**Title**

# Effectiveness of Place-Based, Audio-Narrative Assignments in Undergraduate Introductory Science


## Abstract

In this mixed-methods study, we evaluated the effectiveness of using a place-based, audio-narrative assignment in an undergraduate introductory science course by administering the Questionnaire Assessing Connections to Science (QuACS) to identify changes in 40 students' perceptions of the learning environment and attitudes toward science between January 2017 (pretest) and May 2017 (posttest). Students' responses to an open-ended question served as the qualitative source of data. Statistically significant improvements of over 0.4 standard deviations emerged for the two learning environment scales of *Personal Relevance* and *Innovation*. Further, students reported that they found the assignment provided a unique way to learn science and were helpful for better understanding and relaying complex scientific information.


## Objectives/Purposes of the Research

In 2012, the President's Council of Advisors on Science and Technology (PCAST) forecast that, in the next decade, there would be a shortage of at least one million Science, Technology, Engineering, and Mathematics (STEM) graduates needed to fill jobs created by growth and retirement turnover in the STEM workforce. This shortage, in part, is attributable to the difficulty of recruiting students into STEM degree programs (Beede, Julian, Khan, Lehrman, McKittrick, Langdon, & Doms, 2011). Thus, educators and researchers must seek ways to increase university students' interest in STEM and encourage their pursuit of STEM-related degrees and careers. Novel pedagogical practices such as place-based learning and using student narratives have been found to be effective for engaging students in the sciences by allowing them to make connections between course content and their everyday lives (Campbell, 2005; Epstein, Easton, Murthy, Davidson, de Bruijn, Hayse, Hens, & Lloyd, 2010; Guertin, 2012; Kraal & Regensburger, 2013).

The aim of our study was to use learning environment and student attitude scales to evaluate the effectiveness of using place-based, student-produced audio-narratives to assist students in making meaningful connections to content in introductory science courses, which are generally taken by first- and second-year students who might not typically be considering a STEM degree/career.

## Conceptual Framework

*The Questionnaire Assessing Connections to Science (QuACS)*

For this study, the Questionnaire Assessing Connections to Science (QuACS) (Sirrakos, Heffner, & Fraser, 2017) was used as the quantitative data-collection instrument. The QuACS was developed by combining and adapting scales from the Constructivist Learning Environment Survey (CLES) (Taylor & Fraser, 1991), the College and University Classroom Environment Inventory (CUCEI) (Fraser & Treagust, 1986), the Test of Science-Related Attitudes (TOSRA) (Fraser, 1981), the Students' Attitudes Towards Science (SATS) (Aydeniz & Kotowski, 2014), and the My Attitudes Toward Science (MATS) (Hillman, Zeeman, Tilburg, & List, 2016). The QuACS also contains two additional scales (*Scientific Storytelling* and *Place-Based Learning*) developed by Sirrakos and colleagues (2017). The initial version of the QuACS consisted of seven scales, each with 7 items.

When the instrument was field tested in 2016 with a sample of 495 undergraduate students who were enrolled in introductory-level science courses at a variety of institutions of higher education (Kraal & Sirrakos, 2016; Sirrakos et al., 2017), validity and reliability analyses led to the removal of some items and the collapsing of some scales. The final 47-item version of the QuACS contains six scales (*Personal Relevance, Innovation, Future Intentions to Study Science, Self-Efficacy in Science, Scientific Storytelling, and Place-Based Learning*). Each item is scored 1, 2, 3, 4, and 5, respectively, for the Likert responses of Strongly Disagree, Disagree, Neutral, Agree, and Strongly Agree. Table 1 provides an overview of the instrument's structure along with scale descriptions and sample items.

*Place-based Learning*

One of the overarching problems associated with today's science classrooms is students' inability to make connections with course content (Sirrakos & Fraser, 2017). This lack of personal relevance is often attributed as the cause for students' lack of achievement and persistence in the sciences but, according to Sobel (2004), it can be mitigated through place-based learning. Educators who utilize a place-based approach to teaching encourage their students to engage with their physical and cultural environments as sites of exploration and sense-making (Semken & Freeman, 2008). Sobel (2004) asserts that, because of the emphasis on practical, real-world learning experiences, place-based learning "increases academic achievement, helps students develop stronger ties to their community, enhances students' appreciation for the natural world, and creates a heightened commitment to serving as active, contributing citizens" (p. 7).

