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TECHNICALLY SPEAKING: BUILDING SCIENTIFIC COMMUNICATION SELF-EFFICACY

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Technically Speaking: Building Scientific Communication Self Efficacy

Synopsis:

The overall goal of the project is to improve academic competency and science efficacy to retain undergraduate STEM students so that they graduate and pursue careers/advanced study in STEM. The project focuses specifically on improving scientific communication to achieve this goal. Two learning communities pair biology and chemistry with a public speaking course in order to improve science communication, student engagement and STEM retention. Our aim is to test the curriculum and effectiveness.

Abstract

Effective communication in science is recognized as an important component of training for STEM professionals. This project focuses specifically on improving scientific communication to achieve this goal. Two learning communities that pair STEM research and inquiry activities in biology and chemistry with a public speaking course are being implemented with intentional and sustained instruction and mastery experiences to develop students' science communication skills. The hypothesis is that instruction on how to communicate science effectively can result in an increase in students' understanding, confidence, and identity as a scientist. This can result in greater student engagement in the major and improved retention in STEM disciplines. Our aim is to test this curriculum intervention to determine its effectiveness in improving student communications ability and achievement.

Keywords: communication, science identity, learning communities, STEM, public speaking STEM education.

Background and Significance

Among the many contributors to students' self-efficacy, scientific communication is of significant importance. STEM undergraduate students frequently, when sharing research findings, have difficulty communicating their results to those who are unfamiliar with the subject matter in a way where the listeners can easily understand the concepts. Scientific communication is also linked to building student's science identity, which can lead to retention in STEM. According to Cameron, et al., 2020, if science identity is a significant predictor of career intentions and language use is a precursor to identity, then encouragement and reinforcement of scientific communication skills may be a key strategy for increasing career persistence through the postgraduate and postdoctoral levels. Chan (2011) advocates for beginning this training at the undergraduate level.

In the undergraduate laboratory, written laboratory reports have traditionally been the major means for students to communicate their learning of technical knowledge of science concepts. This requires both synthesizing new conceptual information and translating it into the language of a lab report, which results in a more complex learning process. For the most part, students view the written lab report as the means to obtaining a grade and fail to engage in the deep analysis, reflection and thought that is needed to understand the material until senior year if at all (Berns, 2019). While the literature on communication efficacy tends to favor formal communication skills, it is now recognized that the ability to communicate science to scientific and non-scientific audiences is equally important in building efficacy in students. As a result, labs are increasingly becoming venues to integrate oral communication skills development including talks, posters, and presentations for the general public (Berns, 2019; Crawford, 2019).

The approach for this project involves using of two non-residential learning communities: ARC (Appreciating the Rhetoric of Chemistry) which pairs a chemistry class with a public speaking class and Raising the BAR (Biology and Rhetoric) which pairs a biology course with a public speaking course. Learning theorists have repeatedly asserted that university students frequently fail to use knowledge and skills learned in one class and apply it to another or in their everyday lives (Berryman & Bailey, 1992). Trends in education reform emphasize the importance of a more integrated curriculum for undergraduates (Miller & McCartan, 1990; Marx, 1989). As our world becomes more complex and knowledge more compartmentalized, students need courses that expand their perspective across traditional disciplines. Learning communities fit the bill. Since their inception in the mid-1980's, learning communities have significantly improved curricular reform, student engagement, and retention (Tinto, Goodsell-Love, and Russo 1994; Tinto 1997; Taylor and Associates 2003; Engstrom and Tinto, 2007). As a result, learning communities are frequently implemented on college and university campuses. The success of pairing a skills course (such as Public Speaking or English) with a content course (such as Biology or History) has proven to be successful in several studies (Sorenson, 1988; Stachacz & Brennan,1990). Asking students to apply research and public speaking skills to

Biology and Chemistry courses, as in this project, will help students see the real value of these skills for their future success in both college and professional careers. Taylor (2010) contends that they will become engaged. According to Bandura (1997), mastery experiences are a primary source for building efficacy in a task. Mastery experiences provide opportunities for practicing the strategies needed to perform a task effectively and provide evidence of whether a student has the ability to succeed. At the affective level only if they can see a future utility, benefit, or relevance from their learning". Opportunities to build mastery will be implemented by integrating speeches and reflections as well as presentations to the K12 community.

Project Goals and Objectives

The purpose of the TSP is to offer empirically based research, which may lead to an improvement of undergraduate STEM students' academic competency in oral communication, as well as their scientific efficacy. Thus, the research may lead to higher retention and graduation within STEM fields. Students will then be able to pursue a STEM career or advanced study in a STEM field.

