Teaching Process Skills to Pre-Engineers using Situated Learning—A Case Study

https://doi.org/10.3991/ijep.v8i5.9036

Pamela A. Maher(✉)
University of Nevada, Las Vegas, United States
maherp@unlv.nevada.edu

Janelle M. Bailey
Temple University, Pennsylvania, United States

Allan M. Tucka
College of Southern Nevada, Las Vegas, United States

Abstract—In this case study, undergraduate students presented physics concepts to patrons at a planetarium. This created an early opportunity for these pre-professionals to practice the process skill of oral communication to a lay audience. The case study resulted from working with students participating in a grant called the da Vinci project. It reports on a situated experience pre-engineering and calculus-based physics students had working with their professor to create a brochure and present a physics concept to patrons visiting a public planetarium. Working closely with their professor, students were able to use this required professional skill in a real world (situated) context. This opportunity helped bridge the gap between these pre-professionals' experiences in training and in their careers in STEM fields. Thirty students attending a two-year college in the Southwestern US self-selected to participate in the project. Each student participant built a kit-based model of a machine, designed an informational flyer aligned to state K-12 physical science standards, and presented informally to the public visiting a planetarium. Data were collected from the students via written reflections before and after the presentation and from email correspondence with their professor. Qualitative analyses of these reflections assessed the students' progress toward a finished presentation. Results suggest that obstacles to public speaking fluency come from the fear of making mistakes or giving out misinformation. Opportunities to engage in informal public speaking helped overcome these obstacles. Students demonstrated increased confidence in their ability to share their knowledge with the public after undergoing guided informal speaking practice. The opportunity for students to practice public speaking during their undergraduate training can increase confidence and better prepare them for a career.

Keywords—pre-engineering, process skills, qualitative, situated learning, case study

1 Introduction

Situated learning is an instructional theory based on the work of John Dewey [1] and Lev Vygotsky [2], who claimed that students learn in an environment where they are able to put learned theory into practice by solving problems in a real-world setting [3,4]. In the course of a career, it is necessary for engineers and scientists to present technical information to lay audiences. Essential in the workplace, this and other professional skills are now taught as part of scientific and engineering training [5,6]. The Accreditation Board for Engineering and Technology (ABET) claims that professional skills, such as speaking to lay audiences, are needed because scientists and engineers need more than just scientific skills to be prepared for a career. These practitioners need professional process "soft" skills such as clear oral and written communication abilities because their jobs require working with teams and groups who may not have the technical preparation of engineers [3,7-9]. Engineers and scientists have opportunities to communicate information in their fields to the general public. In addition to being able to communicate effectively, they provide a bridge to public science literacy [10]. These professionals are often called upon to comment on current issues in science and engineering or make presentations to lay audiences, providing information during open houses and citizen information meetings. Fluency in the professional process skill of communication is an asset, particularly since the audiences with whom engineers engage are varied, with non-technical audiences composing 18% of the total engaged group [11].

The following case study uses an early mastery experience opportunity provided by a grant-funded project to examine how student participants worked with mentors [7,12]. In this study the mentors were their professor, the planetarium staff, and the first author. When working with these mentors, students designed a brochure and presented a physics concept to lay audiences visiting a local planetarium. Situated learning is identified as the theoretical framework around which this paper is organized and case study is identified as the method used to implement the study.

2 Literature review

The literature review proceeded according to vom Brocke et al. [13] and Galvan and Galvan [14]. The initial search began with a key word search using peer review journal databases in both engineering and behavioral sciences. We then used this literature for backward and forward searches, with a preference for literature spanning the last decade.

Training engineers often includes lecture format delivered by a professor and note taking done by the student. Pedagogy limited to only this method of instruction leaves young engineers and scientists unprepared for future careers [15] that involve speaking technically to lay audiences. ABET recognized this deficiency and in the 1990's approved the initial Engineering Criteria 2000 [9] that recommends preparation in a set of five scientific skills and a second set of professional skills that include communication. According to Agan [16], inadequate preparation is a factor that hinders fluency when presenting known content, potentially rendering the speaker unable to communicate with an audience. Before implementation of the ABET Engineering Criteria 2000, traditional teaching methods within STEM fields left little preparation for students to speak on STEM topics. Targeted speaking opportunities give students real world experience [17,18], which in turn builds confidence in the ability to handle situations competently in the workplace.

2.1 Scientific skills and professional soft skills

When drafting new accreditation criteria for engineers, a traditional set of five scientific skills were outlined [9]. These scientific skills include the application of mathematics, science, and engineering to their practice; the ability to design experiments and process data; the ability to design a system or process to solve a problem; the ability to identify and solve engineering problems; and the ability to use modern engineering tools. Along with these science skills, an additional set of professional soft skills were added [19].