Dr. Laura Guertin, a professor of Earth Science, has extensively used place-based learning at the undergraduate level. For example, during one of Guertin's (2012) physical science courses, students planned and carried out a two-week awareness campaign that focused on global water issues. As part of the campaign, students created and shared podcasts with the campus and broader communities on topics ranging from water conflicts and pollutants to interviews with leaders of nonprofit water organizations.

*Scientific Narratives or Storytelling*

There has been an increasing trend toward incorporating multimodal representations of science content (Dhingra, 2008; O'Neill & Calabrese-Barton, 2005). Narratives, or storytelling, are one example of an alternative medium to represent science content. Research suggests that narratives usually are easier to comprehend than traditional logical-scientific forms of communication and cultivate a sense of ownership over the content learned, resulting in increased engagement with the content (Dahlstrom, 2014). Scientific narratives can be told through the production of video and/or audio files. Given the variety of media available, audio has a number of unique qualities that suit it particularly well for engaging students. For instance, because very few students have engaged in audio storytelling compared with other forms of media, they are not bound by their prior experiences or expectations. Some higher education science faculty have developed and integrated such assignments into already existing coursework. For example, the purpose of scientific storytelling can be to describe the results of research, explain a scientific process, or offer specific reflections on course content. Malan (2007) asserts that these types of assignments offer the "potential not necessarily to educate better but to educate further" (p. 390).

## Research Methods and Data Sources

In this study, we combined quantitative and qualitative methods to evaluate the impact of a placed-based, audio-narrative assignment into an introductory science course in terms of changes in students' perceptions of the learning environment and their attitudes toward science. The introduction to the assignment is included as Appendix A. Because this study involved human subjects, it was reviewed and approved by a university's institutional review board prior to any data collection.

Data were collected from 40 undergraduate students enrolled in an introductory science course with a laboratory component. Within the sample, male and female students were equally represented. Nearly 75% of the sample was made up of first- and second-year students, with third- and fourth-year students making up the remaining 25%. Further, none of the students enrolled in the course had declared a major area of study in a STEM field. Instead, nearly 25% of students were majoring in Business, about 20% in the Arts and Humanities, and 15% had not yet declared a major area of study. Finally, during a preliminary survey of students in the course, about 30% of the sample indicated that their overall interest in science was low or very low and 50% indicated moderate interest in science.

Quantitative data were collected by administering the QuACS to assess two learning environment scales (*Personal Relevance* and *Innovation*) and four student attitude scales (*Future Intentions to Study Science*, *Self-Efficacy in Science*, *Scientific Storytelling*, and *Place-Based Learning*). The questionnaire was administered to the 40 participants in January 2017 (pretest) and May 2017 (posttest). Qualitative data were collected during the posttest with a single open-ended question that asked students to discuss advantages and limitations of using audio-narrative assignments in learning science.

The validity and reliability of the QuACS were established in a previous study involving 495 undergraduates in 9 classes of introductory science in 5 institutions (Sirrakos, Heffner & Fraser, 2017). Appendix B provides a summary of the factor analysis and reliability results separately for the two learning environment and for the four attitude scales. The tables in Appendix B show that the two learning environment scales together accounted for 64.25% of the variance and had eigenvalues of 2.11 and 6.88 and alpha reliabilities of 0.88 and 0.93. The four attitude scales together accounted for 69.53% of the variance and had eigenvalues that ranged from 1.24 to 15.04 and alpha reliabilities that ranged from 0.89 to 0.95.

## Data Analyses and Findings

Pretest–posttest changes in perceptions of the learning environment and student attitudes toward science were assessed using both statistical significance testing and effect sizes. MANOVA with repeated measure was used to ascertain the statistical significance of pretest–posttest differences for the whole set of six QuACS scales. Because the multivariate test (using Wilks' lambda criterion) yielded significant results, the univariate ANOVA was interpreted for each individual QuACS scale. However, because of the small sample size ($N$=40), statistical power was limited and therefore, we adopted a significance level of 0.1 (instead of the conventional 0.05 level).