To meet the above purpose the goals of the TSP are as follows:

a) to create a paired course learning community focusing on STEM introductory courses and oral communication (i.e., public speaking).

b) to determine the influence of the newly constructed learning communities on the students' scientific communication skills, as measured by rubrics, assessment scales, grades, and students' attitudinal surveys.

c) to explore whether a relationship exist among the learning community's paired coursework on communication self-efficacy as measured by public speaking self-efficacy questionnaire and identity as a scientist as reported and measured in the identity and attitude scale toward science/STEM.

d) to explore whether a relationship exists between the students' communication skills and students' critical thinking.

To meet these goals the project focused on four objectives:

Objective 1: Learning Communities Creation

Objective 2: Improve Oral Scientific Communication

Objective 3: Enhance scientific communication self-efficacy and scientific identity

Objective 4: Improve Critical-thinking Skills

Methodology

Educational Context

The project was implemented in freshmen level biology and chemistry courses through two learning communities in which each science course was paired with the public speaking course, Public Speaking-COMM1110. The first learning community, Raising the Bar (Biology and Rhetoric), paired Public Speaking with the Principles of Biology course, BIOL 2107K. The other, Analyzing the Rhetoric of Chemistry (ARC) paired the public speaking course with the Principles of Chemistry I course, CHEM 1211K or CHEM 1212K. These science courses are required courses for freshman biology, chemistry, and forensic science majors.

Project Set-up Recruitment

The set-up of the learning community and recruitment of the students into the learning community was a concerted effort between several units. The chairperson of the department of Natural Sciences where biology and chemistry reside and the department of Social Sciences for the public speaking course, were informed of the project by the project PI and of the requirements for setting up the course sections. Specifically, we needed to coordinate time slots for these learning community courses that did not overlap but also select times that students would most likely register for these courses. Additionally, the director of admissions and the registrar were brought in to ensure that the courses were listed as a learning community course, and correctly coded to ensure students registered for both courses and to share the opportunity with registering freshmen. Academic advisors for the science students were contacted in person and provided an informational flyer about the learning community to share with students during the advisement process.

Implementation

Raising the Bar Learning Community

In the Principles of Biology I Course of the Raising the Bar Learning Community, students experienced active collaborative learning during laboratory class. Students had complete autonomy to explore and practice scientific reasoning and inquiry by solving laboratory problems in their class assessments and engaging in scientific communication (written and oral) through evaluations in the class.

Students developed speeches on topics and ideas from their biology laboratory experiments that included the scientific method sweeties lab, macromolecules in chemistry, discovering cell and their organelles, and understanding dominant and recessive genes. Students trained as early investigators to conduct experimental laboratory research through these laboratory class exercises that gave them exposure to hands-on laboratory techniques such as utilizing a compound light microscope, preparing microscope slides, using scientific glassware to collect and measure samples, operating laboratory equipment, and accessing various (micro- and macro) size cellular models to visualize foundational concepts. These class laboratory assessments benefitted students learning and adapting to a laboratory's dry and wet environment. Student takeaways from these class laboratory experiences included learning how to solve scientific problems using the scientific method, understanding how to gather and share scientific data, and an exposure to peer-reviewed journals and articles to disseminate scientific findings through conveyed communication.

Analyzing the Rhetoric of Chemistry (ARC) Learning community

In the ARC learning community, the instructor balanced the need to utilize the time to teach students basic concepts of the course that are required prerequisite knowledge for other chemistry courses with the time needed to carry out the requirements to prepare students for the oral communications component in the public speaking course. To achieve this, laboratory activities were set up to include an inquiry-based component wherever possible to encourage students to think about the labs that they were conducting. Principles of Chemistry I topics included, separating components of a mixture, paper chromatography, acids and bases, titrations, and preparing solutions. Principles of Chemistry II topics included chemical bonding, solutions and properties, intermolecular forces, kinetics and colligative properties. Additionally, a mini-research project was implemented in the second half of each course after the midterm. For the mini-project, students were divided into groups of 3-4 students and provided general guidance on potential topics. They were required to formulate a hypothesis and to develop experiments to test their hypothesis. Each group was required to assign tasks/roles to each group member such as a manger, recorder, and technician (to secure supplies and equipment) to help promote participation amongst the group members. In Spring 2024, for the mini-project, we were able to include an additional mastery component to build on communication skills by having students develop a poster presentation. We collaborated with the Center for Undergraduate Research so that students could present their findings during the poster session at the Spring Undergraduate Research Conference, a yearly conference that takes place at the institution. Here students were able to present their speeches developed in the public speaking class to conference judges, faculty, students, and staff. Project topics and hypothesis are indicated in Table 1.

