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National Center for Science and Civic Engagement
2000 P Street NW Suite 308
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About the Journal

Science Education and Civic Engagement: An International Journal is an online, peer-reviewed journal. It publishes articles that examine how to use important civic issues as a context to engage students, stimulate their interest, and promote their success in mathematics and science. By exploring civic questions, we seek to empower students to become active participants in their learning, as well as engaged members of their communities. The journal publishes the following types of articles:

- *Book & Media Reports*
- *Point of View*
- *Project Reports*
- *Research*
- *Review*
- *Science Education & Public Policy*
- *Teaching & Learning*

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SCIENCE EDUCATION & CIVIC ENGAGEMENT
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From the Editors

We are pleased to announce the Summer 2017 issue of *Science Education and Civic Engagement: An International Journal.*

Barbara M. Anthony and **Kathryn M. Reagan** (both at Southwestern University) describe an operations research course in which students partner with local nonprofit organizations. While working with these organizations to optimize their operations, students learn about the issues faced by nonprofits in a real-world context. This article demonstrates that community partnerships can be incorporated into technical filed such as operations research.

Although 22% of the U.S. population lives in rural areas, there is a paucity of research on STEM education issues in these environments. **Sara L. Hartman, Jennifer Hines-Bergmeier,** and **Robert Klein** (all at Ohio University) provide a review of the research literature on informal STEM education in rural communities, with a focus on early childhood education. Based on their analysis, the authors propose that science educators should create and sustain relationships between rural schools and informal STEM partners.

Kim Trask Brown (University of North Carolina Asheville) reports on a science methods course for trainee K-6 teachers, which enabled them to develop event activities and serve as leaders for the regional Science Olympiad Competition. Based on written reflections and survey data, the author concludes that the trainee teachers gained scientific content, pedagogical skills, and desirable professional dispositions related to civic engagement.

Kevin Finn (Merrimack College) provides an account of an undergraduate health sciences course that taught research methods through a partnership with an outdoor education program for 3rd and 4th grade students. The undergraduates provided STEM activities for the elementary school students, and developed their understanding of research methodology by conducting their own research investigation.

Jill Nugent and **Kelly Thrippleton-Hunter** (both at Southern New Hampshire University) examine the challenge of providing experiential learning opportunities for students who are taking online courses. Focusing on an online course for Environmental Science and Geoscience Majors, the authors describe various opportunities for students to gain experience in service learning and civic engagement. Some examples take advantage of technology-enhanced education, such as using the iNaturalist app to organize a collective venture to census local species.

Rae Ostman (Arizona State University) describes a multi-institutional collaborative entitled Nano and Society, which fosters conversations among community members, educators, scientists, and others about nanotechnologies. The author demonstrates how the project supports participant learning within an informal education environment.

The project report by **Davida S. Smyth** (Mercy College) shows how a faculty member's research interests can be used as the foundation for providing students with an authentic research experience in an undergraduate course. During an elective microbiology course, students examine the problem of antibiotic resistance using bacteria that are collected on their own college campus. As part of this investigation, they learn various techniques for preparing and characterizing bacteria, including modern methods of microbial genomics. In this manner, students acquire foundational techniques in microbial analysis while learning about an important global health concerns in the 21st century.

In conclusion, we wish to thank all the authors for sharing their educational initiatives with the readers of this journal.

Community-Engaged Projects in Operations Research

BARBARA M. ANTHONY
Southwestern University

KATHRYN M. REAGAN
ThoughtWorks and Southwestern University

Abstract

Community-engaged learning is not very common in technical fields, but including relevant projects in courses can make it feasible and successful. We present an implementation of an operations research course at a liberal arts college. Working with one of four nonprofit community partners to optimize aspects of their organization, students gained insight into relevant, real-world applications of the field of operations research. By considering many aspects of their solution when presenting it to community partners, students were exposed to some issues facing local nonprofit organizations. We discuss the specific implementation of this course, including both positive learning outcomes and challenging factors.

Introduction

Operations research, a "discipline that deals with the application of advanced analytical methods to help make better decisions" (INFORMS 2017), is used by many organizations. Southwestern University, a small liberal arts college, offers an operations research course cross-listed as business, computer science, and mathematics, which broadens opportunities for students to take computer science courses (Anthony 2012). While civic engagement is popular in colleges, its incorporation into the classroom is less prevalent in STEM disciplines (Butin 2006). Though some computer science courses incorporate community-engaged learning, it frequently occurs in a senior capstone experience (Bloomfield et al. 2014). An interdisciplinary course taken before the senior year can provide more realistic experiences in working with people from different backgrounds. Project-based courses are not uncommon in operations research; colleges are sometimes even paid by outside corporations for such projects (Martonosi 2012).

The operations research course's popularity and increasing support on campus for community-engaged learning worked synergistically to have projects proposed by local community partners (nonprofit organizations) in 2014. The Southwestern University Office of Civic Engagement (OCE) helped facilitate these projects by aiding in the solicitation of partners, providing continuing education to the faculty member, and providing a student Community-Engaged Learning Teaching Assistant (CELTA), whose duties included serving as a liaison between student groups and community partners. The CELTA was a computer science major who had previously taken courses with the instructor and had worked for the OCE for multiple semesters. Together, the instructor and CELTA investigated the value that students found in the project experience, in terms of both more traditional goals of community-engaged learning and the content typical of an operations research course. In the four projects, students partnered with a hippotherapy organization, a local chamber of commerce, and two units on campus.

Methods, Projects, and Partners

Students engaged in a semester-long team project partnering with local nonprofit organizations to solve a problem in need of optimization. Four student teams, working both in class and on their own time, submitted a proposal, a poster with preliminary results, and a final report including an executive summary and full technical details. They also made a final presentation to classmates, the professor, and their community partners. The course is typically a student's first introduction to operations research. Thus, students are learning the basics of the field while simultaneously applying the ideas presented in the course to their project with the community partner. Both quantitative and qualitative data were collected from students about their experiences, with approval from the university's Institutional Review Board. Students were asked identical questions about their attitudes toward community service in general, taken from Bringle's (2004) *The Measure of Service Learning: Research Scales to Assess Student Experiences*, before project groups were assigned and at the end of the semester, while final project reports were being prepared. All answers were given on a 1–7 Likert scale of likelihood (extremely unlikely to extremely likely) or agreement (strongly disagree to strongly agree). The qualitative data was collected from multiple sources, including meetings with the instructor and CELTA, peer and self evaluations, final exam questions, and course evaluations.

Two of the community partners came from area nonprofit organizations: Ride On Center for Kids (R.O.C.K.), a hippotherapy organization, and the Greater Leander (Texas) Chamber of Commerce. The other two partners were internal to the university: the Center for Academic Success and Records (CASAR) and the directors of the new incarnation of Paideia, an interdisciplinary curriculum program unique to Southwestern.

R.O.C.K. "provides equine-assisted therapies and activities to children, adults, and veterans with physical, cognitive, and emotional disabilities" (R.O.C.K.). R.O.C.K. aims to serve as many clients as possible while using limited resources (including staff, arena time, and horses) appropriately. Clients' needs determine whether the therapy sessions are individual or small groups. Students formulated appropriate linear programs for modeling the constraints and objectives, and analyzed the solutions under various assumptions (such as the number of hours a horse can be used each day or week). They recommended that R.O.C.K. alter operating hours to better utilize resources while still serving the same number of clients and prioritize the acquisition of additional horses.

The Leander Chamber of Commerce (LCC) has four membership plans, with different prices and benefits. As a nonprofit, they want to be sustainable while providing value to their members. Students first used linear programming techniques to determine optimal pricing for each of the plans while keeping the same benefits, under the limiting assumption that members would stay on the same plan. They then used knapsack problem techniques to determine the ideal combinations of benefits in the plan that provide the most perceived value to the members for a given cost. As costs and perceived values change and new benefits are considered, LCC can use provided software tools to update offerings.

Currently at Southwestern, academic advisor/advisee assignments are made manually, a time-consuming and suboptimal process. Students worked with the Center for Academic Success and Records to convert their process into a flowchart, assigning measures for compatibility based on stated academic interest and predictors of transitional challenges. The assignment can now be considered as a transportation problem, maximizing the compatibility indicators of the entire incoming class while limiting the number of advisees assigned to any one advisor. The team used a Java program to parse data about students, fed that information to a tool called glpsol within the Gnu Linear Programming Kit (GLPK), to solve the transportation problem, and again used Java to present the output cleanly.

Beginning in Fall 2014, as part of a reconfigured Paideia program, all students are part of an interdisciplinary cluster, making connections across disciplines through a subset of required courses. There are numerous tradeoffs to be considered, for faculty, students, and the university as a whole, when considering the ideal number of clusters, courses, and faculty per cluster. Students developed an Excel tool to model these relationships that will be used by present and future Paideia directors in their decision making. Their recommendation of three new clusters per year provided an ideal balance of number of courses available to students and faculty in the cluster, while allowing for changes in class size in future years.

The creation of groups in a course project often poses an interesting dilemma. Each group had at least one person from each of the three predominant majors represented in the course: computer science, math, and business or economics. For the projects where it was anticipated that higher-level programming languages would be used (as opposed to Excel), multiple computer science majors were assigned. Students were required to complete a questionnaire with questions including their preferences among the projects, their willingness or ability to work with an off-campus partner, and published personality questions in a STEM text (Burger 2008). The instructor and CELTA then assigned groups, based on those responses and their prior experiences in the classroom.

Research on Student Experiences

In the following table, we report some of the statements that most students agreed or strongly agreed with. We also note that most disagreed with the claim "without community service, today's disadvantaged citizens have no hope."

Responses to the final survey were largely similar to the preliminary survey with regard to the number of students who felt an outcome was likely or agreed with a statement, but when quantified as described above, many of the averages for each question fell. (Given the small sample size, 21 students, we look more at general trends than actual numbers.) The other statements in Table 1 changed by at most 0.1 points.

The differences in the average responses are small. Students answering less enthusiastically (e.g., "somewhat likely" instead of "likely" or "agree" instead of "strongly agree") may have felt no differently in the final survey and simply had a hard time discretizing their response. Alternatively, a slight decrease in enthusiasm in final responses may be indicative of end-of-semester fatigue. As students typically did not interact directly with clients of the nonprofit partners, they might not have been able to see the outcomes and benefits of their projects. They

TABLE 1. Selected statements most students agreed with in the preliminary survey, and the percentage of students who responded with agree or strongly agree (6 or 7 on the Likert scale). For all of these statements, the number of students who answered slightly agree (5 on the Likert scale) was at least an additional 10 percent.

Likeliness of experiencing personal satisfaction knowing they are helping others during this service project. 86%
College student volunteers can help improve the local community. 81%
Improving communities is important to maintaining a quality society. 71%
There are people in our own community who need help. 86%
It is important to help people in general. 86%

TABLE 2. Average responses to statements in the preliminary survey and final survey.

	Preliminary Survey	Final Survey
Likeliness of experiencing personal satisfaction.	6.2	5.9
Our community needs good volunteers.	6.0	5.8
College student volunteers can help improve the local community.	6.1	5.7
Improving communities is important to maintaining a quality society.	6.0	5.8

might have also recognized that many clients served by their partners are not socio-economically disadvantaged and perhaps not people whom they would see as "in need."

Since team dynamics can play an important role in the success (or lack thereof) in any group project, students periodically evaluated the contributions of their group members. They rated each group member on a scale of 0 to 4, including themselves, indicating whether they were a team player, the amount of effort put forth, whether they were dependable, their intellectual contribution, and their overall contribution. Student were told that specifics would not be shared with the group members, but the instructor would be speaking with anyone who did not seem to be contributing adequately, in an effort to allow them to improve their performance. Additionally, evaluations would be considered in calculating each student's participation grade, but except in extreme cases, would not affect the project grades. The provided instructions and reminder that it is highly unlikely that everyone is excellent at everything seemed to lead students to give considered answers. In addition, they wrote a single sentence for each group member (including themselves) about their overall impression of said member's performance. These comments typically suggested most group members were pulling their weight. Sometimes their disciplinary backgrounds meant they were a stronger contributor in one area than another. For example, a student who had more accounting experience might be especially skilled at reading financial statements and explaining their contents to others who have more programming experience. This exercise, along with in-class discussions, seemed to help mitigate some of the tensions that occasionally arose with the differences between majors/backgrounds.

The final exam included questions eliciting the benefits and drawbacks of having a group project with a community partner. A few students felt the group project prevented them from learning additional course material because of the time devoted to working on the project. However, most enjoyed delving into a large and real problem. One student noted that "it exposed us to another learning method," another said through the projects students "saw applications of theory which reinforced the ideas learned in lectures," and a third indicated that "'What can I do with this class/theory?' actually gets answered." (In accordance with the IRB consent forms, student quotes are not being attributed to specific individuals.) While many people often think of the benefits of operations research first in terms of money (whether increasing profit or cutting costs), the projects helped students focus on other things that can be optimized, as illustrated in this response: "The group projects gave much more of a feel of the complexities of optimizing real world situations, particularly when profit is not the most important quantity to an organization." Other students talked about the benefits of the project being in the "real world," and of working in teams similar to their anticipated future work environments. A student summed up much of the motivation for doing the group project with community partners in the observation that "reading case studies or doing fictitious projects does not provide the same sense of urgency and rewards as doing a project for someone who can actually benefit from it." The student comments echo many of the benefits purported in literature about community-engaged teaching, including deeper understanding of course material and the ability to transfer knowledge (Furco 2010).

Most drawbacks students reported were logistical in nature, either with their group members or community partners. Frequent concerns were difficulty scheduling meetings (with or without the community partner) and having access to information. One indicated that "people bringing different backgrounds was a benefit in tackling our project, but it was hard to balance the work and make sure everyone pulled equal weight," which led to concerns about receiving a group grade for the project (cumulatively, twenty-five percent of the final course grade). Another stated that community partners "did not fully understand the benefits and applications an OR student can provide" and had nebulous expectations, whether expecting too much or too little. Only a few students indicated a concern that the project resulted in "less time learning concepts with the professor," and most viewed the experiential learning as likely to be retained longer. Most students indicated a desire to keep this component of the course.

Just as the small sample size limits statistical analysis, the frequency of the course offering (typically once every two or three years) and the varying nature of the projects and partners limit meaningful longitudinal studies. One wonders whether such projects increase student engagement and satisfaction, possibly with positive impacts upon retention and graduation. Anecdotally, all non-visiting students in the course have in fact graduated from Southwestern, but given that the students were typically juniors or seniors, that is unsurprising. Likewise, with the variety of majors enrolled and the differences in the projects, other assessments of impacts on overall academic performance are limited. However, in the future it may be possible to determine whether there is a correlation between students' performance on exams and the specific skills and techniques used in their projects.

Discussion: CELTA, Community Partner, and Instructor Reflections

Each team met with the CELTA three times. The first meetings were primarily introductory in nature. Each group had held its first meetings with community partners and was involved in initial planning stages. The two groups working with on-campus partners both had a strong start, with detailed plans in place to find their solutions. Likely because of the connection to campus and the professor's connection to these projects, the expectations were communicated more clearly than those tied to the projects that were based off campus. In contrast, the off-campus partners had more of a vision to be interpreted than a concrete plan to be executed. Though students are often more comfortable with precise directions, the real-world experience of uncertainty and ambiguity is quite valuable.

In the second round of CELTA meetings, group members were still excited but now had some concern about partially completed projects and looming deadlines. The groups had all made substantial progress and were working on posters to be presented at a campus symposium. Three of the four groups were now experiencing more of the challenges of a real-world project, where the scope or goals can change over time. The Academic Advising group felt that some of the partner's requests were growing beyond the original requirements, but had difficulty scheduling face-to-face meetings to discuss the limitations. The Paideia group had the fewest communication obstacles, likely because the primary contact is a professor in the math department. As such, many group members already had a working relationship with her, and would often drop by her office for immediate feedback.

At this point, groups had already considered the obvious stakeholders, but were now asked to reflect further on the non-obvious stakeholders affected by their project, which can be equally important when modeling problems. The Academic Advising group had identified students and professors as the obvious stakeholders, with counseling services and parents as non-obvious stakeholders; both are concerned with students' overall well-being and stress levels, which can be impacted by advising. The Paideia group noted students as the obvious stakeholders, and considered professors as non-obvious stakeholders, due to teaching load and leave considerations. The projects with off-campus partners, not surprisingly, had different stakeholders, with interesting implications. The member working with R.O.C.K. identified the horses as a non-obvious stakeholder. While meeting the needs of obvious stakeholders (the clients, and if they are minors, their parents), it is important to ensure that the horses do not get overworked. Accordingly, group members had to familiarize themselves with seemingly restrictive regulations that R.O.C.K. adheres to concerning the number of hours a horse should work per day and needed to incorporate those into their problem formulation and solution. For the LCC, member organizations are obvious stakeholders, and group members identified residents of Leander as non-obvious stakeholders, since each new resident of Leander receives a directory of businesses that are chamber members, and said membership confers certain credibility. In all groups, students realized that projects can have far broader impacts than initially considered.

The final round of CELTA meetings occurred toward the end of the project, while groups were finalizing their linear programs and solutions and writing their final paper. The completed project portfolio was provided to the instructor and the community partner, and each group gave a final presentation to the entire class, inviting their community partners to attend. While not all partners were able to attend, the possibility that the partner would be present ensured that students had to thoroughly motivate the assumptions made for the project and explain why they were reasonable. All groups already had experience presenting as a team from the campus symposium. Additionally, the poster presentations had increased student enthusiasm when they realized how interested their peers and faculty were in their projects. This was especially true for the groups working with on-campus community partners; students and faculty were able to ask specific questions because they were already familiar with Paideia and the Academic Advising process, which alerted members of these groups to issues with their solution that they might not have previously considered. Many group members talked about broader implications of their projects. A Paideia group representative considered optimizing Paideia to be part of the legacy he leaves behind upon graduation. The R.O.C.K. representative appreciated that the project had relevant business applications, and was excited to be able to apply the knowledge learned in the real world. Overall, group members expressed the opinion that it was a positive, albeit challenging, experience.

During the semester, morale was often correlated with the level of engagement of the community partner; groups that maintained good communication with their partner felt more positive about their projects. Communication challenges occurred with both on- and off-campus partners. While the instructor reassured students that projects could earn good grades despite incomplete partner information (with students making reasonable assumptions based on the information they did have), students naturally wanted to deliver products that met their and their community partner's expectations. Groups that believed their partner would implement the proposed solutions were more satisfied with the experience; yet implementation was not always feasible for the partner. Not surprisingly, when a community partner is more invested in a project, a group often does better work. Accordingly, in future offerings the instructor will have more up-front discussions with both the students and the partners about how to facilitate such communication and commitment.