Professional soft skills are considered attributes pre-engineers and scientists need to be successful in their careers [20,21]. This inclusion into the accreditation standards did not come without controversy. Pushback from academic engineering committees argued that science and engineering degree plans were already full, with some engineering degrees taking five years to complete [22]. Academic program directors and engineering curriculum committees argued that professional soft skills should be part of the training that was learned on the job and not within formal academic engineering programs, making the acquisition of these skills hit or miss. Nevertheless, ABET identified six professional soft skills that are important to include in an engineering curriculum. These skills are divided into awareness skills and process skills. Awareness skills include knowledge of contemporary issues in engineering, lifelong learning to continue to grow in the profession, and awareness of engineering within a context of society and the world [9]. Process skills consist of communication proficiency, the ability to work in teams and groups, and ethics awareness [6] proficiency. According to NARST, process skills provide a foundation for conveying learned science concepts to audiences that may or may not be scientifically literate. These are termed process skills because students learn a robust process to address each skill [23,24].

2.2 Situated learning

Lave and Wenger [25] explored situated learning as an instructional approach, building on the early work of the well-known educational psychologists John Dewey and Lev Vygotsky. Dewey and Vygotsky proposed the idea that students create meaning from the real activities of everyday life. Lave and Wenger extended this to include pedagogy that employs situated learning; learning that embeds content within real-world contexts. This embedding can address student laments such as, “why do we have to learn this?” or “I’m never going to use this” [26,27].

According to Stein [28], situated learning integrates the elements of content, context, community of practice, and participation. Content is situated within a working problem-solving mode where reflection is a part of the learning process. Application of content within a real-life experience takes precedence over retention of facts in isolation. Learning in context breaks down tasks within a real-life situation making learners successful. The context is the real-life situation and content is broken down and used to solve a problem. In situated learning content and context are linked. Within this content/context situation, communities of practice provide the social structure where participants in a common activity share knowledge and ideas that inform a practice [29,30]. Finally, participation is the engagement of the learner with the content and the context [31]. Participation activates agency within a learner and knowledge acquisition becomes a practice of reflecting and interpreting content within context to solve a problem.

Lave [32] argues that learning and the social situation in which learning occurs are closely tied. In this study learning occurred as students participated in the project. The social situation was an informal science learning opportunity involving the general public at a planetarium. Student participants created a brochure and presented a physics concept to this audience using a model and physics laboratory equipment to further demonstrate and explain a scientific concept.

3 Purpose

Society rewards verbal behavior [33]; the student who hesitates or avoids public speaking is at a disadvantage in the competitive fields of physics and pre-engineering. When this project was undertaken, the task was to provide an informal science education experience delivered by student participants to patrons at a public planetarium. What was discovered was that these student participants, all taking courses in pre-engineering or calculus-based physics, were confident going forward with the creation of a brochure but were timid about presenting the same information orally to a live audience. This case study is an examination of how these students worked with the professor to achieve their final projects, why some were hesitant about the public speaking presentations, and what they learned from the project experience.

Engineering and physics training in higher education maintains a prescribed degree plan, often with little room for deviation or elective coursework (particularly in accredited engineering programs). This builds cohorts of students who move through their programs together developing what sociologists call in groups [34]. Reluctance to verbalize orally to members outside in groups creates difficulty for students during their university-to-career transition. A non-robust communication skill set masks talent and ability, holding students back from career and initial job opportunities. This study looks at student participants recruited over three semesters and tracks how these students were supported as they worked toward a final public speaking science presentation.

Couched in the literature, the research questions are: 1) What are the perspectives of 30 students on "how" they presented science concepts to the public? and 2) What themes emerge from the perspectives students had on their experience working with mentors toward their final presentation (the "why")? Perspectives are defined as a particular attitude toward public speaking [35]. We postulated that the perspectives of these students toward public speaking to lay audiences influenced their ability to communicate [36]. The research questions were answered by examining themes that emerged as pre-engineering and physics students worked toward their final public speaking component of the project and the assertions about preparing engineers for communicating in their field using a public service project that can be made from the over-arching responses.

Although the small-scale, case study nature of this project prohibits generalization, there is value in exploring the case in some detail. This is an example of project-based pedagogy that goes beyond a lecture format, something that is not common for most engineering curricula. This approach adds value to pre-engineering programs by leveraging existing resources (here, a planetarium used for both academic and outreach purposes) to give students a chance to transfer their knowledge to the general public and to hone their professional communication skills.

