negatively (or positively) influence their grades. Based on the timing for the consents, not all students were present for the research information presentation and consent signing. Out of 35 students, 22 provided their consent to examine any materials and assessments from the course.

Multiple methods of assessment were incorporated into the course, which aimed to demonstrate the connection between experience and student learning, including quizzes, oral journals, discussion boards, and presentations. The assignments chosen aimed to develop the students' ability to discuss scientific issues with colleagues (i.e., other students and the instructor as grader on content knowledge) and the patients (as represented by the public and the instructor as grader on content dissemination). Throughout the course, students also recorded "oral journals," which were weekly Zoom recordings where students explained concepts they learned that week, why that concept was important and how it related to their potential professional careers. The presentations for the course revolved around student reports of their research work, conclusions drawn from the work, ways to improve their student reports of their research, conclusions about their characterized organism, what the student learned from the work, and finally, what the student wished they could have done with their organism or learned more about during the course. In-depth presentations were recorded and posted to our class symposium website, and the students answered questions live regarding their work during a live-streamed Zoom event.

Here, it is important to note that students could share both their laboratory experience on what they saw and did as well as communicate what lead them to this experience from the other parts of their lives within the "Oral journal." The recording space for the oral journal provided a safe space for students to speak their thoughts truthfully and talk through the concept with the "instructor" who would view them later. They also had the ability to bring in sensitive information that could emotionally affect them without having to show that character aspect in class. Students were prompted to speak casually and not read from a script though using a grid of topics could be helpful initially (Appendices 1 & 2). The privacy and encouragement to incorporate their stories helped to create a culture of storytelling (Alterio, 2003; McKillop, 2005).

Therefore, students had already been recruited for the IRB-approved teaching and scholarship research on how the implemented modifications influenced their knowledge, interest, and engagement towards both research and science when the pandemic struck. Though on a limited population and in only a semester time frame, the students' materials have the ability to demonstrate how the unique circumstance of in-person versus emergency remote learning influenced this student group and provides a real-time examination of how this type of disaster could impact students and their perceptions about learning related to microbiology.

Surviving COVID19—Changes to the Curriculum during a Pandemic

Students had completed a number of activities related to their CURE projects before the SARS-CoV2 virus had caused significant issues in the United States. Unfortunately, the spread of the virus led to school closures. The pandemic changed how the course proceeded and what content students were exposed to along the way. The movement from in-class research activities to remote engagement provided a unique opportunity for both student research and teaching scholarship. The changes to the curriculum and the methods are described below, as the pandemic required significant changes to teaching methodologies which were not expected in the original design of the course.

Students had performed work as scheduled for approximately half of the course (Appendix 3). This work included the students collecting campus soil samples for dilution, creating dilutions and plating them, characterizing their soil, and isolating bacteria. Their plates showed different strains of bacteria and independently students chose bacteria with appearances that interested them. They made decisions based on appearances of which bacteria samples they desired to follow going forward, though as a group we discussed some features, like "curly colonies" will be spreaders and several famous pink colonies have antibiotic activities. They performed initial antibiotic screening on their selected bacteria against safe relatives of human pathogens (*Escherichia coli* and *Staphylococcus epidermis*), as well as performing routine, microscopic bacterial characterizations, including Gram staining.

With the Penn State system being closed physically, students could not continue their work as scheduled. Students were off campus on spring break when the announcement was made, so kits with materials and the student's samples were not created in time. Samples remained in the laboratory and the discussion shifted to what to do next. The University's initial plan was to remain remote for several weeks until the situation passed, which suggested that we would be delayed but that we could return to work and just lose several activities (Appendix 4). With this presumption, the cohort did not want to abandon the work completed. Shortly after our group decided to continue work, Penn State administration made the official announcement that classes would remain remote throughout the spring semester, which would directly impact our ability to continue.

With the move to remote for the semester and increasing cases of COVID19 in Pennsylvania, Penn State also requested that all laboratories have research halted. Since we originally believed we would return to campus, materials for the remainder of the semester were already being prepared. Additionally, with the shutdown, all samples that were not ready for deep freeze storage would have to be discarded, which included every student sample at that point. Given that media for the projects was already made and student samples were ready for the next stages, it was decided to continue the research projects but on a different, catastrophic-type schedule (Appendix 5). Our method for laboratories continued via Zoom meetings for the rest of the semester.