All community partners gave positive feedback about the work completed by the students. The LCC president has benefitted from the tools (e.g. Excel spreadsheets that are easily updatable without any operations research background), the analysis from students, and recommendations from the group about plan offerings and costs. Likewise, R.O.C.K. appreciated the information and made plans to present it to their board. However, like many nonprofit organizations staffed primarily by part-time employees and volunteers, R.O.C.K. experiences frequent staff turnover; the main project contact left the organization shortly after the project was completed, so follow-up has been limited. Likewise, a new director for the Paideia program was selected from the faculty shortly before the class project was completed; she has since used the spreadsheet and tools created and has given positive feedback.

The tools for assigning advisors to advisees require ongoing updates and maintenance by people with sufficient Java knowledge to reflect annual changes such as the number of advisees an advisor currently has. In addition, since the students who need to be assigned are new each year, there is some data processing involved in converting the information students provide on a web form into the format needed for the Java programs and GLPK. Full implementation has not yet happened for various reasons unrelated to the course, but there is support from CASAR staff for eventual usage, and the instructor is willing to do the updates.

One final exam comment was positive overall about the project, but the student wished that the group had "had more time to do more." This issue of the semester-long lifetime of the project is an issue the instructor continues to struggle with. While the deliverable at the end of the semester is expected to be useful to the community partner, often some continued involvement with the partner after implementation would be ideal. Some students may be able to continue the partnership as an independent study, allowing the community partners to have the model refined as they realize limitations, whether due to assumptions the students had to make or to factors that were not readily known in the original problem.

We believe that these projects are in fact rightfully viewed as partnerships, with students acting in a consulting role for the organizations. While there are inherent dangers in community-engaged learning programs that try to "fix" what is "wrong" with a community (Cooks 2004), the partners themselves responded to offerings of these optimization services, and they chose the problem or issue. And of course they also remain in control of how the resulting information is used. Though the instructor and students did have a role in deciding which projects were selected—which does confer a degree of power (Mitchell 2008)—choices were largely based on suitability of the problem for the course (i.e. an optimization problem, not a website redesign). The concern about developing tools without providing people and resources to maintain them long-term, paralleling the concerns of do-gooders who impose their will on others, is worth acknowledging (Illich 1968). We are up-front with the community partners about the time span and limitations, aim to provide useful tools that are easily modifiable, and typically use software (frequently Excel) that their organization already uses.

Partners greatly valued the community-engaged learning relationships with the university, but, consistent with the literature, logistics (student schedules) and communication issues are not easy to overcome (Vernon and Ward 1999). While partners were invested to some degree in the projects, the projects were not their highest priority (nor were they expected to be). The instructor can be more proactive in future years about outlining the expected time commitments and flexibility needed to both the partners when selecting projects and the students when they register for the course. Having tangible results from the 2014 offering may make it easier to solicit future projects, and partners may be more invested when they have a fuller understanding of expected benefits.

Conclusion

This Operations Research course was a productive and positive experience for students and community partners alike. Students benefitted from the hands-on project that required them to apply their knowledge outside of the typical classroom, and gained experience working and solving problems in a large group. The Community-Engaged Learning Teaching Assistant and instructor witnessed student learning in and out of the classroom, and they were able to educate students about community-engaged learning in general while further motivating course content. Finally, the community partners each received a solution to a problem from skilled students, which further strengthened the partnership between Southwestern University and the Georgetown community.

The instructor is committed to continue offering this course with nonprofit partners. Since ideally each project ends with a "solved" problem, partners will often differ from year to year, unlike many community-engaged learning courses which are able to work with the same partners for extended periods of time. Yet organizations may have new problems in mind that are in need of optimization, and can be partners in future offerings. Including presentations from community partners early in the semester could be beneficial, since passion about a project often leads to stronger teamwork, dedication, and enthusiasm about the experience. Though there will always be logistical challenges in courses of this nature, offering a community-engaged learning component in an operations research course is a worthwhile endeavor that results in beneficial learning outcomes and hands-on experience for students, and in tangible products for the partners.

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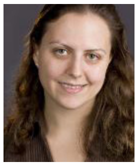
About the Authors



Barbara M. Anthony, (anthonyb@southwestern.edu), the instructor for the operations research course, is an Associate Professor of Computer Science at Southwestern University in Georgetown, Texas. She received her PhD in Algorithms, Combinatorics, and Optimization from Carnegie Mellon University in 2008. She is active in the computer science education community, with a particular interest in introducing students from underrepresented groups to the discipline, and finds ways to bring her theoretical computer science interests into multiple courses.

Kathryn M. Reagan, (kathryn.m.reagan@gmail.com), the CELTA for the operations research course, is a class of 2016 graduate of Southwestern University in computer science. She is currently a consultant software developer for ThoughtWorks. Her passions lie in social and economic justice and computer science education, and she loves finding ways to work within the intersection of those passions.

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Pre-Service Teachers' Acquisition of Content Knowledge, Pedagogical Skills, and Professional Dispositions through Service Learning

KIM TRASK BROWN
University of North Carolina Asheville

Abstract

Teacher candidates seeking a K-6 license took a science methods course during which they participated in focused service learning. Candidates were provided the necessary science content instruction to enable them to write the actual event activities and serve as Event Leaders for the regional Science Olympiad competition. Data related to candidate acquisition of content knowledge, pedagogical skills, and professional dispositions were gathered from candidates' responses to written reflections and standardized surveys. It was concluded that through their practical and engaged work participants learned science content and gained pedagogical skills necessary for teaching science. Further, candidates gained desirable professional dispositions related to such civic engagement elements as developing sustainable partnerships, engaging in mutually beneficial work, and serving a diversity of students.

Introduction

The University of North Carolina Asheville

The University of North Carolina Asheville (UNC Asheville) opened in 1927 as Buncombe County Junior College. The school underwent several name changes, mergers with local governments and school systems, and moves before relocating in 1961 to the present campus.

Asheville-Biltmore College joined the UNC system in 1969 as UNC Asheville, with the distinct mission to offer an excellent undergraduate liberal arts education.

UNC Asheville is the only designated undergraduate liberal arts university in the 17-campus UNC system. UNC Asheville is a public State Institution of Higher Education and is classified as a Baccalaureate College of Arts and Sciences by the Carnegie Classification system. UNC Asheville is accredited by the Commission on Colleges of the Southern Association of Colleges and Schools. The university has received national recognition for its Humanities and Undergraduate Research programs. *U.S. News & World Report* ranks UNC Asheville as one of the top five public liberal arts colleges in its America's Best Colleges edition and lists the Undergraduate Research Program among "Programs to Look For" along with some of the top research universities in the country. UNC Asheville is consistently rated a "Best Buy" in the Fiske Guide to Colleges. UNC Asheville founded the National Conference on Undergraduate Research more than 25 years ago, and the university emphasizes student participation in faculty-mentored research projects. Additionally, most UNC Asheville students undertake career-related internships, and are supervised by university faculty during their time working in the field. Seventeen percent of UNC Asheville students take advantage of study abroad and study away programs. Finally, many courses and on-campus programs engage students in service projects aimed at improving the quality of life at home and around the world, which is a major focus of the university.

Teacher Licensure at UNC Asheville

The mission of UNC Asheville's Department of Education is to prepare candidates for a North Carolina Standard Professional I Teaching license with a liberal arts foundation. The Department of Education engages with all departments across campus in the preparation of professional educators; undergraduate candidates major in an academic area specific to their intended licensure area, along with taking additional courses necessary to earn their North Carolina teaching license. Hence, Education is not a major or a minor, but is an area of concentration in addition to the academic major. This structure reflects the liberal arts model. Undergraduate licensure candidates in K–12 and 9–12 areas major directly in their area of specialty (e.g. those seeking K–12 Art licensure major in Art), candidates in 6–9 areas either major directly in their area of specialty or in Psychology, and candidates in K–6 may choose any major. This model necessitates a strong liaison-based partnership between representatives from each of the academic majors and the Department of Education. Post-baccalaureate candidates who have earned the requisite Bachelor's degree may earn a teaching license by taking the necessary Education courses only, or may take a prescribed set of major courses in addition to their Education courses if they are pursuing licensure in a different area from their undergraduate major. Post-baccalaureate candidates are expected to meet the same program requirements and outcomes as undergraduate candidates. The National Council on Teacher Quality has rated the UNC Asheville Department of Education as a Best Value among North Carolina Colleges of Education, and among the top six teacher preparation programs in the Southeast.

Because UNC Asheville is a liberal arts institution, candidates take Arts and Sciences courses in the departments across campus in which they acquire their content knowledge. Courses taken in the Department of Education are structured to build on this content knowledge in the provision of pedagogical skills. This model is supported by such researchers as Davis and Buttafuso (1994), who provide an historical perspective on the role of small liberal arts colleges and teacher preparation. Their claim is that the type of curricular cooperation that is inherent at liberal arts institutions such as UNC Asheville promotes the development of teachers who are knowledgeable, thoughtful, and reflective.

The schools with which UNC Asheville partners frequently speak to the strength of the liberal arts model. In fact, they claim that the strong content knowledge UNC Asheville teacher licensure graduates possess, coupled with their pedagogical knowledge, puts these graduates at the top of the applicant pool. For all of its strengths and advantages, this liberal arts model does come with limitations. The greatest of these limitations is time in the teacher licensure program. Because Education is not a major at UNC Asheville, and candidates are taking their major and other content courses in other departments, there are precious few hours in each candidate's schedule in which Education courses can fit. All programs have been structured so that undergraduate candidates can graduate with their major and licensure in four years of full-time attendance, but the course of study is intense for these candidates. And this means that Education courses must be efficient at all costs. Therefore, the focus of Education courses at UNC Asheville is almost strictly on pedagogy. It is vital, then, for instructors of Education courses to find ways to reinforce, and in some cases even facilitate the learning of, content knowledge that candidates need—even though Education courses are technically not "supposed to" focus on this.

Background

North Carolina Requirements for Teacher Licensure Programs

In 2009, all licensure programs in North Carolina were revised to meet North Carolina Department of Public Instruction (NCDPI) requirements. As part of these requirements, all licensure programs were to develop Evidences to be completed by each teacher licensure candidate and submitted to NCDPI to show candidate attainment and demonstration of competencies that meet six statewide Standards for 21st Century Teaching and Learning. These standards include candidate attainment of content knowledge, pedagogical skills, and professional dispositions with which the Department of Education at UNC Asheville's Conceptual Framework tenets of Content, Pedagogy, and Professionalism directly align. Following is a summary of the six state-required standards, and the approved Evidences the UNC Asheville Department of Education developed to meet the standards (note that for standards 1 and 4 NCDPI defined a required Evidence for every licensure program in the state)

1. Breadth of Content Knowledge – All candidates completed at least twenty-four semester hours of coursework relevant to the specialty area from a regionally accredited college or university with a grade of C or better in each of the twenty-four hours in order to be licensed. Additionally, all K–6 and Special Education candidates must have received satisfactory scores on the Praxis II exam in order to be licensed.
2. Depth of Content Knowledge – Candidates completed a Content Exploration Project. Data from assessment of this project showed candidates' depth of understanding and application of content knowledge per professional and state standards for the specialty area, and the ability to relate global awareness to the subject.
3. Pedagogical and Professional Knowledge Skills and Dispositions – Candidates created a three- to five-day integrated thematic teaching Unit Plan. Data from assessment of the unit showed candidates' ability to design effective classroom instruction based on P–12 professional and state standards, and use of effective pedagogy and research-verified practice.
4. Pedagogical and Professional Knowledge Skills and Dispositions – All student teachers are evaluated by their supervisor, in consultation with the P–12 clinical faculty member, using the state-required Certification of Teaching Capacity Instrument. All candidates must receive a rating of "Met" on each facet of the instrument on the final evaluation.
5. Positive Impact on Student Learning – Candidates completed an Impact on Student Learning Project. Data from assessment of this project showed candidates' impact on P–12 student learning given state P-12 standards.
6. Leadership and Collaboration – Candidates completed the Professional Development Project: Self, Learner, Community. Data from assessment of this project showed candidates' ability to demonstrate leadership, collaboration, and professional dispositions per professional and state standards for teacher candidates.

Unit faculty applied common rubrics, also approved by NCDPI, to evaluate candidate products related to Evidences 2, 3, 5, and 6, and all candidates had to score a level 3 or higher on each facet of the assignment rubric.

In 2014, the North Carolina State Board of Education (SBE) adopted a policy requiring that all licensure candidates in every licensure area pass the SBE-approved licensure exam(s) for each initial licensure area. For all licensure areas except K–6 and Special Education, these approved exams were the Praxis II. For K–6 and Special Education, the SBE adopted a new Pearson Foundations of Reading and General Curriculum Test. The Pearson Test is comprised of a Foundations of Reading subtest; a General Curriculum Mathematics subtest; and a General Curriculum Multi-Subjects subtest consisting of questions pertaining to Language Arts, History and Social Science, and Science and Technology/Engineering. These subtests are all comprised of multiple choice items testing content knowledge in each area. An Integration of Knowledge and Understanding section is also completed by test takers, which includes a few constructed response items to test pedagogical knowledge. For K–6 and Special Education candidates and licensure programs, the new Pearson Test signified a significant change from the previously required Praxis II exam, which almost exclusively tests pedagogical knowledge. The SBE-adopted policy also included the provision that the Evidences required for standards 2 and 3 would be replaced by candidate scores on the SBE-approved licensure exams. Candidates take their licensure exam(s) as one of the final steps to completing their licensure process, after finishing their licensure program.

Purpose for the Study

The aforementioned liberal arts model and changes to licensure exam requirements posed a new challenge regarding the K–6 licensure program at UNC Asheville. Because of the number of areas in which a candidate must be prepared to teach at the K–6 level (Reading, Language Arts, Mathematics, Science, Social Studies, and Health being among the major ones), the K–6 licensure program at UNC Asheville is by far the largest in terms of the number of Education courses required. UNC Asheville K–6 candidates had enjoyed a 100 percent pass rate on the Praxis II for a number of years before the Pearson test was adopted. However, it is important to remember that the Praxis II centered almost solely on pedagogy. The new Pearson test focuses almost solely on content, whereas K–6 courses focused almost solely on pedagogy in direct alignment with former licensure exam requirements and the liberal arts model. To meet the new requirements, faculty in the K–6 program at UNC Asheville began work to structure courses and experiences to ensure that candidates were provided the knowledge necessary to make them successful in their quest for a license and with regard to the competencies required to be effective teachers, while continuing to serve the needs of the public schools and community. This researcher serves as the instructor for the Elementary Science Methods course and worked to structure the course and provide candidates with science-related learning experiences for these reasons. This project grew as a result of this structuring and the desire to determine its impact.

Specific Goals for Candidates, Students, the Community, and University Faculty

The desired outcome of this project was that UNC Asheville K–6 licensure candidates and participating elementary students, as well as the involved UNC Asheville faculty member who is the instructor of EDUC 322, would benefit from this civic engagement project. This would be made possible through the use of effective teaching strategies, including inquiry, discovery learning, questioning strategies, and demonstrations; active reflection on theories of science education and learning, and how they can be utilized in the classroom and beyond; participation in a variety of educational experiences which positively impact the teaching of science; and sharing responsibility within the greater community for and recognizing the value of collaborations on issues of mutual concern, benefit, and accomplishment.

The specific goals related to this project were as follows:

1. UNC Asheville K–6 licensure candidates will acquire content knowledge necessary for teaching science in their future classrooms.
2. UNC Asheville K–6 licensure candidates will acquire pedagogical skills necessary for teaching science in their future classrooms.
3. UNC Asheville K–6 licensure candidates will acquire professional dispositions necessary for being effective teachers in their future classrooms.

Elementary Science Methods Course

All K–6 licensure candidates are required to take EDUC 322 (Inquiry-Based Science Instruction, K–6). Throughout the semester, candidates enrolled in EDUC 322 learn about effective Science, Technology, Engineering, and Mathematics (STEM) teaching methodology, and how these methodologies translate to their teaching of future elementary students about science and the scientific method. The course has a focus on teaching using the 5E Learning Cycle.

Great emphasis is placed on inquiry and discovery learning, as candidates in the course are afforded traditional classroom learning in addition to participation in hands-on labs aligned with science strands. Candidates also engage in an inquiry-based micro-teaching experience into which the use of Common Core text exemplars are integrated. Given the liberal arts model, the primary goal of the course is to teach effective methodologies for science education, as science content is taught within the other departments in the university outside of the Department of Education. However, science content knowledge is drawn upon throughout the EDUC 322 course within the context of exploring teaching methodologies.

As part of this instruction and practice, licensure candidates in EDUC 322 participate in field experiences during which they gain additional hands-on experience working with elementary students on the teaching of science. Candidates spend six sessions in an elementary classroom observing and/or assisting the classroom teacher, and in addition, each candidate teaches an inquiry-based lesson on their own. Candidates complete a comprehensive Science Notebook as a reflection on the field experience.

Elementary Science Methods and Service Learning

Perhaps the most significant aspect of the EDUC 322 course is candidates' focused participation in service learning. Candidates participated in the Asheville City Schools (ACS) Kids Inquiry Conference (KIC) in the Spring 2010, Spring 2011, Fall 2011, Spring 2012, Fall 2012, Spring 2013, and Spring 2014 semesters. Unfortunately, the event had to be cancelled due to ACS's focus on Read to Achieve mandates. Candidates participated in the Elementary Science Olympiad in the Spring 2013, Spring 2014, Spring 2015, Spring 2016, and Spring 2017 semesters.

The KIC was an event unique to Asheville City Schools, and was conceived as an alternative to the traditional Science Fair activity. The instructor of EDUC 322 partnered with the ACS Science Coach to plan and facilitate the KIC. Throughout each semester in which KIC was held, EDUC 322 candidates completed their field experiences in the classrooms of third, fourth, and fifth grade teachers and students who would be participating in KIC. This provided the EDUC 322 candidates with the opportunity to assist students with their projects and guide students as they engaged in the inquiry and discovery learning necessary to complete their projects. To complete their projects, students, usually working in pairs or groups of three, engaged in scientific inquiry focused on student-generated questions that came from their curiosities about the natural world. The teachers and EDUC 322 candidates guided students in generating these questions and led students through the process of making predictions, collecting data, analyzing the data, and drawing conclusions related to these questions. Students then created a visual presentation of their investigation and results, and prepared to discuss these with peers.