Table 2 shows the average item mean and standard deviation for each QuACS scale for the pretest and posttest. Also the difference between pretest and posttest scores for each scale is reported in Table 2 in terms of statistical significance ($F$ ratio from ANOVA) and effect size (Cohen's $d$). Cohen's (1992) $d$ effect size, which describes the magnitude of the pretest–posttest change for each scale in standard deviation units, is the difference between pretest and posttest means divided by the pooled standard deviation. In reporting pretest–posttest changes in Table 2, we only included effect sizes greater than 0.25 standard deviations based on Cohen's (1992) criteria that suggest that any effect size smaller than this would involve negligible and educationally-unimportant differences.

Effect sizes in Table 2 range between about a quarter of a standard deviation ($d$=0.27) for *Future Intentions to Study Science* to almost half a standard deviation ($d$=0.47) for *Personal Relevance*. For the attitude scales of *Future Intentions to Study Science* and *Place-Based Learning*, pretest–posttest differences were small in magnitude ($d$=0.27 and 0.31, respectively) and statistically nonsignificant. Pretest-posttest differences were statistically significant for the two learning environment scales of *Personal Relevance* ($p$<0.05) and *Innovation* ($p$<0.1), and of modest magnitude ($d$=0.47 and 0.41, respectively). For the four scales for which results are reported in Table 2, there was an increase in scores between pretest and posttest, which supports the efficacy of using these innovative course assignments.

Analysis of qualitative data supported findings from the quantitative data. Students' responses to the open-ended question located at the end of the QuACS were reviewed to identify some of the most frequently-occurring themes. With regard to perceived advantages of the assignment, three themes emerged. The first theme was that the assignment offered students a new and unique way to learn science. Students wrote that the assignment “makes students step out of their comfort zone”, is a “creative and innovative approach to learning new and difficult material”, and “allows students to gain a different skill set”. The second theme that emerged was that the assignment helped students to better understand and relay complex scientific information. Students wrote that the assignment “requires you to pull together facts into a story to ensure that you understand the information” and “is helpful to students who might not really enjoy science because they have to make and see connections to other things”. Relatedly, students discussed the value of the independent research required to successfully complete the assignment. They wrote that the assignment “makes you have to do significant research outside of the classroom” and “requires students to have deep knowledge about their topic”. When describing the limitations of the assignment, two themes emerged from the qualitative data: the naure of the assignment might not appeal to all learners; and the assignment had low cost-benefit. One student wrote that “the amount of time and effort required to complete the assignment was not worth it for the very specific content learned.”

## Significance of the Study

This study has both methodological and practical implications. Methodologically, it was the first use of the QuACS for assessing changes in learning environment perceptions and students’ attitudes accompanying the use of place-based learning and scientific storytelling assignments in undergraduate introductory science courses. Further, this study helps to advance the field of learning environments by evaluating educational innovations in terms of perceptions of the classroom environment (Aldridge & Fraser, 2008; Fraser, 2014; Zandvliet & Fraser, 2005). However, Fraser (2007, p. 112) notes: “Despite the potential value of evaluating educational innovations and new curricula in terms of their impact on transforming the classroom learning environment, only a relatively small number of such studies have been carried out around the world.” Practically, this study is significant because it adds to the growing field of research into the effectiveness of engaging students with these types of assignments in order to engage them more deeply with science content. Finally, data collected during this study were also used to support a recently-funded National Science Foundation grant to continue studying the impact of place-based, audio-narrative assignments at a variety of higher education institutions across the Pennsylvania region.