Students directed the research process during individual meetings with the instructor by helping choose samples to follow through the rest of the process and deciding which tests should be performed on their selected bacterial strain. During a synchronous Zoom meeting, the instructor, alone in a lab setting, would perform inoculation techniques with directions from the student investigator. Each meeting required that the student be involved in the process, since the instructor would ask questions about what to do, as well as encourage conversation about experiences of the pandemic. Students were able to view their samples using multiple camera views. The instructor had erected a cell phone camera stand for sample closeups and a laptop with webcam so the instructor and student could see one another and converse directly. Students were safe at home, but had the ability to direct the instructor to move a sample up, down, left, right or even say "pick the yellow one." Throughout the session, the student and instructor would discuss the importance of each test and also reason through what results might be present. By this point, the instructor had already reviewed the meaning of each diagnostic test and the potential results, so it acted as a review session and an alternative way to build knowledge.

The student and instructor then reviewed results the following week. These individual meetings acted like mentor research meetings, where a principal investigator would be asking what results were achieved and discussing what they meant (Linn et al., 2015). Students could see the color changes and new appearances to their selected specimen thanks to the cell phone video. Students also received pictures of their samples shared through Microsoft Teams. The purpose of sharing images was to provide students with the materials to create their posters and presentations for the now virtual symposium. Finally, students worked in small cohorts via Zoom meetings to discuss plans for the data obtained and critique final symposium materials as part of peer review before the live online symposium occurred. Some student groups worked very effectively to help each other improve their presentations.

Findings

This qualitative and exploratory study presents preliminary results from one semester of student data, which was directly impacted by an unforeseeable national emergency—the COVID19 pandemic. Our curriculum and methods were directly impacted by the pandemic as noted above, so these results include the impact of remote learning, which was noted by some students. Though not the ideal situation, the circumstances did lead to several developing themes, which can be considered significant as nearly 63% of the class consented to the study.

Students had recorded weekly oral journals, along with discussions, posters and symposium presentations, to explain what they had learned and express how it could affect their current lives and future careers. Several major patterns of content interaction, especially within the oral journals, became apparent. First, some students focus solely on what was important to them and why, but fail to address any of the protocols or terminology learned that week. Second, some students explain protocol details very precisely, but using everyday language more than the scientific terminology, so that their explanations utilized simple terminology and stressed steps, but lack explanations of importance. Third, some students incorporate a little bit of both perspectives, for they include somewhat detailed explanations of protocols and use terminology, but then also reflect on how these techniques are important to their future work. The student sample of 22 student falls nearly evenly within these three grouping.

Beyond their interaction with the material and reflection about what they learned, patterns about how the students approached doing the oral journals also surfaced. Within this category, some students tend to be very brief and direct with their commentary. Other students take the recording as very conversational, including what they did and did not like about lab that week, as well as adding their terms and techniques. Finally, some students became the storytellers. These were students who moved beyond just giving brief answers, but were explain the process and then try to connect it to something in their lives. A few students were very open about situations affecting them, which did seem to become more apparent at the very beginning of the course and then again after we discussed COVID19 and the issues we were facing during the pandemic. Some of these students brought in a theme, for example one student ended every session talking about why maintaining a clean environment and preventing contamination would be useful in her future career as a nurse.

Students' storytelling also embraced their lives. For example, illnesses that they experienced they were able to relate to how to diagnose an infection as a result of skills they learned in class. A student mentioned being recently diagnosed with a bacterial infection one week and noted that it was interesting to see how the aseptic (clean) techniques from class could be used to gather a sample from the student in order to isolate the bacteria and make the diagnosis. The procedures of the laboratory had meaning to that student. Another student commented on how each of our lab experiences would apply within the nursing profession. That student focused on the actions the student would take during shifts at the hospital. When someone did not wash their hands, that student commented to the person about why hand hygiene was so important and tried to remind them that washing hands can save lives. Many of the students grasped the idea that surfaces they touched regularly had germs on them and that the surfaces needed to be cleaned more and that they needed to wash before touching other things.