After a semester of work, the students were prepared for the KIC. During the KIC, UNC Asheville hosted the students and their teachers in a conference on the UNC Asheville campus. During the conference, the students presented visual representations of their work, and asked and answered questions from their peers. The EDUC 322 candidates who worked with the participating students and teachers served as conference facilitators. Candidates' roles as facilitators consisted of keeping time during each presentation, aiding with the discussion by asking questions and offering topics for discussion, and assisting students as they rotated to different tables so they could experience a variety of presentations. The instructor of EDUC 322 supervised and guided the candidates as they completed their work during the semester, and instructed candidates regarding safe and ethical practices for working with students. The instructor of EDUC 322 also served as the conference host and facilitator by coordinating all of the logistics for the conference including room reservations, scheduling, bus parking, and arranging for a campus tour for students. Each conference typically involved approximately 200 elementary students and ten elementary teachers.

Science Olympiad is a national program which engages elementary, middle, and high school students in competitions based on national and state STEM standards. Most competitions are team-based, and all require students to engage in hands-on inquiry science activities. Students choose their preferred event(s) from a list of approximately eighteen, and spend the better part of a school year working on their chosen event(s) with their school's sponsor teacher and their peers on the Science Olympiad team in order to prepare for the competition.

The instructor of EDUC 322 has partnered with the Regional Director of the Elementary Science Olympiad, who is also a high school science teacher in an area school. At the beginning of each EDUC 322 semester, the Regional Director visits the EDUC 322 class and together she and the EDUC 322 instructor provide a description of and orientation to Science Olympiad. During this orientation, EDUC 322 candidates are provided information about their role related to their participation as event leaders and event writers for the Science Olympiad competition. This information is on topics such as the event code of ethics, event rules, event writing guidelines, event scoring guidelines, and safe and ethical practices regarding working with students. Throughout the EDUC 322 semesters, candidates work to write their events according to competition standards and under the supervision and guidance of the EDUC 322 instructor. This supervision and guidance involves advising candidates as to the content of their events, providing them with resources to obtain the information necessary to write their events, reviewing and editing their work, assisting them with gaining access to hands-on materials they require to carry out their event, and making copies of student answer sheets and any other written materials needed for events.

EDUC 322 candidates put their knowledge into further practice as they serve as event leaders for the actual Science Olympiad competitions. Event leadership consists of supervising competing students, setting up event materials, and scoring competitors' products. Candidates are supervised by the EDUC 322 course instructor and the Regional Director at each Science Olympiad event.

Methods

Candidate Written Reflections – KIC

Participating EDUC 322 candidates were required to produce written reflections of their experience working on the KIC project. These reflections were graded as part of the course grade for EDUC 322, and evaluated using a standardized rubric. The prompts provided for reflection were as follows:

1. Situational Context – List the date(s) during which you served as a facilitator, how many students were at your table during each session, and how many presentations you saw during each session.
2. Describe – Briefly describe the student presentations for which you served as a facilitator.
3. Analyze – Discuss the presentations you saw in terms of the relevance of the topics of the investigations carried out, the effectiveness of the presentations, and the quality of the questions asked by peers.
4. Appraise – Evaluate what you observed as a facilitator. Discuss any problems that occurred and why they occurred, what questions you have about the KIC process, and other topics you find relevant.
5. Transform – Discuss your involvement in KIC as it relates to your future teaching practice in science. Be sure to answer these questions: What might you do with the knowledge you gained to inform your teaching? How did what you learned by participating in KIC connect with the topics you learned in our course?

Candidate Written Reflections— Science Olympiad

Participating EDUC 322 candidates were required to produce written reflections of their experience working on the Science Olympiad project. These reflections were graded as part of the course grade for EDUC 322, and evaluated using a standardized rubric. The prompts provided for reflection were as follows:

1. Situational Context – Name the event you led and the event with which you assisted. Give a two sentence description of each event.
2. Describe – Describe what you did to prepare the event you led.
3. Analyze – What was student performance like in the event you led? What was the range of student performance? What surprised you?
4. Appraise – Evaluate what you observed as an event leader. Discuss what problems occurred and why they occurred, and what suggestions you have for improving the event you led and the tournament as a whole.

5. Transform – Discuss your involvement in Science Olympiad as it relates to your future teaching practice in science. Be sure to answer these questions: What might you do with the knowledge you gained to inform your teaching? How could you implement your own Science Olympiad experience for your students, even if it wasn't supported in your school or district?

Standardized Science Olympiad Surveys

The standardized surveys used by Science Olympiad as an organization were given to all participating UNC Asheville candidates to gain feedback from them after they served as event leaders, and the results were analyzed. Questions on the survey included the following and were rated by candidates on a scale from 1 (Strongly Disagree) to 5 (Strongly Agree):

1. I was fully prepared to lead this event.
2. Tournament director(s) were well organized.
3. The event rules were clear.
4. The event site for this event was satisfactory.
5. I was provided with the materials and resources I requested.
6. Orientation opportunities were provided to prepare me.
7. Students were prepared for the event.
8. The event was inquiry in nature.

Service Learning Survey

A Service Learning Survey was administered to EDUC 322 candidates as both a pre- and post-assessment of the impact of their participation in service learning. Appropriate IRB guidelines for a classroom-based project were followed. Questions included on the survey were as follows and were rated by candidates on a scale from 1 (Strongly Disagree) to 5 (Strongly Agree):

As a result of participation in service learning I am likely to

1. examine my own cultural experiences
2. educate myself on multiple perspectives
3. use reflection to evaluate my current teaching activities
4. develop lessons that include contributions of all cultures
5. build on learners' strengths
6. teach global awareness
7. incorporate different points of view in my teaching
8. create lessons that require student collaborations
9. incorporate student reflection into lessons
10. encourage students to change things at school they disagree with
11. encourage students to change things in the community they disagree with
12. teach students that they can make a difference
13. teach students to work for equality for people of different races, cultures, or genders
14. make students aware of their political or civil rights
15. teach students that the world outside of school is a good source of curriculum
16. work to improve collaboration between school and community
17. seek a leadership role in curriculum development at my school
18. participate in decision making structures (e.g., school improvement team, district planning team, school board)
19. seek information (e.g., local, state, or national data) when developing school improvement goals
20. have an interest in education policy
21. work to understand community problems
22. work with someone else to solve a community problem
23. become regular volunteer for an electoral organization
24. become a regular volunteer for a non-electoral organization
25. be an active member in a group or organization
26. regularly vote
27. persuade others to vote
28. contact elected officials
29. regularly seek "news" (newspaper, radio, news magazine, internet, TV)

Pearson Science and Technology/ Engineering Subtest

The standardized Pearson test, composed of a Foundations of Reading subtest; a General Curriculum Mathematics subtest; a General Curriculum Multi-Subjects subtest consisting of multiple choice questions pertaining to Language Arts, History and Social Science, and Science and Technology/Engineering; and an Integration of Knowledge and Understanding section which includes a few constructed response items to test pedagogical knowledge as applied to teaching a concept in a content area, has been taken by all K–6 candidates since the 2013–2014 academic year. Each test taker receives an overall Scale Score, a Sub-Area Performance score for each of the three General Curriculum Multi-Subjects subtests, and a score for the Integration of Knowledge and Understanding section. The Sub-Area Performance scores for the multiple choice items are presented on a scale from 1 to 4 to show how many items test takers answered correctly, as follows:

1-Few or none of the items answered correctly
2-Some of the items answered correctly
3-Many of the items answered correctly
4-Most or all of the items answered correctly

The Integration of Knowledge and Understanding scores for the constructed response items are presented on a scale from 1 to 4 to show the quality of the response by the test takers, as follows:

1-Weak, blank, or unscorable
2-Limited
3-Adequate
4-Thorough

For this study, the Sub-Area Performance scores for the Science and Technology/Engineering subtest and the Integration of Knowledge and Understanding scores were analyzed.

Results

Key Findings: Candidate Written Reflections – KIC

Participant responses (N=61) to the written reflection related to their participation in the KIC were evaluated to determine the most common themes that emerged in reference to content and pedagogy. An overwhelming number of participants (N=56) indicated that involvement with the KIC provided them with more science content knowledge. In their reflections on the experience they stated such things as, "I believe the presentations were very effective, because I even learned things that I didn't know before such as Ingles brand bag holds the least amount of weight compared to Best Buy and Wal-Mart…"

Numerous participants (N=50) also noted that their role in the KIC assisted them with learning how students conduct inquiry. Participants' anecdotal comments, such as the following, demonstrate this learning: "…I feel that the process of going through putting together an experiment, making predictions, implementing the experiment, and then having to present their findings was a good exercise and definitely good practice for further inquiry…."

Finally, a number of participants (N=44) suggested that the KIC process taught them to assist students with communicating in scientific terms and carrying out investigations using technological design. This was exemplified in participant comments such as:

> *Participating in the KIC conference will be helpful to me as a future science teacher. I was able to see that students as young as eight and nine are able to follow the science process and they can work through a problem efficiently. For some reason, the age of these students compared to their work surprised me. I wasn't expecting such good quality work and investigations, and I look forward to trying this out in the classroom.*

and:

> *I found that many of the presentations were relevant to a child's life. Many students asked, "So, why did you do this? How does this affect your life?" The students that tested hair ties said they wanted to know what hair [tie] would be best to wear at the playground. The students who tested the batteries said they wanted to know which one lasted the longest for their camping trip. The topics listed above are far different from the science projects I did in elementary school. The topics are things that really matter to the students. One may say that knowing what frozen pizza has the most cheese is not a relevant topic, but what I saw at conference was that it was sometimes the process more than the content that was effective. The students were really engaging in scientific thinking and solving everyday problems using scientific methods. I have no doubt that the students will be better equipped to solve real life science problems because of the conference.*

Key Findings: Candidate Written Reflections – Science Olympiad

Participant responses (N=44) to the written reflection related to their participation in the Science Olympiad were evaluated to determine the most common themes that emerged in reference to content and pedagogy. Almost all participants (N=36) wrote that they felt confident that they could make a Science Olympiad event for their own class or grade level that could be used as a science teaching experience. In fact, some plans, such as the one provided by the following participant, were very fully developed:

> *I would implement a science Olympiad in my classroom by grouping students into two or three and assign 3 events for each to compete in. Students can have a choice of course. It would take place during the end of the year as an all-day event after EOG's as a fun way to end the school year. I could potentially use a designated spot outside for Newton's Notions and an empty room/space near-by for overflow of activities. Stations would have to be condensed in order to fit inside my one classroom and furniture rearranged or taken out of the room for additional space. The groups will have time to prepare similar to the real Science Olympiad. I would bring in volunteers to help with the stations (preferably student teachers, NOT PARENTS) and supervise each event. There would be eight different events inside my classroom. Each event would consist of 3 activities.*

TABLE 1. Average responses to statements in the preliminary survey and final survey.

Survey Item	N Item Responses					Item
	1	2	3	4	5	
1	0	0	2	7	35	4.8
2	0	2	2	5	35	4.7
3	0	0	4	7	33	4.7
4	0	0	2	2	40	4.9
5	3	1	0	3	37	4.6
6	1	0	4	4	35	4.6
7	1	4	5	9	25	4.2
8	0	0	3	8	33	4.7

Note: Item Response choices were 1 (Strongly Disagree), 2 (Disagree), 3 (No Opinion), 4 (Agree), and 5 (Strongly Agree).

Most participants (N=32) said that their participation in Science Olympiad gave them the skills needed for building a classroom science community around the concept of students possessing common scientific knowledge on a variety of topics. Participant reflections demonstrating this include the following:

> *I think this experience made a definite impact as far as me feeling like a REAL teacher. This experience really made being a teacher as real as possible. By observing what students are able to do and what they cannot do, it also enhanced by awareness of upper-level elementary developmental/thinking and where they are with that.*

Many participants (N=30) specified that their involvement in Science Olympiad provided them with ideas centering on multiple means for assessing student knowledge. One participant suggested:

I also can envision possibly using the Science Olympiad as an assessment or testing tool. Should the Olympiad be used as a testing tool, the individual grades would be graded, but not shared. The students could be divided into teams of 4 or 5 students before the testing period. Their test scores would be combined to form a team score. My guess is that this would encourage a higher level of preparation and group study before the test.

Key Findings: Standardized Science Olympiad Survey

Given the nature of this survey and because of its standardization to serve the needs of the established Science Olympiad program, the results shown in Table 1 do not reveal much in terms of participant (N=44) acquisition of skills related to content, pedagogy, or professional dispositions. The exception is with regard to the first and last items. Participants had to have the appropriate content knowledge in order to create their event and be fully prepared to lead it, and most participants had to study and learn content information in order to do so. Therefore, the fact that the mean rating for the first item was 4.8 was a good indicator that participants gained content knowledge as a result of their participation as Science Olympiad event leaders. The mean rating of 4.7

TABLE 2. Results of Service Learning Survey

Survey Item	N Item Responses											
	1 Pre	1 Post	2 Pre	2 Post	3 Pre	3 Post	4 Pre	4 Post	5 Pre	5 Post	Mean Pre	Mean Post
1	0	0	0	4	1	0	46	40	31	34	4.4	4.3
2	0	0	0	0	0	0	27	32	51	46	4.7	4.6
3	0	0	0	0	0	0	38	21	40	57	4.5	4.7
4	0	0	0	0	3	2	28	30	47	46	4.6	4.6
5	0	1	2	1	0	2	22	27	54	47	4.6	4.5
6	0	0	3	2	2	4	28	22	45	50	4.5	4.5
7	0	0	2	1	2	3	18	17	56	57	4.6	4.7
8	0	0	3	2	0	4	29	18	46	54	4.5	4.6
9	0	0	1	0	0	9	30	16	47	53	4.6	4.6
10	0	0	1	4	25	24	45	32	7	18	3.7	3.8
11	0	0	2	4	14	21	52	28	10	25	2.8	3.9
12	0	0	0	0	1	3	9	5	68	70	4.8	4.9
13	0	0	0	1	0	9	38	17	40	51	4.4	4.5
14	0	0	1	3	13	5	34	29	30	41	4.2	4.4
15	0	0	0	0	2	4	22	27	54	47	4.5	4.6
16	0	0	0	0	1	3	39	26	38	49	4.5	4.6
17	0	0	0	0	26	28	32	18	20	32	3.9	4.1
18	0	0	0	0	24	30	33	23	21	25	4.0	3.9
19	0	0	0	2	1	5	58	23	19	48	4.2	4.5
20	0	2	1	0	9	11	34	31	34	34	4.3	4.2
21	0	3	0	2	2	0	48	32	28	41	4.3	4.4
22	0	2	0	0	25	13	38	40	15	33	3.9	4.7
23	0	2	28	15	37	38	7	10	6	13	2.9	3.2
24	1	2	14	13	28	26	24	31	11	6	3.4	3.3
25	0	0	1	4	9	4	46	39	22	31	4.1	4.2
26	0	0	0	0	10	10	23	19	45	49	4.5	4.5
27	1	0	5	6	20	21	24	22	28	29	3.9	3.9
28	1	0	4	4	35	33	19	13	19	28	3.7	3.8
29	2	1	3	2	1	3	35	34	37	38	4.3	4.4

Note: Item Response choices were 1 (Strongly Disagree), 2 (Disagree), 3 (No Opinion), 4 (Agree), and 5 (Strongly Agree).

for the last item was also encouraging, as it suggested that participants understood the nature of inquiry as a result of their role in Science Olympiad.

Key Findings: Service Learning Survey

Participant responses (N=78) to the Service Learning Survey were evaluated to determine the items for which participants showed the most growth between their pre- and post-service learning participation in reference to professional dispositions. From the results illustrated in Table 2, four topics emerged: as a result of their participation participants indicated they were more likely to educate themselves on multiple perspectives, use reflections to evaluate their current teaching activities, teach students that the world outside of school is a good source of curriculum, and work to improve collaboration between school and community.

TABLE 3. Results of Pearson Test Sections

Candidate Exam Year	Science, Technology/ Engineering Score*	Knowledge, Understanding Score**
'14-'15	2	3
'14-'15	3	1
'14-'15	3	2
'14-'15	3	3
'14-'15	4	1
'14-'15	3	1
'14-'15	3	2
'14-'15	2	2
'14-'15	3	3
'14-'15	2	1
'14-'15	1	1
'14-'15	2	2
'14-'15	3	2
'14-'15	3	2
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'15-'16	3	4
'15-'16	2	2
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'15-'16	4	4
'16-'17	4	3
'16-'17	3	3
'16-'17	3	3
'16-'17	4	3
'16-'17	2	1
'16-'17	3	3
'16-'17	3	2
'16-'17	4	2

NOTES:

*Scores were 1 (Few or none of the items answered correctly), 2 (Some of the items answered correctly), 3 (Many of the items answered correctly), and 4 (Most or all of the items answered correctly);

**Scores were 1 (Weak, blank or unscorable), 2 (Limited), 3 (Adequate), and 4 (Thorough)

Key Findings: Pearson Science and Technology/ Engineering Subtest and Integration of Knowledge and Understanding Section

The means of participant results on the Pearson Science and Technology/Engineering Subtest were analyzed by year. For 2014–2015 (N=14) the mean was 2.64. For 2015–2016 (N=12) the mean was 3.08. For 2016–2017 (N=8) the mean was 3.25. The means of participant results on the Pearson Integration of Knowledge and Understanding section were also analyzed. For 2014–2015 (N=14) the mean was 1.86. For 2014–2015 (N=12) the mean was 2.58. For 2016–2017 (N=8) the mean was 2.63. In the 2014–2015 testing year, three participants did not pass the General Curriculum Multi-Subjects subtest the first time they took it. For the 2015–2016 and 2016–2017 testing years the same was true for one participant each year. In all of these instances, for purposes of this study, the first testing attempt was used in figuring the means so that the same level of data was used for all participants.

Discussion and Summary

Two of the goals of this project for participating candidates centered on the acquisition of content knowledge and pedagogical skills necessary for teaching science in their future classrooms. The Key Findings show clearly that these goals were achieved, especially when the results from the instruments used to obtain results in this study are considered together. Specifically, in the Key Findings section above it is stated that the results from the Standardized Science Olympiad Survey as shown in Table 1 do not say much on their own about participant acquisition of skills related to content, pedagogy, or professional dispositions, with the exception of the first and last items. The results related to the first item on this survey do, on their own, suggest that participant content knowledge was improved by their participation in the Science Olympiad. The impact of these results is strengthened by participants' anecdotal comments on the Candidate Written Reflections for the Science Olympiad which include, "I really enjoyed creating my event for the Science Olympiad and I learned a lot about rocks and minerals and became more informed on the information…" and, "I feel like this was a great first time getting to work with older students. I've only worked with kindergarteners so far. I felt confident helping the students because I knew what I was talking about, due to my research on the subject…." The results related to the last item on the Science Olympiad Survey showed that participants understood the nature of inquiry as a result of their role in Science Olympiad.