Table 1. Structure of the Questionnaire Assessing Connections to Science (QuACS)

| Scale | Description | Sample Item | Number of Items |
|---|---|---|---|
| Personal Relevance | The extent to which school science connects with students' out-of-school experiences | This course provides me with a better understanding of the world outside school. | 7 |
| Innovation | The extent to which the instructor utilizes a variety of new activities, teaching techniques, and assignments. | New and different ways of teaching are used in this class. | 7 |
| Future Intentions to Study Science | The extent to which students indicate their intentions to study science in the future or pursue a science-related career. | I intend to study science in the future. | 7 |
| Self-Efficacy in Science | The extent to which students believe that they can be successful in science and communicate scientific information | I am confident I can do well in this science course. | 14 |
| Scientific Storytelling | The extent to which students believe that scientific storytelling assists them in making connections to science. | Combining scientific information from several sources into a story is an interesting way to learn science. | 7 |
| Place-based Learning | The extent to which students believe that the local community is a good source of science learning. | The local community is a useful resource for learning science. | 5 |

Table 2. Average Item Mean and Standard Deviation for Pretest and Posttest and Pretest–Posttest Difference (Effect Size and ANOVA Results) for Each QuACS Scale

| Scale | Mean | | SD | | Differences >0.25 SDs | |
|---|---|---|---|---|---|---|
| | Pre | Post | Pre | Post | *F* | *d* |
| **Learning Environment** | | | | | | |
| Personal Relevance | 3.02 | 3.36 | 0.70 | 0.75 | 4.06** | 0.47 |
| Innovation | 3.89 | 4.14 | 0.66 | 0.56 | 3.34* | 0.41 |
| **Student Attitudes** | | | | | | |
| Future Intentions to Study Science | 2.60 | 2.86 | 0.99 | 0.94 | 1.33 | 0.27 |
| Self-Efficacy | 3.56 | 3.48 | 0.71 | 0.81 | | |
| Scientific Storytelling | 3.80 | 3.88 | 0.72 | 0.74 | | |
| Place-Based Learning | 3.33 | 3.54 | 0.62 | 0.72 | 1.99 | 0.31 |

$N$=40
*$p$<0.1, **$p$<0.05
Cohen's $d$ = difference in means divided by pooled SD

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Appendix A

# Telescopic Topics - Scientific Podcast project

## Introduction to Assignment

What is a podcast? A podcast is a focused, specific audio piece that relays information effectively to a chosen audience.

For this class, we will be researching and writing short (2 minute) scientific podcasts about current topics in planetary science topics for the news hour on the campus radio station. We will record them in the university studios at the end of the semester. The objective of this assignment is:

- To inform the general public about planetary science, space science, and our solar system.
- Effectively communicate scientific information
- Use accurate sources to learn about a planetary science topic.

**Overview of Podcast**:
Boring term papers are only seen by tired faculty eyes…what a waste of your creativity and learning! So, for this assignment, you will be recording your podcast in the university studios and the best ones will be used on the campus radio news hour for our 'Telescopic Topics" segment.

Your selected topic must relate in some way to the general content of this course (Planetary science, NASA Missions, Solar System, process of science) for a ~2 minute audio podcast. Pick something that is interesting and you think would lead to a good scientific story for your fellow classmates. This is a SHORT podcast, so your topic needs to be very focused. If you pick something like the history of rockets, it is too broad and there have been whole BOOKS written on the topic. You need to have a very specific, narrow topic for a successful podcast. It should not be BORING and just repeat facts…tell a story, lead your listeners on a journey to learn about something new and interesting.

**Part 1: Listening to Podcasts and Topic Selection**
Listening to podcasts and audio narratives are an important part of preparing one. We will listen to example podcasts and you will be asked to find examples of podcasts on your own.

The goals of this aspect are:
- Describe the characteristics of effective podcasts
- Find and analyze examples of podcasts/audio narratives related to science

You also need to select your personal topic. Your general topics must be related to our Solar System/Planetary science. Within the broad context of planetary science, I encourage you to link to other fields and interests, such as business, government, arts, and history.

You will submit your topic and respond to these questions:
- What is your topic?
- How does this topic relate to planetary science?
- Why do you think other people will be interested in this?
- What do you need to learn more about to develop a podcast on this topic?

**Part 2: References**
You will assemble 4 references related to your topic to help you prepare to write an accurate and interesting podcast.

This section is focused on you:
- Evaluating online sources for currency, reliability, authority, and purpose/point of view
- Generating an annotation of a source by summarizing and analyzing content

Learning how to find and use good resources is an important skill. We will go to the library for a lab period to learn about finding and evaluating sources. You will write a short, annotated bibliography for each of the references that include a full citation.