When examining the experiences and procedures performed in class, some lessons were discussed more by the students. Handwashing to prevent disease was important to them and many noted how being deliberate about gathering materials so they could prevent transfer had to be a method of focus. Additionally, aseptic technique to prevent contamination was important to them, as they did not want to get the wrong diagnosis. Then Gram staining and its connection to antibiotic type was of great interest to them, as it was something they could see, did not struggle with performing, and could narrow down the class of antibiotics needed, as they understood that some types of antibiotics did not work well on Gram negative organisms, which was a concept from a previous lesson. Finally, pipetting was a technique that they initially noted as difficult, but when the context of the procedures changed from just transferring a liquid from point to point and was about working with a bacterium, then the procedure took on a whole new meaning and made sense because there was something else to see.

In contrast, some concepts were hardly discussed, which suggests that the comprehension of the topic was also less. The main concepts that fell into this category were the differential and selective media plates, as well as biochemical tests, that were part of our remote experience. The students knew that the media would help them narrow down their bacteria from other potential organisms, but why tests were performed or what the tests could tell them did not make it into regular journals. Students did mention the tests during their practice presentation, but presentations were also recorded with their posters present to them. Whether the form of lesson was the sole influence for the lack of discussion or if it was related to the number of tests occurring at the time due to the change in format is hard to decipher.

As the class discussed the coronavirus, the ways it spread, the symptoms it caused, how to mask properly, along with the concerns the students had, the oral journals and discussions began to reflect an understanding that what was going on with this contagious virus was not normal. Students within a month of being remote and in lockdown realized that we needed to do more to prevent the spread. Students expressed concerned for healthcare workers in the field and hoped people would wear masks properly and stay home to help the process. Several of the students accepted that it was hard to for them stay home, since they were not used to doing so and many still had to go to work. They understood that you have to leave home to make money in many cases. However, about a quarter of those participating in the study also noted that they believed this pandemic would change how healthcare was provided. Unfortunately, several of them also feared that the changes going on, like wearing a mask, were going to become part of their everyday lives. They were, in general, also concerned that "COVID will never end."

Beyond COVID19 impacting their home lives, the students commented about how the research process changed as a result. The change to the curriculum layout removed for several students their way to connect their experiences to the concepts. They explained this made the material harder to learn. They noted that being online was different and in general, they did not like being online for their lab classes. They missed being able to do the procedures we were talking about during the lecture portion. Seeing it was not the same as doing it. The plates we had inoculated together during our Zoom sessions were interesting, but they wished they could see the details. Without being able to repeat some tests because of possible contamination or confusing results due to time and material constraints, the affected students became frustrated with the process, as their results were not as clear as they would have desired. It is important to note that students had expressed their frustration with procedures before the pandemic, but some of these issues became repetitive themes in their oral journals after the pandemic.

Overall, several themes were present in students' responses. 1) Students believed that handwashing was extremely important, not only to healthcare workers, but to everyone. This theme began at the beginning of the semester when we discussed handwashing, but for multiple students was carried throughout their discussions. Additionally, after the rise of coronavirus, the importance of handwashing again came into discussions of a number of students. 2) The students believed that knowledge of antibiotic use and ability to aid in discovery were crucial factors for students entering allied health careers. Many students were concerned that antibiotic resistance was developing for more bacteria each year. They had basic understandings of how and why antibiotic resistance was growing and wished that more people would be educated about the issue. They were also excited to know that their work could potentially have an impact on this battle, for they understood that without new antibiotic research one day we could have diseases that might not be able to be treated, which would change healthcare altogether. 3) Students expressed an interest in expanding their work to investigate connections between their projects and potential future treatments for the current coronavirus. 4) Students also desired to perform those last hands-on activities, for they suggested that seeing it under a camera was different than doing and seeing it in person, which changed their experience. 5) In general, students appreciated the experience, wished it were not interrupted, and would go participate again.