Participant reflections support this claim. As one participant stated:

> *I definitely want to incorporate my event stations into activities that students could do in my future classroom. Rocks and Minerals can be boring for certain students but having activities to incorporate learning makes it more enjoyable for students. After taking several education classes I have learned through myself that hands-on activities give me a better understanding of information and make learning more enjoyable when you are able to be creative through acting and building things. The students really enjoyed looking at the rocks and minerals I had as samples and the students seemed to be very intrigued.*

The Pearson test components, as a standardized and quantitative measure of participant learning, can also be considered in concert with the Standardized Science Olympiad Survey. As can be seen, the means related to the subtests of of science content and pedagogical knowledge increase each testing year. As described in the Background section, the KIC was terminated by ACS after the Spring 2014 semester. Additionally, the Science Olympiad is held only in Spring semesters. EDUC 322 was offered every semester until Spring 2016 and thereafter was offered only in Spring semesters. Therefore, there were some participants who completed their licensure program and the Pearson test in the 2014–2015 and 2015–2016 testing years without having participated in either one of the EDUC 322 service learning activities. All participants who completed their licensure program and the Pearson test in the 2016–2017 testing year participated in at least the Science Olympiad activity. The increased means on the analyzed Pearson test component strengthen the conclusion that participants' knowledge regarding both content and pedagogy increased, despite the technicality that EDUC 322 is not "supposed to" teach content. It is the assumption of this researcher that this outcome is due to the practical and engaged work in which participants were involved as part of their service learning.

Another project goal centered on the acquisition of professional dispositions candidates will need to be effective teachers in their future classrooms. The definition of professional dispositions has been widely disputed, as there are many dimensions through which the concept can be delineated. The quest to define dispositions dates back to seminal works, such as those completed by Arthur W. Combs in the 1960s, which sought to determine the dispositions that effective teachers must possess (Wasicsko 1977). There is also great deliberation over whether or not dispositions can be taught, or if they are simply acquired (Cummins and Asempapa 2013). Many researchers, such as Combs and Wasicsko, have developed a series of assessment tools related to pre-service teacher professional dispositions. But again, the tools are contested due to their content, purpose, and validity. Given these debates, many teacher education programs such as that at UNC Asheville provide their own definitions of professional dispositions, and seek to combine formal assessment of them through the use of prescribed tools with performance-based assessment as candidates are engaged in authentic experiences. At UNC Asheville, candidates displaying professional dispositions to a satisfactory degree are defined within the following parameters:

- Collaborative teachers who demonstrate awareness of and appreciation for the communities in which they teach and who foster mutually beneficial relationships with the community.
- Responsible teachers who exemplify the skills, behaviors, dispositions, and responsibilities expected of members of the teaching profession.
- Reflective teachers who maintain a commitment to excellence and to the continuous assessment, adaptation, and improvement of the teaching-learning process.
- Humane teachers who value the dignity of every individual and foster a supportive climate of intellectual inquiry, passion for learning, and social justice.

The themes that emerged from the Service Learning Survey results, as described in the Key Findings, show that project participants gained knowledge and skills in the area of acquiring desirable professional dispositions, especially when analyzed in conjunction with participant reflections. For example, one participant noted:

This Science Olympiad experience confirms my compassion and love for children and desire for being a teacher even during some crazy days. It also confirms my desire to help them learn and discover new knowledge while becoming confident in their science skills. This learning experience was really cool to be a part of and I felt like I was doing something truly important to further children's interest in science and education. I am happy and proud to say that I was able to participate in the Science Olympiad and confidently show the work that my fellow peers and I produced for such a well-known competition. I will always reflect on the experience as a future teacher and use it to influence my decisions as a teacher in a positive way.

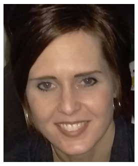
The supposition of this researcher is that the field work in which participants were engaged, which can actually be defined as service learning, and the specific Service Learning activities in which they participated can set candidates on the path to civic engagement. Specific civic engagement elements that were realized include the fact that sustainable partnerships were developed, the work was mutually beneficial, and candidates learned to serve a diversity of children. Participants were able to realize the potential for forming partnerships to benefit their future classrooms. One participant's reflection showed this clearly, as the participant stated:

If implementation of my own Science Olympiad were not supported in my school or district, I could look to the community and to private industry for support. The concept of the Olympiad is valuable to fostering scientific education and to meeting the current and future needs of the world. Science is life and to neglect it in our children's education and preparation for life is not an option.

In summary, education in Science, Technology, Engineering, and Math (STEM) competencies is a growing area in terms of career and workplace skills. Interest in this area has to be started in elementary schools in order to ensure that students are not only being introduced to science skills but are also actively engaged in scientific processes and engineering design cycles. The KIC and Science Olympiad were designed to support elementary science standards, and to assist teachers in fostering these skills in their students. The involvement of the pre-service teachers who served as participants in this study and created quality, age-appropriate science challenges for students, is helping to achieve these long-term goals for students and support STEM education.

ASCD (formerly the Association for Supervision and Curriculum Development) is one of the most prominent professional associations in the field of Education. ASCD provides resources, training, research, and programs that emphasize transformational leadership, global engagement, poverty and equity, redefining student success, and teaching and learning (ASCD 2016). "The ASCD defines citizenship as a concern for the rights, responsibilities, and tasks associated with governing. It identifies citizenship competencies as an important component of civic responsibility. These competencies include acquiring and using information, assessing involvement, making decisions and judgments, communicating, cooperating, promoting interests, assigning meaning, and applying citizenship competencies to new situations" (Constitutional Rights Foundation 2000, 4). The participants in this study were introduced to this information toward the beginning of the EDUC 322 course. Then, throughout the course, discussions were held and activities were completed related to teaching candidates how educating students in STEM areas as well as helping them understand the ethical use of science and scientific data are contributing to candidates' and students' citizenship, civic engagement, and civic responsibility—both through their current engagement with students and schools and in their future teaching careers. All of this discussion and activity completion is grounded in the framework of strategies for effectively teaching a diversity of students in the public school classroom according to STEM education principles. Additionally, the participants in this project were provided with a responsibility to both teach and learn within a service and civically engaging context. As a result, they were able to learn to teach using discovery, while engaging in discovery learning themselves. Given their self-reflections, it is evident that the participants are excited about and prepared for the prospects of related responsibilities in their future teaching. And, given the results of the measure of student learning, each group of participants is entering the classroom more prepared in terms of their content and pedagogical knowledge than the one before it.

About the Author



Kim Brown is an Associate Professor and the Chairperson of the Department of Education at the University of North Carolina Asheville. Kim teaches numerous licensure courses, including Inquiry-Based Science Instruction for candidates seeking elementary licensure. For her curricular and service work in this course, Kim was named a University SENCER Fellow. Kim has been very involved in work related to the University of North Carolina Asheville's liberal arts model, serving as the chairperson of the university's Integrative Liberal Studies Oversight Committee and the university's representative on the state-level General Education Council. Kim was the university's recipient of the 2014 Distinguished Service Award.

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Teaching Research to Undergraduates through an Outdoor Education Program

KEVIN FINN
Merrimack College

Abstract

There has been an increased emphasis in recent years on implementing active learning strategies in science courses for undergraduate students. Particularly, undergraduate research methods courses have focused on incorporating pedagogies that utilize a practical application of the course content. As a result, we created a research methods course for undergraduate health sciences students to teach them about research methodology through a hands-on project. The health sciences students were part of an outdoor education program, where for one week third and fourth grade students from an elementary school came to a camp as part of an outdoor education experience. The health sciences students taught the children a variety of STEM (Science, Technology, Engineering and Mathematics) and health/wellness skills and content. In addition, the undergraduate students learned about research methods by conducting their own studies during this outdoor education program. The benefits were twofold. The health sciences students learned about research methodology in an applied and practical manner and the elementary school children experienced STEM education in an outdoor environment.

Introduction

The value of active learning in science education has been emphasized by many national organizations (American Association for the Advancement of Science 1993: Association of American Colleges and Universities 2007; National Research Council 1999, 2003a, 2003b; National Science Foundation 1996). Encouraging students to formulate their own ideas, interpret data, generate conclusions from experimental evidence, and participate in other hands-on activities can be more effective than the passive learning that typically occurs during lecturing. The increased recognition of the value of active learning is supported by a growing body of evidence demonstrating the effectiveness of incorporating active learning techniques in the undergraduate classroom (Prince 2004). The literature has shown improved learning when a variety of active learning strategies were used in a wide range of science disciplines including physics (Hake 1998), chemistry (Niaz et al. 2002; Towns and Grant 1997), biology (Burrowes 2003), nursing (Clark et al. 2008), and physiology (Mierson 1998).

In most health sciences undergraduate programs, a research methods course is part of the curriculum. Many faculty who teach undergraduate research courses are aware of the challenges that are associated with making this material practical for students. Research is an area that students have unfavorable attitudes toward, attitudes that may become even more negative upon taking a research methods course (Sizemore and Lewandowski 2009). One potential reason for the lack of interest is students' inability to perceive themselves as engaged in meaningful research activities as undergraduate students (Rash 2005; Macheski et al. 2008). The literature has demonstrated that students tend to learn abstract concepts more fully when they can apply them to their to "real world" settings (Macheski et al., 2008). In our health sciences department, we have implemented active learning strategies utilizing other approaches (FitzPatrick and Campisi 2009; Campisi and Finn 2011; FitzPatrick et al. 2011; Finn and Campisi 2015), but we wanted to create a way to specifically teach research methods using active learning in an outdoor education program. After examining the effects of active learning pedagogies on student learning and perceptions for a number of years, we have implemented different pedagogies such as clickers, peer-led team mentoring, and group and collaborative learning, to examine how active learning effects both student learning and perceptions. Many of these pedagogies have improved student learning and have had positive impact on student perceptions.

For the outdoor education project, we redesigned our undergraduate research methods course to incorporate participation in a research project. We hoped that stimulating interest in research through active and collaborative learning would allow students to understand the practical implication of research.

The Outdoor Education Program

During this project, 100 third and fourth grade children participated in a five-day, five hour/day outdoor education program that took place at a local day camp owned by the YMCA. This program was a joint venture between the city's school district and the local YMCA to provide elementary students with an exciting opportunity to participate in active learning in a camp setting. This was the first outdoor experience in a camp environment for many students who participated in this program. As part of being enrolled in the research methods course, the health sciences undergraduate students implemented this outdoor education program by utilizing the camp's program areas and natural ecosystems to provide the children with unique experiential learning activities in four main curricular areas: science and math, healthy living, environmental education, and team building. These engaging activities and the use of natural surroundings encouraged the children to explore their interests and abilities in a safe and nurturing environment. Below is more detail on each section of the curriculum.

1. **Environmental Education:** This component of the curriculum corresponds with the goals of the school system, the Massachusetts State School Standards, and the New National Science Standards. Each day, students learned about a different ecosystem at the camp (e.g. the wetlands, fresh water lake, forest, and open field) through a combination of hands-on experiments and lectures. In each ecosystem, students learned about the different types of animals, plant life, rocks, the cycles of natural resources, and the dangers

that each ecosystem faces, among other topics. Students also took nature hikes and performed on-site field tests, including taking water and soil samples and testing pH.

2. **The Science and Math of Camp:** This component of the program included several physical activities that provided the opportunity for students to learn math and science skills. These activities included

   - *Maps* –The goal of this module was to allow students to develop and make maps using scale, topography, measurements, and other skills.
   - *Archery* – While participating in archery, students were provided the opportunity to learn about velocity, rate of speed, distance, inertia, and gravity.
   - *Canoeing* – While participating in this activity, students could learn about propulsion, angles, planes, kinesiology and biomechanics, resistance and friction, and wind and currents.
   - *Gaga* –The goal of this activity was for students to learn how to play the popular camp game Gaga. While playing, they wear devices such as a pedometer, to measure steps, distance traveled, and overall activity levels. Students took the data from these devices and recorded it, and then, using the Active Science curriculum, analyzed the data, answered questions, and drew conclusions about the data.

3. **Team Building:** The team-building component was a progressive learning experience where students were encouraged to challenge themselves in a variety of different ways. This provided emotional and physical growth and gave each student the feeling of self worth and self-accomplishment. The week began with team-building activities on land, such as "get to know you" games, trust falls, spotting techniques, and problem-solving games. As the group mastered the land activities, they moved to the low ropes course. At the camp, there were seven low ropes elements. Each element had two groups participating (one group spotting and one group climbing). After mastering the low ropes course elements, students over the age of ten had the option of trying the high ropes course. There were seven high ropes course elements, including a zip line. Younger students (over the age of eight) had the chance to try the giant swing. The camp's ropes course offered a variety of fun opportunities to build trust, solve problems and learn the value of collaborative teamwork.

4. **Healthy Living:** During this component of the program, students were exposed information about living healthy lifestyles. These included safety concepts, healthy eating and nutrition, and physical activity. Activities included Water and Boating Safety, Garden Project, Fitness Challenge, Otterthon Relay Race, and Field and Court Games. The students were encouraged to participate, be active, and have fun with their classmates. They learned about the importance of being physically active, having good nutrition habits, and overall what it means to be healthy.

Research Methods Course

The research methods course was delivered during the summer session for six weeks. Twelve students were enrolled in the course. During the first two weeks of class, the health sciences students learned about the outdoor education program and became familiar with the curriculum and content that they would be teaching to the children. From there, the class was divided into four groups of three students each to come up with a research question that they wanted to investigate during the program. As part of the course, one of the first assignments that the students completed was a proposal that detailed the specifics of the research project. They were required to provide a research question, hypothesis, methods (participants, data collection, data analysis), and the type of research design that they were interested in carrying out. Based on what they learned at the beginning of the course about the types of research designs, they created a study and a question to match the design. Once the students completed the assignment on the design of their study, the instructor met with each group to review it. The instructor provided feedback on ways to improve the study and the students worked to incorporate the changes to make the design stronger. This back and forth process happened until the instructor felt the design was well thought out and could answer the research question.

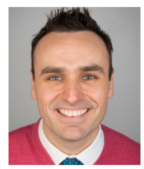
Prior to going into the field, the students had a solid research study that addressed a specific research question. The research questions the students focused on were specific to the one-week outdoor education experience. Two of the student projects focused on assessing the amount and level of physical activity that the participants accumulated while in the outdoor education program. They compared physical activity levels such as sedentary, light, moderate, and vigorous between classes, curriculum components, age, and gender. Another group assessed the science learning that occurred during the camp. They performed pre- and post-assessment to determine science knowledge that was gained through the experience. They had a control group that did not perform the outdoor education program for a comparison. The last group examined the participants' perceptions of learning in the outdoor education environment. They conducted surveys of all participants at the end of camp and then interviewed a subset of children to gather their feedback on the outdoor experience.

During weeks three and four of the course, the health sciences students were in the field implementing the curriculum and collecting data. At the end of the course (weeks five and six), the students returned to the classroom to analyze their data. The students learned about the different types of statistical analysis (correlational, independent t-test, ANOVA) that could be performed based on their design and research question. The hands-on application of real data to teach the statistical analysis portion of this course was viewed positively by both the students and the instructor. They worked on creating a final paper and presentation that represented the results of their study. The course concluded with a presentation from each group to the YMCA senior leadership, board members, classroom teachers and administrators, and faculty.

Conclusion

This approach was a way to demonstrate how to teach research methods to undergraduate health sciences students through a community-based initiative in an urban school district. The health sciences students felt that a project-based approach was an effective way to learn the content of the course. The course objectives were met through demonstration of performance on course quizzes and through designing and carrying out a research study, analyzing the data, and writing and presenting the results of the project. As we continue to offer this course, we will use this approach to create measures that assess student perceptions of learning for both the health sciences students and the elementary school children. The active learning and student-centered pedagogical strategy created a culture of ownership over the research project and excited students about the course material. In many science lecture and laboratory courses, active learning can be an effective method to improve student learning and understanding and to improve student attitudes about a subject. Incorporating a team-based research project that uses the outdoor environment into a research methods course can help prepare students for future research experiences and their professional careers.

About the Author



Dr. Kevin Finn is an Associate Professor and Chair of Health Sciences at Merrimack College. His area of expertise is curriculum and teaching in the health professions with a focus around increasing physical activity in children. Kevin is a licensed athletic trainer in Massachusetts and a certified strength and conditioning specialist.

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Informal STEM Learning: The State of Research, Access and Equity in Rural Early Childhood Settings

SARA L. HARTMAN
Ohio University

JENNIFER HINES-BERGMEIER
Ohio University

ROBERT KLEIN
Ohio University

Abstract

Even though 22 percent of Americans live in rural areas, rural locations have repeatedly been overlooked as research sites. Rural settings represent areas rich in early childhood STEM education research opportunities, yet very little rural STEM education research exists. This review highlights the limited extent of informal STEM learning research in rural early childhood settings as well as the impact that rurality has on teacher engagement and rural school STEM accessibility. A model that promotes active and collaborative partnerships between informal learning practitioners, community entities, and early childhood teachers represents an effective way to advance access to, equity in, and research about informal STEM learning experiences in rural settings. To foster this engaged learning paradigm, researchers must seek to develop and nourish meaningful relationships between informal STEM partners and schools in rural areas.

Introduction

Approximately 22 percent of the U.S. population, or nearly sixty million people, currently live in rural areas (United States Census Bureau 2014),[1] yet the scarcity of research related to rural education has been noted for

1 Reflecting the complex nature of rural settings, slight variation in descriptive rural statistics may be found across sources.

decades in comprehensive literature reviews (Arnold et al. 2005; DeYoung 1987; Kannapel and DeYoung 1999; Stapel and DeYoung 2011; Waters et al. 2008). The editor of the *Journal for Research in Mathematics Education* even went so far as to call the lack of focus on rural education an "attention deficit disorder" in published research (Silver 2003). With nearly 19 percent of America's schoolchildren attending rural public schools (Showalter et al. 2017), rural settings represent areas rich in STEM education research opportunities (Avery 2013; Avery and Kassam 2011). Yet rural specific issues, such as distance to services and access to professional development in STEM fields, create barriers that often prevent rurally located teachers and students from having equitable access to STEM learning opportunities (Banilower et al. 2013; Goodpastor et al. 2012).

The need for this review arises from the limited extent of informal STEM learning research in rural early childhood settings as well as the impact that rurality has on teacher engagement and rural school STEM accessibility. Recognizing the value rural areas provide as STEM research sites and capitalizing on the strengths of closely connected rural communities is helpful in addressing the accessibility and equity concerns detailed in this review. Additionally, collaborative partnerships that bridge formal and informal learning experiences represent an important mechanism for addressing access and equity in rural early childhood settings.