**Part 3: Script writing and peer review**
Effective communicate about complex topics is an important and vital job skill. But it is challenging to distill complicated information into a focused story. Therefore, we will use this assignment to practice translating scientific information into new stories for a general audience.

The objectives of this section are to:

- Create an interesting, accurate podcast on a scientific topic
- Incorporate scientific information from reliable sources
- Connect with a general public (non-scientific) audience to effectively communicate
- Collaborate in the peer review process

These audio narratives (podcasts) will be interesting, accurate stories about planetary science. Though short, they will require a lot of revision and attempts. We will be helping each other through careful peer review and practice telling our scientific stories.

One average, people speak about 100-120 words per minute. Your podcast will be between 2 minutes so you should be looking at something around 250 words. It's not many! Choose words carefully. Your recorded podcast must match your script word-for-word.

**Part 4: Recording and reflection**
The recording will happen during a lab period in the studio.

The recording will be evaluated for

- Accuracy in matching the script
- Tone and timing related to the reading of the script

## Appendix B

Factor Analysis Results for QuACS Learning Environment Scales

| Item | Factor Loadings | |
|---|---|---|
| | Personal Relevance | Innovation |
| PR 1 | 0.57 | |
| PR 8 | 0.74 | |
| PR 15 | 0.68 | |
| PR 22 | 0.58 | |
| PR 29 | 0.68 | |
| PR 36 | 0.77 | |
| PR 43 | 0.73 | |
| IN 2 | | 0.73 |
| IN 9 | | 0.79 |
| IN 16 | | 0.76 |
| IN 23 | | 0.71 |
| IN 30 | | 0.87 |
| IN 37 | | 0.68 |
| IN 44 | | 0.83 |
| % Variance | 15.09 | 49.16 |
| Eigenvalue | 2.11 | 6.88 |
| Alpha Reliability | 0.88 | 0.93 |

Principal axis factor analysis with varimax rotation and Kaiser normalization
Total variance = 64.25%
Factor loadings smaller than 0.50 omitted

Factor Analysis Results for QuACS Attitude Scales

| Item | Factor Loadings | | | |
|---|---|---|---|---|
| | Future Intentions to Study Science | Self-Efficacy | Scientific Storytelling | Place-Based Learning |
| FI 3 | 0.80 | | | |
| FI 10 | 0.60 | | | |
| FI 17 | 0.84 | | | |
| FI 24 | 0.68 | | | |
| FI 31 | 0.82 | | | |
| FI 38 | 0.83 | | | |
| FI 45 | 0.82 | | | |
| SE 4 | | 0.70 | | |
| SE 11 | | 0.73 | | |
| SE 18 | | 0.78 | | |
| SE 25 | | 0.67 | | |
| SE 32 | | 0.78 | | |
| SE 39 | | 0.76 | | |
| SE 46 | | 0.72 | | |
| SE 5 | | 0.64 | | |
| SE 12 | | 0.75 | | |
| SE 19 | | 0.77 | | |
| SE 26 | | 0.75 | | |
| SE 33 | | 0.78 | | |
| SE 40 | | 0.76 | | |
| SE 47 | | 0.75 | | |
| SS 6 | | | 0.61 | |
| SS 13 | | | 0.68 | |
| SS 20 | | | 0.58 | |
| SS 27 | | | 0.69 | |
| SS.34 | | | 0.79 | |
| SS 41 | | | 0.64 | |
| SS 48 | | | 0.61 | |
| PB 7 | | | | 0.54 |
| PB 21 | | | | 0.66 |
| PB 28 | | | | 0.69 |
| PB 42 | | | | 0.59 |
| PB 49 | | | | 0.70 |
| % Variance | 11.67 | 45.57 | 8.55 | 3.74 |
| Eigenvalue | 3.85 | 15.04 | 2.82 | 1.24 |
| Alpha Reliability | 0.94 | 0.95 | 0.91 | 0.89 |

Principal axis factor analysis with varimax rotation and Kaiser normalization
Total variance = 69.53%
Factor loadings smaller than 0.50 omitted