Discussion

In examining how this CURE implementation applied to transformative learning, the elements of transformative learning were present throughout. In contrast to many lectures, especially in science, learning has focused on portraying content, while failing to bring experiences to students to allow them to apply information to their own lives. Unfortunately, many laboratory courses have also been directly to that same type of portrayal rather than creating the experiences to put practical techniques into action. This antibiotic discovery CURE provided nursing students with experiences for the processes needed to discover bacteria with the potential to create antibiotic type compounds. Since nurses and common citizens need and utilize antibiotics, the content for the course then has a visible connection to student lives.

Beyond the issues raised from the COVID19 pandemic, the opportunity given for storytelling also faced its own challenges. On the face of it, some students were challenged with the technology, for they had bad connections which disrupted the flow of their ideas (or at least interpretation of such) or had problems using the technology the first few times ("Is this recording? No, it can't be recording." Stop recording). Additionally, the generalized layout of content that should be covered within an oral journal (i.e., explanation of the week's protocols and terminology, how it applies to your life, and how it applies to your future profession) were taken as a script. Some students only answered these questions and did not elaborate upon them. For several of these students, storytelling and reflection really were not achieved, as the content of the oral journal seem to be very blunt. Unfortunately, As McKillop (2005) notes, providing such a listing for content can be for some students as a simple checklist. When they are focused on completing the items on the list, the reflective aspect is lost.

Multiple students mentioned being hands-on learners and losing the hands-on component changed everything for them. For these students, per their oral journals, the amount of reflection also reduced because they no longer could go through the process. The change was apparent as several of these students had embraced storytelling before the pandemic began and had previously included significant details. This unintended change could be reflective of how these students embraced the experience of doing the science as physically manipulating items in space. Concepts of hands-on learning in science support these students' experiences. As Satterthwait (2010) notes, "cooperative learning, object manipulation and embodiment, contribute to the underlying efficacy of hands-on activities in science education" (p. 9). The ability of the students to touch and feel objects used in the procedures cause neural interactions and involve the whole body. As one student noted, "I just can't organize myself anymore." The simple sensations can help the students make sense of the experience.

Further Research

Given that the semester was disrupted by the pandemic, comparing this first semester with other versions of the course can help see the impact that the remote learning phase had on students and their comprehension of material. Having additional student populations will show if the commentary of those initial weeks includes additional patterns for student perceptions. As of the writing of this manuscript, the SARS-CoV2 virus still rages across the United States and will directly influence the implementation of this CURE for the Spring 2021 semester. It is too early to tell, of course, whether we will return and be able to perform the majority of experiments for the project or not or if antibiotic discovery will move from soil bacteria to another source, including culinary organisms. The use of organism type could be an area to examine to see if students care more about things that come from their foods.

Seeing how modality influences students would be another avenue to examine going forward. One aspect for this type of work would be seeing how a completely remote CURE project could influence student perceptions on topics as noted in oral journals. Also, the hope is one semester we will return to a more pre-COVID experience where students remain in the laboratory working with groups the entire semester, which would actually demonstrate the originally proposed form of this CURE. Here seeing how students interact with the content after a pandemic would also be an interesting twist because these students would have only had a pandemic in their lifetime.

Since students missed out on the experience, if we do have another switch to remote during a semester, are there other methods for having the students continue to perform the work? For students in the region, can small groups be arranged for them to come to campus to do the work, so they can have the experience of doing each test themselves and promote that hands-on aspect. If buildings can be utilized, there is a significant possibility for this option. More extreme social distancing protocols can be implemented, but the amount of time needed to have such operations is significant for a lone instructor. Within the current implementation, the lone instructor invested an hour per student per week for several weeks, which is not sustainable over a long period, as well as not feasible in larger classes. Though, the use of teaching assistants, laboratory assistants, and additional research students has the potential to help expand this opportunity to larger numbers of students.

Additionally, can kits be created to give to students so they can continue with their organism? There is potential for such work, if sufficient time to assemble the kits is provided by the institution and/or state. The switch to emergency remote learning happened when students were away for break and occurred only 10 days before the entire state of Pennsylvania was placed in lockdown. Creating and coordinating such efforts is doable, but would require days for the kits to be designed, approved by Penn State's Environmental Health and Safety committee, prepared for all the media to be used, organized and mailed. However, transportation and disposal could potentially cause problems to this effort. The pedagogy would be worth examining.