Background

Rural Settings—Underrepresented in the National Conversation

Though research about informal learning settings is not uncommon, a significant report on formal-informal collaborations made no specific mention of rural examples (Bevan et al. 2010). The value of learning science in informal environments is well recognized, but an informed approach for ensuring equity is essential in order to fully engage nondominant groups, including those in low-income and rural areas (Fenichel and Schweingruber 2010). While urban locales share similar challenges, rural locales have a way of magnifying certain challenges and opportunities that differ from urban locales. Informal STEM learning experiences are unevenly distributed with rural communities typically underserved, which, given the educational impact of informal learning experiences, may further contribute to placing rural students at a long-term economic disadvantage (Matterson and Holman 2012). Children's museums, which typically have a strong STEM focus, are amongst the fastest growing types of museum, yet in a recent survey of children's museum professionals, only five percent of respondents were from rural locations (Luke and Windleharth 2013). Worse, the outreach activities of large metropolitan museums run the risk of embracing urban-centric assumptions, which may align poorly with rural experiences.

Given the centrality of community and place to rural areas, rural children's museums have the potential to serve as an anchor in the broader learning ecosystem of rural communities, including formal and informal learning collaborations (Luke and Garvin 2014), serving to connect across disciplines and even generations. But while 22 percent of Americans live in rural areas (United States Census Bureau 2014), only twelve percent of children's museums are located within rural areas (Association of Children's Museums 2015). This highlights yet another need for increased access to rural STEM learning experiences. In particular, a survey of research in children's museums concluded that 56 percent of the research was conducted at only seven museums (all in large metropolitan areas) and only approximately four percent of the research involved teachers (Luke and Windleharth 2013), emphasizing the need for additional research specifically related to the role of museums for early childhood education and teacher collaborations in rural settings.

Developing interdisciplinary learning ecosystems that utilize existing and new partnerships (communities-schools-universities) has the potential to foster significant resiliency factors in the face of the many barriers to informal STEM learning that exist in rural settings. A recent National Research Council report (Bell et al. 2009) highlighted the overlapping goals of schools and informal (non-school) settings in science learning and the complementary role that informal settings can play in supporting learning progressions. The report emphasized that informal STEM learning experiences have the potential to be designed specifically to align with the K–12 science and math curriculum goals, even when the experiences may be infrequent (Bell et al. 2009). This type of intentional alignment could significantly enhance the impact of the informal STEM learning experience. However, despite recognition of the tremendous learning potential stemming from collaborations between informal learning organizations and schools, there is relatively little research on these types of collaborations in rural early childhood settings (Avery 2013; Avery and Kassam 2011). This is surprising given the close-knit nature of most rural communities, where collaboration between local industry, business, artists, and K–12 educators should be easier than in metropolitan centers (cf. the case of Meriwether Lewis Junior-Senior High School in Howley et al. [2010] for an example of a rural math educator using community relations to craft connections of mathematics to place).

Rural Schooling—Then and Now

The reasons for the exclusion of rural areas from current research date as far back as the 1900s and are inextricably linked to location, social position, politics, and poverty (DeYoung 1995). During the 19th century and early 20th century, schooling was rural for a majority of Americans, as one-room schoolhouses were the norm (Theobald 1991, 1997). Over the course of the 19th century and extending to the present, American schools and modern life simultaneously institutionalized a more industrialized and one-package-fits-all model. The contracts issued by many schools and districts to engage efficiency programs modeled after business applications suggests that the industrial model persists. As part of this movement, schools underwent a shift from one-room schools to a more factory-based style of education that made it easier for teachers to be monitored, curriculum to be standardized, students' progress to be tracked, and the education process to be governed by qualified education experts instead of local community members (Smith 1999). Consolidation became a further expression of the push toward efficiency, standardization, and "bottom-line" thinking in the mid-to-latter 20th century (Herzog and Pittman 1999; Howley 1991). The consolidation experiment is an especially salient example of how following the same model as urban or suburban schools did not solve rural schooling's issues. Indeed, the impact of large organizational scale and high transportation-to-instructional expenditures may be creating more problems than they are solving.

Rural schools face continued challenges today. In particular, rural schools experience lower income bases, difficulty in attracting and keeping teachers, lack of access to quality professional teacher development, and decreased access to informal STEM experiences for students, families, and teachers in rural regions (Avery 2013; Avery and Kassam 2011; Goodpastor et al. 2012; Herzog and Pittman 1999; Monk 2007; Schafft and Jackson 2011). Children in rural schools are identified for special education services more often and for gifted services less often than their non-rural peers (DeYoung 1993; Pendarvis and Wood 2009; Seal and Harmon 1995). Adult commutes are longer (and accordingly, transportation expenses are greater), and children living in rural areas often experience longer bus rides to and from school (Seal and Harmon 1995) than their non-rural counterparts. As teachers in rural schools are often the school's sole representatives of their content area, the issue of professional isolation creates a concern that is specific to rural schooling (Monk 2007). Additionally, teachers in rural schools have reduced access to quality professional development (Monk 2007). For example, only 11 percent of rural schools provided one-on-one science-focused coaching to science teachers compared to 30 percent in urban schools (Banilower et al. 2013). These circumstances create educational risk factors for both students and teachers, and highlight the need to foster resiliency factors in underserved rural regions (Malloy and Allen 2007). Resiliency factors, which enable people to be successful in the face of adversity, create protective mechanisms that help mitigate risk factors and are essential in overcoming high-risk educational conditions (Henderson and Milstein 2003; Krovetz 1999; Malloy and Allen 2007). These descriptors illuminate the need for increased access to informal STEM learning experiences for children and teachers alike, but also create considerable challenges in reaching the rural areas that would most benefit from increased informal STEM learning opportunities.

Barriers to Rural STEM Accessibility and Equity

Despite improvements in transportation (and communication technologies), getting rural schools and families to access places of informal learning is still difficult (Ellegard and Vilhelmson 2004). Dubbed the "friction of distance," transport to informal learning events is impacted by distance and ease of reaching a location (Ellegard and Vilhelmson 2004). Increased access to funding for informal STEM learning events and transportation to reach them is an ongoing and pressing issue for rurally located schools (Schafft and Jackson 2011; Sipple and Brent 2008). Even when an informal STEM organization is regionally accessible, rural schools are sometimes unable to pay for even a short bus ride (Hartman and Hines-Bergmeier 2015). Charging admission fees in impoverished rural regions also presents serious accessibility issues, as many families and school districts are unable to afford even a modest admission fee (Hartman and Hines-Bergmeier 2015). The recently launched "Museums for All" initiative, co-sponsored by the Association for Children's Museums and the Institute for Museum and Library Services, is an important new direction for ensuring access and equity regardless of economic status. Beyond financial and geographic challenges, a deep connection to home and community cultures and contexts needs to be woven throughout the fabric of STEM informal learning experiences in order to achieve true equity for underrepresented or non-dominant groups such as rural communities (Fenichel and Schweingruber 2010).

Additionally, distrust of outsiders is a common characteristic in rural areas, making gaining entry to rural settings a challenging prospect (Hartman 2013; Seal and Harmon, 1995). Historically, rural residents' perception was that outsiders came to make them more like the rest of the world and to offer suggestions for improvement and change, and this made them wary and distrustful of people who are considered outsiders (Cooper et al. 2010; Edwards et al. 2006; Hartman 2013). In informal learning settings, this idea may be more specifically defined as social exclusion (Sandell 1998). Described as a breakdown in the links between individuals and their connections to the community, state services, and institutions, social exclusion is a concern in rural areas (Sandell 1998). Even when an educational STEM entity is associated with long-time local residents, overcoming issues created by rural residents' cultural view of outsiders and the theory of social exclusion present ongoing challenges for places of informal STEM learning (Hartman and Hines-Bergmeier 2015). Also challenging is the fact that, in rural communities, education and educational institutions are often perceived by community members as "one-way tickets" out—a tool for preparing children for jobs elsewhere, and thus espousing a set of values contrary to that of the close kinship and connections held in rural communities (Corbett 2007). Recruiting talent away from communities is perceived as yet another form of resource extraction, sometimes called "brain drain." Strategies to overcome these barriers involve innovative, cross-contextual learning fostered by collaborative partnerships.

Cross-Contextual Learning in Early Childhood Settings

Early Childhood Education refers specifically to the time of rapid growth and development during the ages of three to eight (Follari 2011; Morrison 2015). Children in this age group are characterized by their willingness to take risks, curiosity about the world around them, and desire to be actively engaged in learning experiences (Follari 2011; Morrison 2015). Learning experiences that foster creativity, critical thinking, problem solving, and a view of the world that is globally-minded and interdisciplinary are essential for children in the early years (Semmel 2009). Importantly, informal learning settings are places that encourage both independent and group exploration, are inherently play-based, and emphasize hands-on learning. These environments are designed to foster a high level of engagement and represent a model that is developmentally appropriate for young learners (Bell et al. 2009; Semmel 2009).

Though data from rural areas are scarce, research data that document bridging the gap between school and informal learning show promise for revolutionizing the way schools and community organizations interact to improve learning for children (Avery and Kassam 2011; Behrendt and Franklin 2014; Bevan et al. 2010; Duran et al. 2009; Fallik et al. 2013). Distinctions between "school math" or "school science" and "real math/science" may lead many students to develop negative dispositions toward STEM inquiry (Braund and Reiss 2006). Cross-contextual learning is a term for bridging the gap between the learning that occurs at school and the learning that happens informally at places such as museums, libraries, and/or parks (Fallik et al. 2013). By building upon experiences that occur in informal settings, classroom teachers are better able to create meaningful, engaged learning experiences in formal settings (Behrendt and Franklin 2014; Fallik et al. 2013). However, effective cross-contextual learning is challenging for teachers and places that provide informal learning experiences for children (Avery 2013; Avery and Kassam 2011; Fallik et al. 2013; Russell et al. 2013).

Early childhood teachers often have limited content knowledge of math and science, which contributes to low self-efficacy in math and science teaching and to decisions to devote less classroom time to teaching science (Murphy et al. 2007; Schneider et al. 2007; Ma 2010); conditions that impede cross-contextual learning. Effective cross-contextual learning is important, because recent research suggests that bridging the gap between formal and informal settings shows the most promise for both increased student gains and early childhood teacher comfort with STEM topics (Avery and Kassam 2011; Behrendt and Franklin 2014; Fallik et al. 2013). By engaging in collaborative partnerships, rural classroom teachers and informal STEM educational entities may capitalize on opportunities to increase STEM literacy and interest through informal STEM learning experiences (Bell et al. 2009; Russell et al. 2013). This is especially important in rural areas where access to traditionally recognized venues for informal learning opportunities, such as museums, are scarce (Avery and Kassam 2011; National Research Council 2015). To truly engage in cross-contextual learning that impacts the learning of young children in rural areas, collaboration between stakeholders is the essential ingredient (Bell et al. 2009; Russell et al. 2013).

Strength in Collaborative Partnerships

Rural areas have a strong sense of community, and the people living there feel strong family and community ties (DeYoung 1995; Goodpastor et al. 2012; Schafft and Jackson 2011; Vaughn and Saul 2013). Additionally, despite the challenges rural schools face, teachers who work in rural schools often report high levels of job satisfaction and professional collegiality (Howley and Howley 2006; Monk 2007). Given concerns associated with outsider distrust in rural settings (Cooper et al. 2010; Edwards et al. 2006; Hartman 2013), leveraging community entities and place-based teachers as partners in advancing informal STEM learning presents a strong and sustainable model in rural areas (Avery 2013; Avery and Kassam 2011; Fenichel and Schweingruber 2010; Goodpastor et al. 2012). Rural areas offer real-life, immediate access to outdoor learning experiences that are not readily available in urban and suburban school settings (Avery and Kassam 2011). Collaborative partnerships between teachers and informal STEM practitioners that capitalize on the unique environmental offerings of rural areas may impact STEM learning in an authentic, hands-on way that makes learning come to life for young children within the context of their own backyards.

To realize the full potential of already well-connected rural communities, balancing organizational and individual motivations of participants is important (Malm et al. 2012). As teachers serve as bridge builders between all stakeholders, they are essential members of collaborative partnerships, and especially in rural areas (Vaughn and Saul 2013). With the added component of distrust of outsiders, this makes community and teacher involvement in collaborative partnerships especially important for advancing informal STEM research and accessibility in rural areas (Avery 2013; Avery and Kassam 2011; Goodpastor et al. 2012). Informal learning partnerships in rural settings should be created from the ground up with rural partners involved from the beginning and serving as leaders in the process.

Looking to the Future

With more than a fifth of the U.S. population living rurally (U.S. Census Bureau 2014), the education research community and United States educational policy have an obligation to make sure that young children have access to high-quality STEM experiences, both in school (formal) and out of school (informal). Given the highly engaged and curious nature of children in the early years, early childhood settings provide important sites to explore the characteristics and impact of informal STEM learning in new and innovative ways. A model that promotes active and collaborative partnerships between informal learning practitioners, community entities, and classroom teachers represents an effective way to advance accessibility, equity, and research for informal STEM learning experiences in rural early childhood settings (Avery 2013; Avery and Kassam 2011; Goodpastor et al. 2012). The key to this engaged learning paradigm is fostering strong collaborative partnerships that capitalize on the strengths of rural areas and the educators who live there, and researchers must therefore develop and nourish meaningful relationships between rural, informal STEM partners and schools. Increased research usually brings increased funding, and both are needed to help end the pervasive cycle that keeps rural informal STEM learning both underfunded and underrepresented in the research literature. Twenty-first century demands for rurally located resources and opportunities (e.g., alternative energy sources) suggest that STEM talent and knowledge of rural places may be key to the future prosperity of the United States, and that talent must be nurtured beyond the walls of school buildings and from a very young age. The creative talent necessary for meeting those needs will include knowledge and understanding of rural place and communities, as well as of science and mathematics. Educational research has an important role to play in both bridging the gap between current realities and future prospects and in making community partners of formal and informal learning environs.

About the Authors

Sara L. Hartman is an Assistant Professor of Early Childhood Education in the Department of Teacher Education at Ohio University. She earned a Ph.D. in Teaching, Curriculum, and Learning from the University of Nebraska and has research interests related to school-community partnerships in rural early childhood settings. Sara is the co-founder and Board President of the Ohio Valley Museum of Discovery. She enjoys drinking tea and reading books to children and is happiest when she can do both at the same time. Sara can be reached for comments or questions at hartmans@ohio.edu.

Jennifer Hines-Bergmeier is a Professor of Chemistry and Biochemistry at Ohio University. She co-founded the Ohio Valley Museum of Discovery, served as its first Board President, and continues to serve as a board member. She earned a Ph.D. in Medicinal Chemistry from the University of Michigan, where she also spent time working with the Ann Arbor Hands-On Museum. Like all good chemists, Jennifer enjoys mixing and stirring, especially in the kitchen with her family.

Robert Klein is an Associate Professor and the Undergraduate Chair in the Department of Mathematics at Ohio University. He earned a Ph.D. in Education from The Ohio State University and has research interests pertaining to the socio-cultural aspects of education and rural education. Robert is very involved in Math Circles for students and teachers in the United States and Central America and is Executive Director of the Alliance of Indigenous Math Circles. In his free time, he enjoys posing and discussing questions that cannot be solved, such as "what happened to my free time?"

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Experiential Learning in the 21st Century: Service Learning and Civic Engagement Opportunities in the Online Science Classroom

JILL NUGENT
Southern New Hampshire University

KELLY THRIPPLETON-HUNTER
Southern New Hampshire University

Abstract

Online higher education programs provide opportunities and access to students who might not have enrolled in a higher education program otherwise. As the demand for these online programs increases, including those in the STEM fields, the need for experiential learning opportunities becomes critical. Experiential learning in the online environment can take place in a multitude of ways, can generate student engagement, and can incorporate collaborative learning opportunities. Together, these courses will involve hands-on learning experiences that address real-world needs, service learning, and civic engagement, all which encompass the central focus for these opportunities and are the foundation on which these courses will be built.

Introduction

A growing demand for online higher education programs brings with it the challenge of incorporating civic engagement responsibilities into an online environment. According to the 2015 Survey of Online Learning, conducted by the Babson Survey Research Group and published in the Online Learning Consortium's Online Report Card (Allen et al. 2016), 2.85 million students are taking all of their courses in an online environment, while another 2.79 million are taking at least one online course.

To put that in perspective, more than one in four students (28 percent) took at least one online course in the fall of 2014. Southern New Hampshire University's College of Online and Continuing Education (SNHU COCE) currently serves online students and offers more than 200 online college degrees and certificates, including those in Environmental Science and Geosciences. The demand for individuals in these fields is expected to increase 10 to 11 percent faster than average between 2014 and 2024, according to the Bureau of Labor Statistics (2016); therefore, providing innovative, hands-on, experiential learning opportunities for these students is crucial.

SNHU COCE incorporates experiential learning opportunities into its online STEM programs with a unique approach. Experiential learning is grounded in the work of John Dewey, Kurt Lewin, and Jean Piaget (Kolb 1984). Dewey (1938) argued that education and learning are social and interactive processes and stated that there is a connection between education and personal experience. Lewin and his Lewinian Model of Action Research and Laboratory Training focused on learning as facilitated by experience, acquisition of data, and observations. Piaget's Model of Learning and Cognitive Development incorporates aspects of these two, but also adds reflection and action to the mix. Together, the philosophy of experiential learning can best be described as a process of learning as opposed to learning on the basis of outcomes (Kolb 1984). According to Kolb (1984), "knowledge is created through the transformation of experience." (See *Figure 1* for a depiction of experiential learning in the 21st century framed in the context of Kolb's experiential learning cycle.)