Table 1. ARC Learning Community Mini-Project Poster Presentations

Group#	Title	Hypothesis
1	**The Impact of Temperature on a Super Absorbent Polymer**	The super absorbent polymer called sodium polyacrylate will absorb more liquid at low temperature
2	**Antacid Efficacy Unveiled: Exploring Ingredients, Dosages, and Reaction Dynamics in Acid Neutralization**	Antacids from different brands, even if they contain the same active ingredient, may have different effectiveness due to variations in formulation or manufacturing processes.
3	**Organic vs Non-organic: Which has the most vitamin C?**	If various non-organic and organic fruits are tested for the highest amount of vitamin C, then organic fruits will have the highest concentration of vitamin C.
4	**The Impact of pH level on a Super Absorbent Polymer**	The ability of a superabsorbent polymer to absorb water will be greater at higher pH levels
5	**Pigmentation in Blue Sports Drinks**	Although blue sports drinks come in different shades, they still contain the same type of pigments.

Public Speaking Course

For each learning community, three speeches were required. There were several practice sessions that prepped the students for the speeches. The students had only one opportunity to deliver a speech. In other words, if they did not do well, they did not have the opportunity to do it again.

An important aspect of the public speaking component was the preparation of an outline of each speech which included an introduction, body and concluding statement. For example, for the ARC Learning community, the first speech was a 2-3 min speech on the importance of chemistry to students' careers.

> **Intro:** Share that the chemistry class will help you in your career (include your career)
> **Body:** Share two or three reasons that explains specifically how the class will prepare you for your career. For example, will it provide a meaningful foundation?
> **Conclusion:** Briefly review the reasons, and offer a memorable statement.

As students progressed to conducting experiments and mini-research projects, students' speeches of no more than 4 minutes centered around describing the hypothesis of the project, the experiments used to test the hypothesis, explaining the results and how they supported their hypothesis as well as any memorable moments that they experienced.

Two student facilitators were recruited to participate in the project, from among students who had previously taken the speech class and demonstrated strong oral communication skills, professionalism, and engaging attitudes that would allow them to interact comfortably with the class. The facilitators were required to attend all class sessions and had preparatory sessions with the instructor, before the first-class period, to discuss objectives and their responsibilities in the project. In addition to conducting several practice sessions with students before each major speech, facilitators were also present when students were drafting their outlines and speeches (during class). The facilitators would follow the instructor's actions and look over the students' shoulders as they were working. The facilitators would also answer questions and offer opinions—as to how to improve the students' work. After each practice session with the student facilitators, the students would practice in front of the professor. At the end of the class, the student facilitators and the professor would compare notes to assess the improvement level from the initial practice session to the final practice session.

Throughout the process, the speech professor was in constant communication with the STEM instructor for each learning community to better understand the science that students were involved in, including visiting the class at the beginning of the semester.

The rubric below was used to evaluate student's progress.

Public Speaking
Evaluation Form

Evaluation Symbols
(+) Satisfactory
(-) Needs Improvement

Name:
Grade:

	Satisfactory	*Needs Improvement*
3-Second Rule		
Eye Contact/Use of Note Cards		
Quotation and Lead-in (2)		
Volume/Rate		
Verbal Appropriateness		
Physical Presence		
Fluency		
Personality/Enthusiasm		
Organization		
Time Limit		

ADDITONAL COMMENTS:

Assessment

Each student in the learning community was required to engage in reflection exercises to determine their progression throughout the course. Reflection prompts were designed to address students understanding of the science content of their speeches and how the techniques of effective communication learned in the course contributed to effective presentations. They also reflected on their progress and how they perceived their presentation skills improved throughout the course

STEM Identity and Scientific Self-Efficacy.

To assess students' perceptions on STEM identity we used the one-item STEM Professional Identity Overlap measure, a pictorial scale developed by Aron et al., 1992 and validated by McDonald et al., 2019. Students were given the pictorial scale in the pre-post test survey and were allowed to select how they felt the set of overlapping circles measured their self-image overlapping with that of a STEM professional. In addition, measures of science identity and attitudes toward science were adapted to assess STEM identity (Chen et al., 2021), and scientific self-efficacy (Thomas, Anderson, and Nashon, 2008).

Findings and Discussion

STEM Professional Identity Overlap. Preliminary results of the STEM Professional Identity Overlap from the Pre-tests across all of the participants (*n*=42) indicate that a majority of the students' rated their STEM professional and current self-image at the middle to the high image range (Image 4-Image 7) (*n*=30), with the remainder in the lower image range (Image 1-Image 3) (*n*=11), and one student not selecting a picture.