Conclusion

Though unconventional, the modified research process saved the CURE. The approach was not implemented ideally, but still managed to engage students in the research process and provide a mechanism for the students to reflect on their experiences. Students were still able to obtain data on their isolated bacteria, in order to learn what made their specimen special, while also having the opportunity to use reflective learning and develop that skill into storytelling. Continuing to provide students with the opportunity to engage in storytelling remains a goal of this CURE implementation and it is hopeful that this methodology will demonstrate to other science instructors that storytelling can bring out the ideas instructors want to focus on, while providing a language for students to express themselves and prepare to communicate those ideas to others.

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Appendix

Fighting for the CURE: Antibiotic Discovery and Storytelling during the Time of COVID

Appendix 1: Syllabus Prompt for Oral Journals

The student will keep an **oral journal** on the procedures assigned to them during the semester. In this weekly assignment, students will record briefly their understanding of the work performed during this week's labs and explain why it is important, as if they were explaining it to someone not in the field. This will help them review why the content is important and prepare for the larger presentation associated with the project. Don't worry about being perfect—that's not the point of the exercise—the point is to gauge how you develop your thoughts as we go through the semester. Let it come naturally and answer the question from the heart using the knowledge you have at each stage.

Recordings can be done on your phone, through the OneStop Presentation area in the library, or on a computer with camera. The oral journal will have its recording done through a Zoom link provided to each student individually, so that it is automatically shared with the instructor for grading purposes alone. Though video is in part easier, voice recording at the minimum is necessary, for I are looking for you to explain your thoughts in your words, your way, and incorporate your story. The instructor is the only one to see recordings to ensure confidentiality, so don't worry about how you look or if you have perfect grammar. Recordings will not be played in the office or public areas. At the end of the semester after all grading is complete and grades are submitted, recordings will be deleted.

Appendix 2: Grid System Promoted to Students to Aid in Oral Journals

Since some students expressed in class that they might forget things, the instructor suggested a tool to aid in their oral journals, so they could provide themselves some key words to help trigger thoughts.

Appendix 3: Original Course Outline Set before Pandemic.
All Exercise (Ex) Numbers are from the Essential Microbiology Laboratory Theory and Application by Leboffe and Pierce.

Wk.	Tuesday Tasks/Assignment	Thursday Tasks/Assignment
1	Introduction; Safety; Handwashing; Ex. 1-1 Glogerm	**Safety Quiz**; Ex. 2-1 Ubiquity of Microorganisms
2	Results from Ubiquity; Ex. 1-2 Aseptic Technique	Results from Aseptic Technique; Ex. 1-3 Streak Plate
3	Results from Streak Plate; Ex. 1-4 Spread Plate	Results from Spread; Ex. 2-7 Anaerobic Jar
4	Results from Anaerobic; Pipette and Dilution Lecture and Practice	Ex. 2-12 Standard Plate Count
5	Results from Standard Plate Count; lecture on antibiotics and antibiotic resistance; examination of prepared germicide plates from Ex. 2-11; background on project	Soil attainment at start of class; Soil plating with dilutions in class (on Canvas instructions)
6	Results from soil plating; pick and patch (on Canvas instructions)—master plate formation	Pick and Patch for antibiotic production to initial bacterial resistance (on Canvas Instructions)
7	Ex. 3-1 Introduction to Light Microscopes; Examination of Bacteria (on Canvas instructions)	Results Pick and Patch; Streak of desired cultures that show antibiotic production (on Canvas instructions); remake Master Plates
8	Pick and Patch for antibiotic production to initial bacterial resistance (on Canvas Instructions); **Assigning Formal Midterm Essay**	Ex. 3-3 Simple Stains, Ex. 3-4 Negative Stains, Ex. 3-5 Gram Stain to Characterize Chosen Bacteria
	Spring Break – No Class	Spring Break – No Class
9	Results Pick and Patch; Streak of desired cultures that show antibiotic production (on Canvas instructions); **Midterm essay due**	Selective Media for Selective Cultures– Ex. 4-1 Mannitol Salt Agar (MSA), Ex-4-2 MacConkey Agar (MAC), Ex. 4-3 Eosin Methylene Blue Agar
10	Results from Selective Media, remake Master plates with chosen strains from streaks; Bacterial Metabolism Lecture	Fermentation studies on Chosen Bacteria, Ex. 5-2 Phenol Red Broths, 5-3 Methyl Red and Voges Proskauer; Respiration tests 5-4 Catalase test, 5-5 oxidase test, 5-6 Nitrate Reduction Test
11	Results from Fermentation and Respiration; Nutrient utilization 5-7 Citrate, 5-9 Starch Hydrolysis (Amylase), 5-11 SIM Media, 5-12 Triple Iron Agar, 5-14 Blood Agar; On Canvas 5-14 Gelatinase printout, On Canvas 5-13 Caseinase printout	Results from Nutrient Utilization; Streaks for Purification and Isolation (on Canvas); Discussion of Results to Date what they mean in general—**make appointment to meet instruction for your specific results**
12	PCR lecture and PCR prep (on Canvas instructions) and sizing up best antibiotic producing samples (on Canvas instructions)	Gel electrophoresis and sending samples; Antibiotic TestingEx—6-1 Antimicrobial Susceptibility Test: Disk Diffusion (Kirby-Bauer) Method on your samples to determine if your bacteria have resistance to any antibiotics