The purpose of the experiential learning courses for our online learners is to provide students with an opportunity to gain experience in their chosen field. In this report, we'll focus specifically on civic engagement and service learning opportunities within the experiential learning courses. Civic engagement and service learning opportunities promote a sense of community and civic responsibility using reflective thinking to develop the students' academic skills. Students participating in these types of immersive opportunities have the chance to work in local communities, address current environmental issues, and assist communities in implementing solutions. Course outcomes for the experiential learning courses revolve around guided reflection. The act of

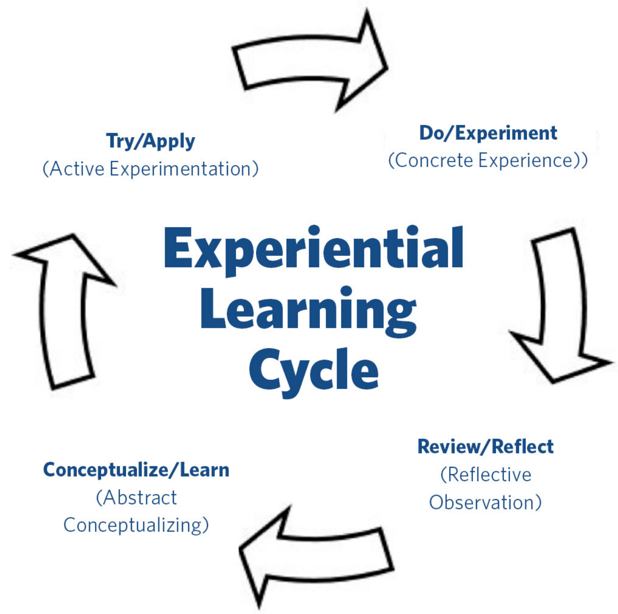


FIGURE 1. Experiential Learning in the 21st century framed in the context of Kolb's experiential learning cycle (Kolb 1984).

reflection is often a process that allows for the reorganization of knowledge and thought in order to attain greater insight (Moon 2004, 82). According to Moon (2004), understanding, decision making, resolution, and action outcomes can result from the use of reflective processes, including reflective journaling. Together, these reflective processes link reflection with the process of learning.

In the experiential courses, students reflect on scientific practices and real-world situations; they reflect on how experiential learning opportunities play a role in driving the achievement of their goals, and examine the relationship between the application of scientific inquiry and their real-world experiences. Students engage in reflective learning by participating in various discussions with their peers (collaborative reflection), along with writing in weekly journals to document their journey through the many experiences they encounter (personal reflection). (See *Figure 2* for an overview of student journal guidelines.) Upon completion of the course, students produce a guided written reflective piece that summarizes all of their experiences and details how those experiences have influenced their personal goals and future career path and helped identify what questions they may still have as they go forth in their educational and professional careers.

Overview: Your journal is a valuable tool for reflecting on and analyzing your experiences each week. Your instructor will provide you with feedback each week that can inform your approach and help you create a more successful final project. You will use your collective journal entries and instructor feedback as tools for crafting your final written reflection.

Prompt: In addition to the weekly journal critical elements that you will see each week, this journal entry requires you to describe both your background and the expectations around this experiential learning opportunity.

For this journal entry, you should summarize your experience and provide specific details to address the following:

- **Background and Expectation Critical Elements**
    - Describe your **interests and background** within the field of science.
    - Describe your **expectations** around the experiential learning opportunities in this course, as well as how this course will assist you in your personal and career development.

You should also address the following:

- **Weekly Journal Critical Elements**
    - Provide an overview of tasks and key activities (training, discussions, labs, assessments, etc.) in which you were engaged during the week, and describe how you applied **scientific inquiry** to work through these tasks and key activities.
    - Describe an objective of your weekly tasks and activities that you were **successful** in accomplishing, and explain why you were successful.
    - Consider an objective from your weekly tasks and activities that you were **least successful** in accomplishing, and:
        1. Describe how you identified those **challenges**. Consider any prior coursework and/or work experiences.
        2. What did you learn as a result of this experience? What might you do differently in the future to minimize the chance of reoccurrence, or how might you change your approach to **resolve** or overcome it?
    - Summarize your weekly experiences and what you have gained from them using appropriate **scientific terminology**.

FIGURE 2. An overview of journal guidelines

Online Experiential Learning in Science through Service Learning and Civic Engagement

Service learning has been identified as a high-impact practice that promotes higher-level learning and success (Kuh 2008; Brownell and Swaner 2010). The National Task Force on Civic Learning and Democratic Engagement (2012) is calling for renewed energy in community engagement, civic engagement, and service learning. Service learning and civic engagement involve building a sense of responsibility to one's community and allow students the opportunity to apply concepts and ideas learned in class to real-life situations and scenarios (Holland et al. 2008, 165). Experiential learning with an emphasis on service learning and civic engagement in the online science learning environment can take place in a multitude of ways and can, in fact, generate high levels of student engagement and collaborative learning opportunities. The learning can take place in both the student's local community and in the online environment where students interact with their peers and a faculty member, sharing, communicating, problem solving, and reflecting throughout the course.

At Southern New Hampshire University's College of Online and Continuing Education, the goal is to provide students with meaningful learning experiences that connect to real-world relevance. To achieve this goal, an online science experiential learning undergraduate course has been created for our Environmental Science and Geoscience majors that includes varying topics that rotate throughout the year. Students may take this elective course up to two times in total. (See *Figure 3* for the Course at a Glance Overview.)

Students engage in short-term immersive learning experiences that span roughly two months and include a minimum of seventy documented hours of experience. (See *Figure 4* for the required weekly student timesheet template.) Students have the opportunity to engage in service while concurrently reflecting on their experience, exploring personal and professional development opportunities, applying scientific concepts to real-world situations, and developing competencies and skills around a desired career interest. The course also allows students to make personal connections in their field of interest and provides a face-to-face experience where students can demonstrate competency in the field to potential future employers, colleagues, or collaborators.

Module	Topics and Assignments
1	1-1 Experiential Learning Weekly Activities (Non-graded) 1-2 Discussion 1-3 Background and Expectations Journal 1-4 Timesheet Activity 1-5 SNHU Career Center (Non-graded)
2	2-1 Experiential Learning Journal 2-2 Timesheet Activity
3	3-1 Experiential Learning Journal 3-2 Timesheet Activity
4	4-1 Discussion 4-2 Course Mission Journal 4-3 Timesheet Activity
5	5-1 Experiential Learning Journal 5-2 Timesheet Activity
6	6-1 Discussion 6-2 Experiential Learning Journal 6-3 Timesheet Activity
7	7-1 Final Project Submission: Written Reflection 7-2 Timesheet Activity
8	8-1 Discussion 8-2 SNHU Career Center (Non-graded)

FIGURE 3. Course at a Glance Overview

Southern New Hampshire University

SCI 360 Timesheet Template

This sheet must be filled out to capture your experiential learning activities for each module. By the end of this course, you are required to complete a minimum of 70 hours of course-related activities. It is strongly recommended that you strive for 10 hours each week.

These timesheets MUST be filled out weekly.

Full Name: Click here to enter text.
Module: Click here to enter text.
Activity Confirmation (for instructor use only): Click here to enter text.

Week of (Monday start date)	Title of Activity	Activity Type and Source	Hours Completed
mm/dd/yyyy		**Type**: **Source**:	
mm/dd/yyyy		**Type**: **Source**:	
mm/dd/yyyy		**Type**: **Source**:	

FIGURE 4. Weekly Student Timesheet Template

Examples of topics that focus on service learning and civic engagement in science for the online science experiential learning course are discussed below.

Service Learning

Service learning is a form of experiential learning that involves equal focus on student learning and community service goals. Service learning encompasses both reflection and reciprocity, where students actively participate in the service learning project and reflect on their experiences, in a dynamic action-reflection process. In *Service-Learning in Higher Education* (1996), Barbara Jacoby writes, "Service-learning is a form of experiential education in which students engage in activities that address human and community needs together with structured opportunities for reflection designed to achieve desired learning outcomes." Therefore, in the online experiential learning course, students are actively engaged in learning opportunities that address a real-world need, while also providing time for reflection and discussion as learners progress towards mastery of course learning outcomes.

Service Learning and Grant Writing

Students learn to write a science grant in a real-world setting. They are tasked with finding and working with a local community partner organization in their area (such as a local, state, or national agency or park, museum, wildlife center, science center, aquarium, or zoo). The students work with their chosen entity to develop a grant proposal for funding that will be submitted to a granting agency for consideration. Students are not assessed on the outcome of the grant application process, but rather the outcomes and assessment focus on the experiential reflective learning process. In this experience, students make connections in their local community, serve the organization's need by submitting a grant on their behalf, and gain a marketable skill.

Service Learning and Field Experience

Field experience can be interpreted broadly, but generally refers to gaining experience in the field in which the student would like to work. For example, it may include service in a branch within the Department of the Interior, e.g. National Park Service (NPS), United States Fish and Wildlife Service (FWS), United States Geological Service (USGS), or serving on a local (city or county) geographic information system (GIS) project. Conversely, it may involve students who serve as data analysts on a scientific study that encompasses large data sets ready for analysis and synthesis. In this case, students work collaboratively with a faculty member who provides the raw data for the course, and the team of faculty and students work together to analyze and synthesize the data. The data analysis and synthesis could also include a final communication of those science results in a journal, data report, or other research publication.

Field experience allows students to gain skills that will help them in their future careers, and to make connections in the field, add to their professional network, and serve the needs of a community project or organization by serving its overall goal or mission in some capacity.

Civic Engagement

Civic engagement centers on making a real-world difference in the community while concurrently developing knowledge, skills, competencies, and abilities to achieve successful course and community project outcomes. Civic engagement can take on many forms in the higher education environment, and it prepares students to be engaged citizens. In our civically engaged experiential learning opportunities, students work on authentic science projects that are designed to make a difference in the community and provide students with real-world experience in science.

FIGURE 5. In online experiential learning, the world is our lab

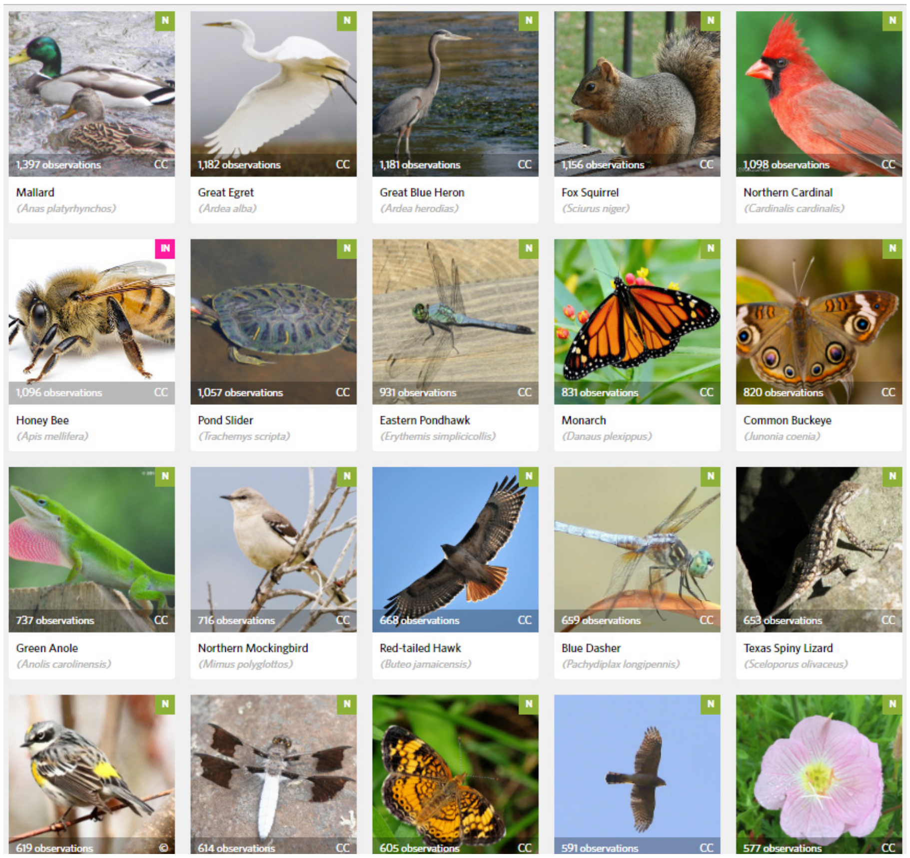


FIGURE 6. Updated Species Guide on iNaturalist

Civic Engagement through Community Citizen Science

In the online science experiential learning classroom, the world is our lab (*Figure 5*). Citizen science, or public participation in science, offers science students the opportunity to engage in science along with a greater community of collaborators or participants. Students gain experience facilitating and leading the public in real-world science. For example, students may create a citizen science species monitoring project on iNaturalist and host a BioBlitz in their local area. A BioBlitz refers to a period of time (such as a weekend) when organisms in a certain geographic area are surveyed and documented. The iNaturalist mobile device app allows for the BioBlitz to take place, with participants using smart phones and uploading images of the organism to the iNaturalist project.

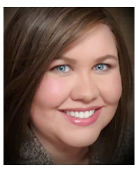
In 2017, the "City Nature Challenge," which began in California in 2016, became a national event. The April "City Nature Challenge" (Natural History Museum of Los Angeles County 2017) coincided with "National Citizen Science Day" and included a friendly BioBlitz-style competition among sixteen cities across the United States. The "City Nature Challenge" uses iNaturalist to document species in a given area during a set period of time. Therefore, events like this can be a way for students to get involved in their local community and organize, lead, and facilitate BioBlitz events with the public. Engagement in community citizen science and BioBlitz events can lead to publishing ideas and opportunities for students, including the creation of a blog relating their experiences. Reporting about the experience is beneficial to the learning process, and also serves to reinforce an important aspect of the science process: communicating the science. In addition, science students help identify organisms that come in from participant observations during the challenge, and ultimately student participation helps to "crowdsource" and update species guides for each region. (See *Figure 6* for an example of the updated species guide from the North Texas area, following the 2017 City Nature Challenge.) In 2018, the City Nature Challenge will be a global event. Imagine the unlimited possibilities for your own students when the world comes together in a locally engaged, globally connected iNaturalist BioBlitz next spring.

Conclusion and Discussion

The journey into experiential learning in the online science classroom has only just begun and the service learning and civic engagement examples discussed in this article are only the beginning for online experiential learning opportunities in science. We look forward to continuously learning from our students and our colleagues, and to applying collective stakeholder feedback as we further expand our course topic offerings. We welcome and invite discussion and collaboration with the entire SENCER community as we continue the exciting journey and evolution in online science education to serve the twenty-first-century learner.

About the Authors

Kelly Thrippleton-Hunter is a Faculty Lead for Undergraduate Science at Southern New Hampshire University's College of Online and Continuing Education. She received two B.S. degrees, one in Zoology and the other in Environmental Biology and Ecology, from California State University, Long Beach in 2002, a Ph.D. in Environmental Toxicology from the University of California, Riverside in 2009, and an M.A.T. in Science from Western Governors University in 2015.



Jill Nugent is the Associate Dean for Science at Southern New Hampshire University's College of Online and Continuing Education. She is currently a doctoral candidate at Texas Tech University, investigating locally engaged, globally connected citizen science in university science courses.

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Conversations about Technology and Society: Techniques and Strategies to Encourage Civic Engagement in Museums

RAE OSTMAN
Arizona State University

Abstract

Museums are changing the way they connect with their communities by positioning themselves as venues for civic engagement and multidirectional dialogue. Through an effort known as Nano and Society, hundreds of museums and universities have collaborated to encourage conversations among community members, educators, scientists, and others about nanotechnologies. Nano and Society conversations focus on public audiences' experiences and values, validating their opinions and identifying a role for them in making decisions about emerging technologies. This article describes how the content and design of Nano and Society conversations support participant learning, shares facilitation techniques that educators and scientists can use to implement the conversations in informal learning settings, and summarizes the professional and public impacts of the project.

Introduction

The National Informal STEM Education Network (NISE Net) is a community of informal educators and scientists dedicated to supporting learning about science, technology, engineering, and math (STEM) across the United States. Network partners include over 600 museums, universities, and other organizations that work together to develop, implement, and study methods for engaging public audiences in learning about current STEM research and its social dimensions (Ostman 2017).

The Network has experimented with a variety of educational products to engage public audiences in learning about the societal and ethical implications of current STEM research. These include interactive exhibits (Ostman 2015) and hands-on activities that invite exploration and discovery (Ostman 2016a, 2016b); forums that encourage dialogue among experts and citizens (Herring 2010; Lowenthal 2016); museum theatre programs that use theatrical techniques to create and cultivate emotional connections (Long and Ostman 2012); and games to foster play and social interaction (Porcello et al. 2017). Of these approaches to the social dimensions of STEM, to date the most widely adopted products and practices were developed as part of a project known as Nano and Society.

The project included a year of planning and development in 2011–2012 and was launched in 2012–2013 with a series of workshops that involved more than 50 museums and universities across the United States. The project team created a set of key concepts for conversations about nanotechnologies, a variety of conversational activities, and a suite of training materials. In 2013–2016, Nano and Society concepts, strategies, and resources were also incorporated into hands-on activity kits and exhibits that were distributed to hundreds more Network partners.

Early in the project, the team talked to professionals at Network partner organizations, including museums and universities, to learn more about the barriers to and opportunities for incorporating public learning experiences focusing on the societal and ethical implications of nanotechnologies. These discussions indicated what was needed in order for this content to be widely integrated into partners' programming. First, Nano and Society themes had to be offered through common engagement formats that partner organizations were already using, such as hands-on activities, rather than new formats that were resource-intensive to learn and implement. Second, partners felt that an open-ended, conversational approach focusing on the public's own ideas and values was more appropriate for their public audiences than a comprehensive discussion of costs, risks, and benefits of complex new technologies. And third, Network partners needed professional development in order to gain the necessary skills and confidence to implement this new approach.

The Nano and Society project team included members from Arizona State University, the Museum of Life and Science, the Museum of Science and Industry, the Oregon Museum of Science and Industry, the Science Museum of Minnesota, and the Sciencenter in Ithaca, New York. The work was supported by the NISE Network (in its original identity as the Nanoscale Informal Science Education Network) and the Center for Nanotechnology in Society at Arizona State University (CNS-ASU), each funded by the National Science Foundation for more than 11 years.

The resulting Nano and Society activities engage museum staff, scientists, and visitors in meaningful conversations about the relevance of emerging technologies to our lives. The conversations are designed to focus on participants' own experiences and values related to technologies, to validate their opinions and identify a role for them in making decisions about emerging technologies, and to support learning as a social process. They are skillfully facilitated by educators or scientists to help participants apply their ideas to decisions about future nanotechnologies that we face as a society. This article describes how the content and design of Nano and Society conversations support participant learning, shares techniques that educators and scientists can use to implement the conversations in informal settings such as museums, and summarizes the professional and public impacts of the project.

Multidirectional Dialogue

Museums and their community partners represent an ideal location for people to explore perspectives on emerging technologies. Museums serve broad and sizeable audiences across the United States and are perceived as trusted venues for learning and socializing (AAM 2015). Although museums are increasingly interested in serving as community forums and promoting civic engagement, as a whole the field is not yet well equipped to do so in a way that is universally welcoming. In response, the Nano and Society project focused on increasing the capacity of museums across the country to engage their audiences in meaningful conversations about nanotechnologies.