Preliminary results of the STEM Professional Identity Overlap from the Post-tests across all of the participants (*n*=24) and indicate that a majority of the students rated their STEM professional and current self-image in the middle to the high image range (Image 4-Image 7) (*n*=18), with the remainder in the lower image range (Image 1-Image 3) (*n*=6).

A preliminary analysis of the paired responses on the STEM Professional Identity Overlap shows that of the four paired responses in **Year 1**, only one student selected two different images for the pre-test and the post-test (Image 5/ 2), lowering their STEM image in the post-test. The other three students selected the same image each time (Image 6, Image 7, Image 2). In **Year 2**, of the 8 paired responses, three students selected the same image each time (Image 4, Image 2, Image 4), with the other five students selecting different images (Image 4/7, Image 4/5, Image 6/7, Image 4/3, Image 4/6), with only one student of the five lowering their STEM image in the post-test. In **Year 3**, of the 16 paired responses, seven students selected the same image each time (Image 5, Image 4, Image 2, Image 3, Image 4, Image 7, Image 7), with the other nine students selecting different images (Image 1/4, Image 4/3, Image 5/7, Image 4/5, Image 5/4, Image 5/1, Image 4/5, Image 5/3, Image 6/5), with five students of the nine lowering their STEM image selection in the post-test.

If we break out the difference between the Biology and the Chemistry courses then there is a slight difference. In Year 1 (Chemistry), there was only one student who lowered their STEM image in the post-test, and the Freshman student chose Image 2 after having chosen Image 5 in the pre-test. In Year 2 (Biology), there was also only one student who lowered their STEM image in the post test, with a sophomore student choosing Image 3 after having chosen Image 4 in the pre-test.

In Year 3, which had students in both Biology and Chemistry, one student in the Biology section lowered their STEM image in the post-test, with the sophomore student choosing Image 3 after having chosen Image 4 in the pre-test. The other four students who lowered their STEM image in the post-test were in the Chemistry section, with the Images changing from pre-post as follows: Pre 5 to Post 4 (Freshman), Pre 5 to Post 1(Freshman), Pre 5 to Post 3 (Sophomore), and Pre 6 to Post 5 (Sophomore). More analysis will be needed to further determine why these students lowered their STEM Image. However, due to the anonymity of the surveys, there is no way to determine whether the students' final grades or perception of the final grades, were indicated within the lowering. Additionally, there does not appear to be a significant difference in academic levels, but further analysis is needed.

Student Identity as a Scientist. A modification of Chen et al (2021) from their original format was completed and moved from a 4-question, 5 Likert scale, to a 3-question, 3 Likert Scale. For example, the survey question "I am a science person" was changed to "I am a STEM person." Two sentences asking the participant whether their family or friends think of them as a "science person" were collapsed into one survey question "My family & friends think of me as a STEM person." The final survey question used by Chen et al (2021) was only changed to indicate STEM and not science, "My teachers/instructors think of me as a STEM person." No preliminary analysis has been completed at this time.

Self-Efficacy as a Scientist. The survey slightly modified the SEMLI-S of Thomas, Anderson, and Nashon (2008) by inserting "science and communication course" in place of the phrase "course." This was to make sure the students understood that each course in the learning community was important and that both courses would make them better at being a "scientist" including increasing their self-efficacy, or confidence in their performance as a scientist. The six survey questions contain statements such as "I believe I will get an excellent grade in the science and communication course," "I am confident I can do a good job on the assignments and tests in the science and communication course," and "I know I can master the skills being taught in the science and the communication course." No preliminary analysis has been completed at this time.

Conclusions

Analysis of the data continues. However, the project team has made several observations that show promise in this approach. There was a noticeable improvement in students' skills in orally communicating the science that they were involved in throughout the semester as a result of the activities. Accordingly, the students clearly understood and implemented suggestions provided by the student facilitators. The final evolution of the students showed progressive improvement for each of the three speeches, demonstrated knowledge of appropriate delivery techniques, and the overall performance of each speech was significantly better than each previous practice session.

Students' participation and presentations at the Undergraduate conference was especially memorable. They were clearly excited about their final poster and enthusiastically shared their research using the skills and preparation provided in the public speaking class. The increase in confidence levels from the beginning of the semester was evident. As the semester closed after several classroom interactions, the students in the Raising the Bar started to share a commonality - an admiration for STEM, especially biology. Students began to not only enhance their classroom biology and public speaking skills but also communicate and exchange scientific ideas with each other, elevate their collective scientific knowledge base, defend their research and stance about scientific issues, and communicate and advocate for scientific problems that concern them.

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