13	Results from Kirby Bauer; Antibiotic extraction part 1 (on Canvas instruction)	Antibiotic extraction part 2 (on Canvas instruction)
14	Antibiotic testing against Eukaryotes (on Canvas instructions)	Final Results; Make up day; Working on Posters/Presentations
15	**Presentations (Research Forum)**	**Final Practical**

Appendix 4: Proposed Course Schedule Change Assuming a Return to Campus
The course went essentially as scheduled through week 8 which was before spring break in March. Penn State University moved to remote learning during the middle of spring break because of rising cases of the SARS-CoV2. Emergency remote learning was initially scheduled to last several weeks, so the schedule below was proposed and explained to students.

Tue	Tuesday Tasks/Assignment	Thu	Thursday Tasks/Assignment
3/17	**Midterm essay due** Explanation of changes for labs upcoming—and modifications to assignments (syllabus changes) Lecture Content on: Abstracts, Posters and initial preparations using already determined materials. Tech aspects for the projects and presentations Students will be required to make contact with the instructor on progress before April 14.	3/19	Lecture Content on: Selective and Differential Media with purposes—Ex. 4-1 Mannitol Salt Agar (MSA), Ex-4-2 MacConkey Agar (MAC), Ex. 4-3 Eosin Methylene Blue Agar
3/23	Lecture Content on: Bacterial Metabolism Lecture—Fermentation studies on Chosen Bacteria, Ex. 5-2 Phenol Red Broths, 5-3 Methyl Red and Voges Proskauer; Respiration tests 5-4 Catalase test, 5-5 oxidase test, 5-6 Nitrate Reduction Test	3/26	Lecture Content on: Nutrient utilization 5-7 Citrate, 5-9 Starch Hydrolysis (Amylase), 5-11 SIM Media, 5-12 Triple Iron Agar, 5-14 Blood Agar; On Canvas 5-14 Gelatinase printout, On Canvas 5-13 Caseinase printout
3/30	Lecture Content on: PCR lecture and PCR prep, Gel electrophoresis, and DNA testing, including connections to Coronavirus	4/2	Lecture Content on: Types of viruses commonly worked with in laboratory settings; Virus propagation and purification in a lab setting; Phage Therapy
4/7	Laboratory in Person Content: Students will set up tubes for Fermentation studies on Chosen Bacteria, Ex. 5-2 Phenol Red Broths, 5-3 Methyl Red and Voges Proskauer; Respiration tests 5-4 Catalase test, 5-5 oxidase test, 5-6 Nitrate Reduction Test	4/9	Laboratory in Person Content: Results from fermentation; students will set up plates with selective and differential media with purposes - Ex. 4-1 Mannitol Salt Agar (MSA), Ex-4-2 MacConkey Agar (MAC), Ex. 4-3 Eosin Methylene Blue Agar
4/14	Laboratory in Person Content: Results from Selective and Differential Media; 5-7 Citrate, 5-9 Starch Hydrolysis (Amylase), 5-11 SIM Media, 5-12 Triple Iron Agar, 5-14 Blood Agar; On Canvas 5-14 Gelatinase printout, On Canvas 5-13 Caseinase printout	4/16	Antibiotic Testing – Ex. 6-1 Antimicrobial Susceptibility Test: Disk Diffusion (Kirby-Bauer) Method on your samples to determine if your bacteria have resistance to any antibiotics; Antibiotic extraction part 1(on Canvas instruction)
4/21	Results from Kirby Bauer; Antibiotic extraction part 2 (on Canvas instruction)	4/23	Antibiotic testing against Eukaryotes (on Canvas instructions)
4/28	Working on Posters/Presentations	**4/30**	**Symposium**
Final Exam Week – Final Practical – online availability			