The project is part of a growing movement for museums to provide a space for thoughtful reflection and civil conversation among multiple and diverse public audiences. Leaders, researchers, and practitioners across the field are calling for museums to serve as essential community resources and provide authentic, participatory learning experiences that address relevant and timely issues (Davis et al. 2003; Kadlec 2013; McCallie et al. 2009; Simon 2010). Professional organizations and funders emphasize the convening power of STEM-rich museums and their potential to promote civic engagement related to science-in-society (e.g. AAAS 2017; ASTC 2017; Ecsite 2017; IMLS 2017; NSF 2017; Science Center World Summit 2014).

One aspect of this movement has been the development of programs that address issues that their communities care about, introduce current scientific research, bring together scientists and community members, and provide multidirectional dialogue and engagement among participants. Museums of all types are increasingly experimenting with dialogue-based programming and exhibitions, particularly for addressing complex, contested, or sensitive topics (Bell 2013; Davies et al. 2009; Kollmann 2011; Kollmann et al. 2012; Kollmann et al., 2013; Lehr et al. 2007; McCallie et al. 2007; Ostman et al. 2013; Reich et al. 2007).

The Public Conversations Project defines dialogue as "any conversation in which participants search for understanding rather than for agreements or solutions," and which is clearly distinct from "polarized debate" (Herzig and Chasin 2011, 3). The National Coalition for Dialogue & Deliberation characterizes dialogue as a process that "increases understanding, builds trust, and enables people to be open to listening to perspectives that are very different from their own" (NCDD 2014, 1). Dialogue allows people to share their values, perspectives, and experiences about difficult issues and to hear from others. It helps dispel stereotypes, build trust, and open people's minds to ideas that are different from their own. Dialogue can, and often does, lead to both personal and collaborative action, but that action is not an essential outcome of dialogue (Bell 2013; Davies et al. 2009).

As a public engagement process, dialogue has several general characteristics. It involves utilizing facilitators and ground rules to create a safe atmosphere for honest, productive discussion; framing the issue, questions, and discussion material in a balanced and accurate manner; talking face-to-face; considering all sides of an issue; and establishing a foundation for continued reflection and possibly for future decisions or actions (NCDD 2014, 1). Within this general definition, the Nano and Society team focused on creating opportunities for dialogue that could be integrated seamlessly into a regular museum visit, were appropriate for general public audiences, and could be facilitated by any staff member or volunteer.

FIGURE 1. Museum visitors use an exhibit challenging them to build a future that includes new nanotechnologies. *Photo by Emily Maletz, courtesy of the NISE Network.*

Nanotechnology and Society Content

Nanoscale science and engineering is a relatively new, interdisciplinary field of research that studies and manipulates matter at the level of atoms and molecules, enabling innovations in materials and devices. Some new nanomaterials and technologies allow improvements to existing products, such as computer chips, sunblock, and stain-resistant fabrics, while others could be transformative, such as elevators to space, invisibility cloaks, and cures for cancer. Because nanotechnologies are still developing, as a society we can influence what they are and how they are used. While the capability to create and use new technologies is based on advances in science and engineering, our individual and collective decisions about which technologies to develop and use are societal issues, with cultural, ethical, environmental, political, and economic dimensions. In order to participate fully in decisions about emerging technologies, Americans need both scientific and citizenship literacy skills (Partnership for 21st Century Skills 2015).

Nano and Society conversations offer participants an opportunity to understand the relationship between technologies and society, consider how emerging technologies will influence our lives, and learn how we can shape the development of new technologies. In other words, these conversations explore our values as individuals and consider the kind of future we want to build. Three "big ideas" provide a conceptual framework for the conversations: (1) Values shape how technologies are developed and adopted; (2) Technologies affect social relationships; and (3) Technologies work because they are part of larger systems (Wetmore et al. 2013).

Nano and Society conversations explore the many dimensions of the relationship between technology and society. They acknowledge that we will always have imperfect information about risks, benefits, and consequences, but emphasize that as individuals and as a society we still must make decisions about what science we will pursue and what technologies we will use. The goal of the conversation is not to solve complex issues on the spot, but rather to give public audiences the opportunity to develop knowledge, skills, and attitudes that are essential to engage deeply with current science and to participate as citizens. This shift to a science-in-society framework gives every visitor a role in the conversation, since the discussion is not about the technical aspects of scientific advances, but rather about the possibilities science and technology raise for our future, and what we want that future to be as individuals and communities.

Design Strategies

Nano and Society conversation are designed to have a flexible format, to include interactive elements, and to focus on accessible key concepts. They are relatively brief experiences that can be offered on the museum floor or incorporated into longer programs. They usually include a hands-on activity, demonstration, game, or other interactive element as a conversation-starter. Educators, scientists, and public audiences with a wide range of background knowledge and experience can participate in them equally, because they focus on the aspects of technologies that everyone has experience with: their own values, possible impacts on their social relationships, and

FIGURE 2. Educators and scientists learn a game where participants prioritize the development of new nanotechnologies. *Photo by Emily Maletz, courtesy of the NISE Network.*

the ways technologies interact as parts of systems in their lives. These design strategies allow the conversations to be used in a variety of ways in informal settings, with diverse participants.

The Nano and Society team uses a "cupcake" analogy to explain how these conversations are different from other kinds of informal learning experiences that focus on technologies. In a typical demonstration about a new technology, a museum educator might focus on the technology, talking about why it is amazing, who invented it, and how it is made. Finally, the educator might conclude by describing the impact that the technology could have on society and ask if there are any questions. In this approach, the societal and ethical implications of the technology are added on at the very end of the experience, like the sprinkles on top of a cupcake. In a Nano and Society conversation, the social dimensions of the technology are baked into the experience, not sprinkled on top. Both society and technology are integral and are considered together throughout the conversation.

For example, in a game called "Exploring Nano & Society—You Decide," participants are given a set of cards that present a variety of new and emerging nanotechnologies, such as gold nanoshells for treating cancer and miniature military drones. The cards include the kinds of basic information described above, but the interaction does not focus on the technical aspects of the technologies. Rather, the participant group is asked to browse the new technologies and decide which ones they think are most important for society and should be prioritized for development. Usually, participants quickly realize that there are many different factors that determine which technologies are most "important," and they discover that there are different opinions within their group. Often, participants are concerned that there may be downsides or unintended consequences to these technologies that we cannot predict. They may decide that the potential benefits of some technologies seem worth the potential costs and risks, while others do not. They may even go so far as to "ban" one or more of the options as too risky. Other technologies may be declared cool by some but frivolous by others, with negligible benefits. When the group settles on a scheme (or schemes), the facilitator introduces a character card. These cards present different people from around the world, such as a mother in Mozambique or an Iraqi soldier, and suggests some of the things those characters value and are concerned about. The group is asked to reprioritize the technologies based on the perspective of the character on the card. This resorting activity helps the group to see that technologies benefit individuals and countries in different ways and to different degrees, and that different people and countries may be interested in developing and using different kinds of technologies.

The design of the You Decide activity is simple, but it promotes rich conversations. Often, participants raise most of the key learning concepts amongst themselves, with just a bit of guidance from the facilitator. The facilitator joins in at key moments: explaining the game play, helping the group clarify their thoughts about a particular technology, judiciously choosing a character card that offers a different perspective, and helping the group draw some general conclusions from the game. Throughout, the conversation focuses equally on technologies and society, rather than primarily on the technologies themselves. That is, the social dimensions of technologies are baked into the conversation, not sprinkled on top.

Facilitation Techniques

In Nano and Society conversations, the typical roles of the educator or scientist and the participant shift. The educator or scientist takes on the role of facilitator rather than expert, asking questions, offering ideas or information to consider, and providing new perspectives. Meanwhile, participants take on some authority by contributing their values and experiences related to technologies. The facilitator guides the conversation by helping participants reflect on and form their own ideas and opinions and by introducing new perspectives and issues (Ostman et al. 2013; Wetmore et al. 2013).

Network educators have identified several techniques that help them facilitate interesting and meaningful conversations. The facilitator first invites participants to try the activity, demo, or game.“This introductory experience establishes rapport, provides some basic familiarity with nanotechnology, and introduces a topic for conversation. Then, the facilitator initiates a conversation by asking questions or making observations about what participants say and do. This validates participants' perspectives and establishes a two-way interaction focused on developing ideas, rather than a one-way presentation of information. Then, the facilitator draws out participants' experiences and values related to technologies. The facilitator might reflect participants' ideas, ask open-ended questions, make connections to things participants are familiar with from from everyday life, or offer additional information for consideration. The facilitator gently guides the conversation, following participants' interests and ideas. While the facilitator always has the key concepts in mind, and often has a repertoire of talking points and connections related to a given activity, the conversation never follows a set script. The facilitator also makes sure to involve everyone in the group. Finally, the facilitator

FIGURE 3. Museum visitors experiment with refraction and talk about what would happen if invisibility cloaks existed. *Photo by Emily Maletz, courtesy of the NISE Network.*

follows participants' cues, recognizing when the group is ready to move on and wrapping up graciously (Ostman et al. 2013).

For example, in the "Exploring Nano & Society—Invisibility" activity, the facilitator starts with a classic science demonstration about the refraction of light in order to spark participants' curiosity. The facilitator explains that researchers are experimenting with ways of bending light to cloak objects, making them invisible to the human eye or to surveillance devices. So far, they have only succeeded at the nanoscale, but full-size invisibility cloaks could be coming soon. The facilitator then initiates a conversation about what participants would do if they had an invisibility cloak. A child might suggest mischievous activities, such as staying up past her bedtime or spying on her brother. The educator might ask the child how she would feel if someone spied on her using an invisibility cloak, leading to a discussion about privacy rights. A parent might ask what would happen if criminals had invisibility cloaks, turning the conversation to government regulation of technologies. Another child might suggest we need additional technologies—such as a cloak-detector—to deal with the problems this new invisibility technology introduces. The facilitator might point out that many of these issues have come up with previous technologies, and the group might think about how we can learn from some of these previous experiences.

Whichever way the conversation goes, the facilitator can draw out one or more of the Nano and Society key concepts. As they think and talk about the invisibility cloak, participants come to understand some of the ways in which they make and contribute to decisions about technologies. They recognize how this new technology would affect the way they interact with other people. And they articulate kind of future they want to live in and the ways they think emerging technologies may help build or block that future.

In a successfully facilitated conversation, participants enjoy their experience, develop an understanding of one or more of the key concepts of technology and society, connect these concepts to their own lives, and recognize their role as a decision-maker with regard to technologies (Wetmore et al. 2013). All parties in a conversation—educators, scientists, and public participants—explore

FIGURE 4. An educator and museum visitors imagine what our world would be like if it were possible to take an elevator to space. *Photo by Gary Hodges, courtesy of the NISE Network.*

concepts and practice ways of learning, talking about, and thinking about technologies that they can continue to apply in other aspects of their work and lives.

Another activity, "Exploring Nano & Society—Space Elevator," asks participants to imagine what would happen if new nanomaterials made it possible for us to build elevators into space and invites them to sketch or talk about their ideas. Among intergenerational groups, children often feel confident drawing, while the facilitator and adults in the group discuss and ask questions. For example, at a community science night, one young girl meticulously drew a picture of a future space elevator, detailing how it would be powered, who could ride it, the route it would take through the solar system, training requirements for elevator staff, and the food they would serve on board. An adult then asked a simple but powerful question: "What's up there when you arrive?" This led to a imaginative discussion about what kind of infrastructure we would build if we were colonizing space. As the girl started to draw houses, family members wondered, "Would our houses look like houses on Earth or would they have to be different for us to survive in space? Do we need mailboxes in space? Can we get mail? How do we communicate with people on Earth?" The act of drawing in concrete details inspired the group to consider a whole variety of interrelated systems and social structures we have on Earth and make decisions about whether or not they might need or want to recreate them if they were starting fresh somewhere else.

Ideally, these conversations empower participants (educators, scientists, and publics) to come to understand the role we all have in developing and adopting technologies, the ways those technologies affect our personal relationships and our society more broadly, and the ways all technologies work as part of interconnected systems. The three "big ideas" of Nano and Society are a powerful way to engage visitors in learning about nanotechnology. They spark interest and enjoyment, demonstrate relevance by connecting science and engineering with society, and indicate some of the ways that new technologies may affect our lives.

Professional Resources and Training

In order to share the Nano and Society approach across the Network, and to ensure museum staff and volunteers were comfortable with the new approach and resources, NISE Net and ASU-CNS committed to providing a comprehensive range of professional development opportunities and resources.

In 2012–13, the project team offered multi-day, in-person professional development workshops in four locations across the United States. Around 100 professionals from 50 different organizations were invited to attend the workshop. The workshops were organized around the three big ideas. Following an introduction to the project goals and rationale, each unit included improv exercises designed to build facilitation skills and comfort related to open-ended conversations, practical experience learning and delivering Nano and Society conversations in small groups, and deeper exploration of one big idea as a large group. The workshops concluded with training in a Network practice known as team-based inquiry, which gave educators methods and tools to experiment with and identify facilitation techniques that support audience engagement and learning (Pattison et al. 2014).

FIGURE 5. Educators and scientists learn an improv exercise that develops their facilitation skills. *Photo by Emily Maletz, courtesy of the NISE Network.*

Workshop participants were provided with physical kits they could use to do a similar training with their own staff and volunteers and to implement the activities with audiences at their home organization. The training kits included sample training agendas; an overview slide presentation explaining the rationale for exploring the social dimensions of technologies in an informal learning setting; short, humorous videos exploring the big ideas; guides for a set of improv exercises to strengthen essential skills; team-based inquiry tools; and physical materials and supplies to try out and implement a series of Nano and Society conversations. While the Nano and Society project used a "train-the-trainer" model, completely faithful implementation of the workshop, or the conversation activities, was not essential; it was more important that participants implemented the resources in a way that was appropriate, sustainable, and empowering for their institution and audiences.

The project also built in several follow-up opportunities for workshop participants. There were two online sessions scheduled soon after the in-person workshops, designed to support museums as they began to train additional staff and volunteers and implement the programming. The first online session oriented museums to their physical kits and the resources they contained and was intended to prepare the participants from the in-person workshop to train other educators at their organization. The second online session provided an opportunity to discuss facilitation strategies with peers and was intended to allow educators to share their experiences and insights as they began having Nano and Society conversations with public audiences. Finally, NISE Net's Network-Wide Meeting offered an additional in-person opportunity for workshop participants to reconnect and share their learnings with others.

After the initial series of workshop trainings, all the Nano and Society materials were made available online for free download (Sciencenter et al. 2012), and additional Nano and Society trainings were offered online and in other Network meetings. As with all Network resources, the Nano and Society materials are open source and distributed through a Creative Commons license, and Network partners are encouraged to adapt them to fit their mission, educational setting, and local audiences.

Project Impact

The Nano and Society project has had a great impact on the NISE Network community. The products and professional practices developed by the project are widely used, with partners across the United States engaging multiple and diverse public audiences in conversations about technology and society.

Nano and Society has been studied in terms of professional learning, public learning, and research-to-practice partnerships. As a capacity-building project, it was included in the Network's professional impacts summative evaluation study (Goss et al. 2016). Nano and Society public educational activities were incorporated into a variety of Network products, and their public impacts are assessed as part of the overall summative evaluation of those products (see Kollmann et al. 2015; Svarovsky et al. 2013; Svarovsky et al. 2014). Finally, the project was included as a case in a research study that examined how complex science ideas are made accessible to public audiences through research-to-practice partnerships between university scientists and museum professionals (Lundh et al. 2014).

NISE Net's logic model articulates the Network's overall theory of change. Essentially, the Network achieves public impact through the efforts of our institutional partners, including museums, universities, and other organizations committed to informal STEM education. The Network provides professional development and educational products to our institutional partners. Staff and volunteers implement these resources, establishing additional local partnerships and engaging local public audiences. Thus, the direct impact of the Network (and efforts such as Nano and Society) is on our professional partners, and the indirect impact is on the public audiences they engage (see Bequette et al. 2017, 15–17).

Consistent with the Network logic model, the Nano and Society project's primary goal was to increase the capacity of informal educators to engage public audiences in learning about the social dimensions of nanotechnologies, with the expectation that they would then implement conversations with their local audiences. The project addressed two related professional impact goals for the Network: by participating in the Network, professionals would (1) understand theories, methods, and practices for effectively engaging diverse public audiences in learning about nano; and (2) utilize professional resources and educational products for engaging diverse public audiences in learning about nanoscale science, engineering, and technology.

The NISE Network Professional Impacts Summative Evaluation is a longitudinal study of individual professionals, primarily working at museums and universities, over the final three years of the Nanoscale Informal Science Education Network (project years 7-10) (Goss et al. 2016). The study explored how involvement with NISE Net impacted professionals' sense of community, learning about nano, and use of nano educational products and practices. It employed two data collection methods over three years: an annual partner survey that involved a total of 597 professionals, and yearly interviews with a representative subset of 21 professionals (Goss et al. 2016). Within the study, the Nano and Society project was considered in terms of the two relevant professional impact goals described above: the degree to which Network partners adopted the professional practices it represented, and the degree to which they used the professional resources and public products it distributed.

The evaluation team found that over the study period, professionals reported becoming more confident in Nano and Society concepts and increased the extent to which they attributed that confidence to NISE Net. The percentage of professionals who reported using Nano and Society practices for engaging the public grew, and individuals reported increasing the amount of time they focused on societal and ethical implications of nanotechnologies with their audiences. By the end of the funded project period (year 10), 83 percent of all Network professional partners engaged the public in Nano and Society content. Of these, 94 percent used Network resources (Goss et al. 2016, 65–66, 72, 95–96). Half of the study respondents in the final study year (project year 10) also reported using Nano and Society ideas to engage audiences in learning about other STEM topics, transferring the skills and techniques they had learned to other aspects of their work (Goss et al. 2016, 98–99). These findings are particularly impressive when compared to evaluation results prior to the Nano and Society effort (project year 5), when only a small percentage of Network partners engaged public audiences in learning about the societal and ethical implications of nanotechnologies (Kollmann 2011).

The professional impacts summative evaluation also offers some potential explanations for why Nano and Society practices and products had a large impact on the Network, while others promoted by the Network were used less extensively. The authors note that in conceiving the Nano and Society project, Network leadership took into account the summative evaluation of related previous work; a team was assigned to learn about partners' barriers and needs with regard to this challenging content, and new partnerships were established and substantial resources were dedicated to acting upon this information (Goss et al. 2016, 93). A full suite of professional resources helped professionals learn conversation practices, train others at their own organization, and share their results across the Network. A group of educational products, specifically designed to be integrated into activities Network partners already engaged in, provided concrete opportunities to implement Nano and Society ideas and practices immediately (Goss et al. 2016, 100).