Appendix 5: Catastrophic Course Schedule Change with Considerations of Pandemic.
The course went essentially as scheduled through week 8 which was before spring break in March. Penn State University moved to remote learning during the middle of spring break because of rising cases of the SARS-CoV2. Emergency remote learning was extended for the remainder of the semester, which led to schedule below.

Tue	Tuesday Tasks/Assignment	Thu	Thursday Tasks/Assignment
3/17	**Midterm essay due** Changes to Schedule and Assignment due dates Lecture Content on: Abstracts, Posters and initial preparations using already determined materials. Tech aspects for the projects and presentations	3/19	New Updates on changes Lecture Content on: Selective and Differential Media with purposes and Bacterial Metabolism Lecture
3/2-3/27	In order to continue the project so students learn some of the content per their own results, meeting for the next two weeks will be individually based. Students will schedule a time to live stream with the instructor. Ms. Smith will be in a lab to set up samples for each student. Students will instruct Ms. Smith on how to perform tasks and explain what bacteria to test. Students will have the ability to take notes on the set up and will meet again next week for the results meetings, which will also be individual. Ex. 5-2 Phenol Red Broths, 5-3 Methyl Red and Voges Proskauer; 5-4 Catalase test, 5-5 oxidase test, 5-6 Nitrate Reduction Test; Ex. 4-1 Mannitol Salt Agar (MSA), Ex-4-2 MacConkey Agar (MAC), Ex. 4-3 Eosin Methylene Blue Agar; 5-7 Citrate, 5-9 Starch Hydrolysis (Amylase), 5-11 SIM Media, 5-12 Triple Iron Agar, 5-14 Blood Agar; On Canvas 5-14 Gelatinase printout, On Canvas 5-13 Caseinase printout; Nutrient agar or Tryptic Soy Agar for sample to store		
3/30-4/3	Students will have the ability to take notes on the results meetings, which will be individual.		
4/7	Lecture Content on: PCR lecture and PCR prep, Gel electrophoresis, and DNA testing, including connections to Coronavirus	4/9	Lecture Content: Explanation of SARS-CoV2 virus structure and pathogenesis
4/14	Lecture Content: Explanation of SARS-CoV2 virus	4/16	Lecture Content on: Other types of Virus testing; Phage Therapy
4/21	Lecture Content: Other Common Laboratory Tests—6-2 Kirby Bauer Antibiotic Disc Susceptibility Testing and Throat Cultures	4/23	Poster work session online with peer reviews—during regular lab time on Canvas
4/28	Working on Posters/Presentations and final run through with Ms. Smith and peer groups	**4/30**	**Digital Symposium**—Digital Symposium during class time. Materials for symposium due by day before.
Final Exam Week—Final Practical—online availability			

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Additional Note: A description of the use of Zoom technology for laboratory interaction during the pandemic was included in a paper submitted by this author to the Journal of Microbiology and Biology Education. There are no conflicts of interest to disclose.

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