The NISE Net Years 6-10 Evaluation Summary Report (Bequette et al. 2017) provides additional insight, identifying some of the general strategies that helped the Network to build the capacity of the field to do programming related to nanoscale science, engineering, and technology (including Nano and Society conversations). One successful strategy was creating educational products that model and embed best practices through their design, helping to ensure successful public learning outcomes and professional learning through implementation (Bequette et al. 2017, 44–45). Another important strategy was providing professional development opportunities that allow for deeper learning and sharing of ideas and expertise among Network partners (Bequette et al. 2017, 46–47).

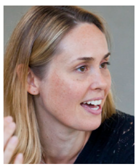
Since 2013, Nano and Society concepts and conversation activities have been integrated throughout the Network's educational products, including our most widely distributed and used materials: NanoDays kits of hands-on activities and the *Nano* small footprint exhibition. Because Nano and Society is now embedded into much of our public engagement work, the Network does not have data on the number of people who participated in Nano and Society conversations specifically. We do know that as of 2015, over eleven million people each year participate in NanoDays and the *Nano* exhibition which both incorporate Nano and Society conversations and concepts (Svarovsky et al. 2015; see also Kollmann et al. 2015). In addition, many Network partners are applying the practices and tools they have learned (such as improv exercises to train staff in facilitation techniques) to other content areas and work at their own institutions. And finally, the Network leadership and development teams continue to use Nano and Society ideas, models, and strategies for new projects that focus on a variety of STEM fields, further extending the impact of the project.

Conclusions

Science centers, children's museums, and other informal science learning organizations are increasingly finding ways to connect with our communities and make the experiences we offer more relevant to our audiences' lives. By incorporating participants' own perspectives into their learning experiences and by fostering productive social interactions, we hope to make museum learning opportunities more impactful and engaging for our audiences. At the same time, professional organizations and funding agencies seek to encourage dialogue among scientists, engineers, policymakers, and people everywhere in order to help understand and solve a variety of pressing global and local issues. As institutions that are trusted by all of these parties, informal learning organizations provide an important venue for these conversations, fostering civic engagement and dialogue.

Through Nano and Society and subsequent projects, NISE Net partners are working together to encourage multidirectional dialogue among community members, educators, scientists, and others. In Nano and Society conversations, insight occurs when participants think about the people that imagine, create, and decide to use technologies. They come to understand the role we all have in developing and adopting technologies, and the ways that those technologies affect our personal relationships and our society more broadly. Ultimately, Nano and Society conversations can help people feel empowered to make and contribute to decisions about new and emerging technologies.

About the Author



Rae Ostman is a faculty member in the School for the Future of Innovation in Society at Arizona State University and director of the National Informal STEM Education Network (NISE Net). She has broad experience planning, developing, implementing, and studying museum exhibits, programs, media, and other learning experiences in partnership with diverse organizations. She can be reached at rostman@asu.edu or 607-882-1119.

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An Authentic Course-Based Research Experience in Antibiotic Resistance and Microbial Genomics

DAVIDA S. SMYTH
Mercy College

Abstract

We have designed and implemented a novel microbiology elective course "Microbiology of Urban Spaces" to provide students with a transformative education in microbial ecology and genomics. It champions the values of general education while making sure students are well equipped for their future careers. Infusing my personal research into the course allowed me the time and resources needed to advance my own research, while allowing the students to tackle an authentic and real-world problem that they can be passionate about. Several students who were engaged in the research course developed their own research projects during the summer, based upon their own ideas and questions. These students have taken the first steps towards developing the mindset and confidence in themselves that will enable them to succeed in their future scientific endeavors. Though still in its infancy, this course shows great promise to promote SENCER ideals at Mercy College and beyond.

Introduction

A Capacious and Civic Issue

Bacteria residing in the environment can act as reservoirs for resistance, having been exposed to many antimicrobials such as disinfectants, heavy metals, and antibiotics

(He et al. 2014). Frequently encountered in the environment are the Staphylococci, many species of which are human pathogens. Especially problematic are the coagulase negative staphylococci, as they are among the most resistant, the most prevalent in environmental settings, and frequently the source of hospital-acquired infections of immunocompromised patients (Becker et al. 2014).

One of the most recognized and worrying antibiotic-resistant bacteria is a form of *Staphylococcus aureus* called MRSA or Methicillin Resistant *Staphylococcus aureus*. MRSA is recognized as a serious threat by the CDC, causing 80,000 infections and 11,000 deaths annually (CDC 2013). About one in three people carry Staphylococci asymptomatically in their noses. Several different mechanisms of transmission have been described for MRSA and it is frequently isolated from the environment (Smith et al. 2010). The recent emergence of community-associated MRSA or CA-MRSA has had a huge impact on the field, as the bacteria are acquired by people with no known risk factors. What is known about transmission of MRSA (Smith et al. 2010), particularly in the built environment, has generated many questions that can be of interest to our students. Such questions can include the following: Is the choice of material used in construction important in how long bacteria can adhere to a surface? Are some types of staphylococci better able to adhere to surfaces than others? Can some surfaces facilitate colonization by bacteria more readily than others?

Many Mercy students are studying to be healthcare professionals, such as nurses and veterinary technologists. As such, they are usually familiar with antibiotic-resistant bacteria. Thus, my goal is to help students understand the role of human activity, particularly the role they themselves can play, in driving or tackling this problem. Antibiotic resistance is now being recognized as a global threat (Nathan and Cars 2014). Over the past ten years, the Infectious Diseases Society of America, the Centers for Disease Control and Prevention, the World Health Organization (WHO), and the World Economic Forum have placed antibiotic-resistant bacteria at center stage. The WHO exclaimed in April 2014 (WHO 2014) that the problem "threatens the achievements of modern medicine. A post-antibiotic era—in which common infections and minor injuries can kill—is a very real possibility for the 21st century." The Obama administration released a National Action Plan for Combating Antibiotic-Resistant Bacteria in March 2015 (The White House 2015a). The 2016 federal budget almost doubled the amount of federal funding for combating and preventing antibiotic resistance to more than $1.2 billion (The White House 2015b). Our success or failure in the coming years will depend upon continued support for these initiatives and having a well-educated workforce, ready and prepared to tackle this capacious problem.

Results and Discussion

Students As Researchers

Incorporating research into the classroom, be it the lecture or the laboratory, affords all students an opportunity to be included in and exposed to research, which their economic means, schedule, or background may prevent them from otherwise experiencing (Bangera and Brownell 2014; Gasper and Gardner 2013). Engaging students in undergraduate research can promote retention and career readiness and increase enrollment in graduate studies. It can improve their critical thinking and problem solving abilities as well as their independence (Auchincloss et al. 2014; Harrison et al. 2011; Jordan et al. 2014; Lopatto et al. 2008). Thus, the aim of this ongoing project is to design, implement, and improve upon a novel course-based undergraduate research experience that investigates the prevalence and persistence of antibiotic-resistant staphylococcal bacteria in the environment. By participating in this course, students engage with the literature and keep pace with new developments in antibiotic resistance research; they learn about government-driven and global efforts to combat resistance; and finally, they present their work in a public forum. They begin to understand the dual roles that research and education play in tackling this capacious problem. The course involves isolating and characterizing specific antibiotic-resistant staphylococci colonizing the campus, using a range of classical and next-generation techniques and correlating these findings with metagenetics, a novel technology that allows the researcher to sample all DNA at a site (Blow 2008). This new course called "Microbiology of Urban Spaces" directly ties into my own research agenda and expertise and helps me to recruit and retain a team willing and ready to tackle the problem. Student learning outcomes are presented in Box 1 and specific activities in Box 2. The data generated as part of this project are used as a foundation for further student projects in the summer and have served as preliminary data for federal grant proposals and to obtain funding to support and sustain the course.

Briefly, students isolate individual bacteria using media selective for antibiotic and heavy metal resistance and characterize them phenotypically and genotypically over the course of the semester. They use a BSL2 lab that was recently refurbished for the purpose of microbiological research. The students are then encouraged to design their own phenotypic-based experiments (antibiograms, biofilms, adherence) to be conducted over the summer, and to develop their own research questions while continuing to harness the technologies and techniques learned in the course. The course is designed such that the metagenetic data are available for analysis towards the end, allowing time to expose the students to other characteristics and mechanisms leveraged by environmental staphylococci. The metagenetic component (swabbing, isolating DNA, and sequencing) is entirely at the discretion and choice of the students. In the first meeting of the course, students are introduced to my research questions and the work that my students and I have completed to date. They then brainstorm what sites would be of interest to target for sampling in view of my research and considering their own research questions. Once they have discussed and planned, the students, working as a team, sample various sites on campus. In Spring 2016, we targeted the new residence hall and sites such as elevator buttons, door handles, and handrails, and in Fall 2016, we targeted various water bodies in the vicinity of Mercy, including the Hudson and East Rivers and the Old Croton Aqueduct. The data we generated in Spring 2016 revealed the impact of human presence on newly colonized buildings at Mercy, and we have begun to design experiments targeting the specific organisms we have isolated and identified on surfaces there. While my original target was antibiotic-resistant staphylococci, we have also used metagenetics to identify the presence of Acinetobacter, Pseudomonas and Streptococcus on surfaces, many species and strains of which are also resistant to antibiotics. We shall adapt and modify our screening in future semesters.

How the Students Are Evaluated

Microbiology of Urban Spaces is designed not only to improve students' knowledge and understanding of research and antibiotic resistance, but also to train them to be 21st-century citizens. Students are expected to work in teams and build their communication skills. In this digital age we use instant messenger and group chats to facilitate communication. Dropbox is used to store course materials, protocols, and data in shared folders. Digital lab books are used (viewable to all team members) to ensure notes are updated regularly. Students are expected to be able to use and develop their quantitative reasoning skills and develop mastery of basic microbiology techniques such as dilutions, conversions, and basic computational tools and to generate a properly formatted bibliography. Above all else, the course encourages critical thinking and teamwork; students are able to choose their own sampling sites, interpret their findings, and learn from their mistakes. Repetition and iteration ensure mastery. Students are graded on the basis of their participating in lab meetings and lab activities, their detailed lab books, their final papers, and the generation of a scholarly poster. In addition, a survey based upon the SENCER SALG is administered at the beginning and end of the course, as well as the standard Mercy College End of Course surveys.

Student Success, Course Limitations, and Reflections

Since the pilot, I have been able to recruit eight students to participate each semester, and the course has gone through three iterations. Each section has been a success, with students reporting their enjoyment, self-satisfaction with their learning, and demonstrating their improvement in knowledge and skills over the span of the semester. Many had never generated a poster, worked with computational tools, or used molecular biology techniques except in class (if at all). Two students registered to take the course for a second time. Feedback from the End of Course and SALG surveys was positive as indicated in Box 3 and 4 (though not all students responded). In Spring 2016, when asked on the End of Course survey "if they would recommend a course to their friends and why," students answered, "Sure, opens your eyes to the world of research and looks great when applying to any grad

BOX 1
STUDENT LEARNING OUTCOMES:

1. Students will gain experience in reading, interpreting, and critiquing primary research articles.
2. Students will be trained in the use of microbiological and molecular lab equipment, methods, and standard operating procedures of the instructor.
3. Students will utilize classical and next-generation microbiology techniques to identify, quantify, and isolate organisms.
4. Students will gain experience in the formulation of hypotheses and the design of a research plan.
5. Students will learn how to document their findings and maintain an online laboratory notebook.
6. Students will learn how to generate a literature review and to maintain a bibliography in Zotero.
7. Students will have the opportunity to gather, interpret, and present their own data, in oral and written form.
8. By participating in grading of peer presentations and reports, students will gain an insight into both sides of the peer-review process.
9. Students will gain insights into the essential roles that bacteria play in ecosystems, their ubiquity in nature, and the impact of perturbing microbial populations.
10. Students will gain insights into the role of human activity in the evolution of bacterial antibiotic and antimicrobial resistance.

BOX 2
STUDENT ACTIVITIES:

- Swabbing surfaces and isolating DNA from the swabs
- Basic laboratory techniques and practices (dilutions, media preparation, sterilization)
- Environmental surface sampling using contact agar plates
- Colony purification and presumptive identification
- DNA isolation and electrophoresis
- PCR and sequencing
- SCCmec typing
- Metagenetic Sequencing, BLAST, and Data Analysis

BOX 3
END OF SEMESTER SURVEY RESPONSES (SPRING AND FALL 2016, N=5 STUDENT RESPONDENTS):

What activity or aspect of the course was most effective?

- Hands-on experience
- Research and hands-on experience
- The collecting of bacteria from our designated sites.
- The freedom to practice and experience a research project
- Performing different processes such as extraction and isolation of DNA using detailed procedures

What activity or aspect of the course was least effective?

- None
- Lecture (?)
- This course required more equipment that the school couldn't provide or provided late.
- We only meet once a week officially

Any additional comments?

- Very rewarding experience
- Class provides a wide variety of research opportunities for us students. But like I mentioned before, not enough support from the school financially. Learned a lot from this course and enjoyed every minute of it. Felt limited because we didn't have enough equipment the course asked for.
- Great course! Learned a lot and the Professor seemed prepared for every unexpected situation
- Prof. Smyth is a wonderful mentor, and the best professor I ever had. Her passion for biology inspires me. Her constant support helped me to achieve my goals.

schools," and "Yes, I personally learned a lot more about microbiology research and improved my skills." Limitations and student concerns were also noted in the end of semester surveys, where a student revealed that they didn't enjoy the lectures. Interestingly, student frustration with backordered/missing lab supplies also manifested itself on the end of semester surveys, indicating that they were indeed having an authentic experience. The minimal budget and modest lab facilities limit some of what can be done at Mercy. Students also learned that working in the lab is frequently frustrating and not always for reasons under our control.

BOX 4
END OF SPRING 2017 – SALG SURVEY (N=4 RESPONDENTS)

Q1. Please comment on how THE WAY THIS CLASS WAS TAUGHT helps you REMEMBER key ideas.

- "Hands-on learning puts into practice what I read about (i.e. PCR'ing, antibiogram, gel electrophoresis)."
- "I liked the hands-on stuff—it helped me remember what we talked about "
- "Well, Dr. Smyth was great at explaining things to us, even if we didn't quite get it the first time. Reading research papers on pubmed forced me to really delve into the subject matter, which made me understand the concepts better. "
- "I learn well through application of knowledge, therefore, this class was an applied reinforcement of what I learned in Microbiology lecture."

Q2. Please comment on how has this class CHANGED YOUR ATTITUDES toward this subject.

- "I need more time in the subject area to feel more confident. It was amazing to talk about what I was doing even if I didn't understand everything. "
- "Before this class, I wasn't very well versed in Microbiology, even though I took the class. In terms of the practical stuff we did in class, I was very intimidated and felt like there was no way I was going to be doing all that! However, I have mastered using a pipette, I was able to load those tiny gels, and I definitely feel more confident around a laboratory. Because I know more about antibiotic resistance now, my interest in the topic as a whole has increased. "
- "My attitude has changed towards feeling the urgency of being knowledgeable of and acting upon bacterial resistance. "

Q3. Please comment on what SKILLS you have gained as a result of this class.

- "Presenting our poster forced me out of my comfort zone, but having confidence in the work we did helped me push past it. "
- "DNA extractions, swabbing sample sites, PCR and gel electrophoresis, making and presenting a poster, explaining my work to other scientists, using Zotero, writing a scientific paper"
- "I have greatly improved my lab etiquette skills and my research skills."

Q4. What will you CARRY WITH YOU into other classes or other aspects of your life?

- "While learning about the subject matter, I was able to apply it to my other classes."
- "Washing my hands a whole lot more. Practicing aseptic techniques, and being more calculated and precise in my measurements. Not using Purell or other hand sanitizers as a replacement for washing hands. Being more cognizant of the cleaning materials I use."
- "I will carry the knowledge and applications that I was able to acquire through this class. These factors will prove to be useful in my later studies."

Several of the students who were in the Spring 2016 pilot continued to work on their projects over the summer and developed their own areas of research such as prevalence of enterotoxin genes, detection of bacteria in the gym, natural antimicrobials, and using antimicrobials in building products. At the end of both Spring semesters, students in the class presented their work at a local conference, the Westchester Undergraduate Research conference. In addition, students who continued their Spring 2016 projects into the summer presented their own independent research projects at national and international meetings such as CSTEP (Collegiate Science and Technology Entry Program), ABRCMS (Annual Biomedical Research Conference for Minority Students) and Microbe (the American Society for Microbiology Annual Meeting). On the basis of their abstracts, one student was awarded a partial travel grant to attend ABRCMS and received an honorary mention for her poster at CSTEP. Another student was awarded an ASM Capstone award to attend and present at Microbe 2017.

One of the most useful aspects of the course was using digital tools to facilitate teamwork and continual feedback. The use of Dropbox to store the digital lab books, though simple, was a successful social experience, as the students and I were able to engage with one another and make comments on each other's work; it was particularly useful since many of the students had jobs and commuted to school. The students could also make use of pictures and notes taken in class shared via Dropbox to ensure that their own lab books were up to date and not missing details. The groups used WhatsApp to connect with one another and to stay in contact throughout the course. This meant that students truly behaved as if they were on a team and worked as a unit throughout. When working on their poster in Spring 2017, the students took it upon themselves to book a conference room and displayed the poster on the screen as they worked together in order to ensure that their poster was generated collaboratively and collectively.

Summary and Future Directions

Undergraduate research experiences can greatly enhance the career development and readiness of all students in STEM fields, and they have shown substantial impact on the retention of students in STEM disciplines. By integrating my research into a classroom-based research experience, I have enabled students to gain exposure to research while enhancing their critical thinking, communication, quantitative reasoning, and teamwork skills. For three semesters, I have had eight students register and the feedback has been positive. Working with the students has also rewarded me: useful and intriguing data were generated, which now inform my research and further student projects in the lab. In the coming semesters, I will continue to improve upon and modify this course so that it exemplifies a SENCER Model Course and provides a truly transformative and successful experience for our students.

About the Author

Davida S. Smyth is an Associate Professor and Chair of Natural Sciences at Mercy College in Dobbs Ferry, New York. A SENCER Leadership Fellow, her research focuses on the genomics of *Staphylococcus aureus* and the impact of antibiotic resistance in clinical and environmental strains of staphylococci. She is also interested in pedagogical research in the area of student reading skills in STEM disciplines and peer-led team learning in Biology.

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