4 Methods

This paper reports on findings from a case study involving students recruited for a grant funded project. Student participants assembled a small model based on one of da Vinci's proposed machine codas, worked with their professor to write a one-page interpretive flyer to explain a physics concept demonstrated by the model, and explained this concept to patrons at a planetarium using the model and a piece of lab equipment borrowed from the college physics laboratory. The case was the study of these pre-engineering and calculus-based physics students recruited for the project from their classes at a two-year college. This case was a bounded system, bounded by place—the college in which the study was done—and bounded by the course sections from which the student participants were recruited. This case study was also bounded by time, the three semesters (a total of 12 months) during which the project proceeded. This paper reports on a single instrumental case study where the experience of students was investigated as they interacted with the project task and their mentors. Student participants' perspectives were captured using data instruments discussed in the following sections.

4.1 Theoretical Framework

The study was structured and collected data were viewed through the lens of situated learning theory [25]. In this case study, student participants make meaning of their experience when explaining what they know in the disciplines of pre-engineering and physics within the situation of the project. The students used their expertise—their "learning"—to help the lay public make sense of physics concepts. By connecting what they knew to the new context of the machine models and reflecting on their experience, student participants were able to make meaning of their experience to advance their own knowledge.

4.2 Setting and Participants

The study setting was a planetarium associated with a two-year college. The planetarium is part of the physical science department used to teach astronomy lecture and laboratory courses during the week, host school field trips on weekday mornings, and offer public presentations on stars and planets during the weekend.

The participants were students at a two-year college and from now on are referred to as the students. At this college the student body consisted of 43,000 (22,000 full-time equivalent) students with a median age of 28 years old. Two-thirds of all students apply for federal financial aid; a total of 53% of the student population receives federal funding to support their education. Students represent a diverse ethnicity, with 23% of the total population Hispanic and 12% African American (data taken from the institution's research division, blinded per human subjects research standards).

Students in this study self-selected from a two-semester sequence (plus a summer semester) of calculus-based physics courses or two pre-engineering courses offered at the college, with the exception of one student. This student, enrolled in one of the target courses, attended a nearby four-year university. The target courses from which the students were recruited were PHYS 180 Physics for Scientists and Engineers and PHYS 181 Physics for Scientists and Engineers II. Students were also recruited from pre-engineering ME 242 Dynamics and CEE 241 Statics, which have calculus-based physics (PHYS 180) as a prerequisite. CEE 241 and ME 242 are final courses in the pre-engineering program, resulting in either an Associate of Science and/or a transfer to a four-year university to earn a Bachelor of Science in Engineering or other Bachelor of Science degrees.

The project's profile matrix (Table 1) shows 30 (student) cases detailed across six attributes. From this matrix the average age of students is 27.2 years old, slightly younger than the college's average of 28 years old. It is postulated that this population will put their training into practice within the next two to five years, less if ending their studies with a two-year Associate of Science degree. Further examination of the profile matrix reveals that 17% of the students are female and 83% are male. This follows current trends in higher education enrollment with "male students earning the majority of bachelor's degrees in engineering, and physics" [37, p. 4]. Ethnicity breakdowns reveal 7% of students as Latino/as, 10% Black, 13% Asian, and 70% White. These breakdowns comport with findings by Aikenhead [38] and Leggon and Pearson [39] that gains in the number of students from underrepresented groups studying physics and engineering still remain weak. The profile matrix provides information on the students and is one of seven data sources collected in this study. All data sources are examined further in the following sections of this paper.

Table 1. Students by Pseudonym

Case	Pseudonym	Major	Ethnicity	Gender	Age	Birthplace
1SP	Dalia	Engineering	Latina	F	32	Cuba
2SU	Tom	Undeclared	White	M	23	New Zealand
3SU	Brock	Electrical Engineering Tech	White	M	28	USA
4F	Tony	Pre-Engineering	White	M	21	USA
5SU	Thane	Computer Information Tech	Asian	M	29	Mexico
6F	Charlie	Chemistry	Black	M	21	Eritrea
7SP	Mick	Physics	Asian	M	16	China
8SP	Joe	Associate of Science	White	M	40	USA
9SU	Rick	Undeclared	White	M	27	USA
10SU	Lonnie	Electrical Engineering Tech	White	M	21	USA
11F	Jim	Undeclared	Black	M	25	USA
12SU	Edgar	Civil Engineering	White	M	23	USA
13SU	Craig	Chemical Engineering	White	M	26	USA
14F	Roy	Mechanical Engineering	White	M	25	USA
15SU	Earl	Mathematics	White	M	26	USA
16SU	Monty	Associate of Arts	White	M	22	USA
17SU	James	Pre-Engineering	White	M	35	USA
18SP	Dan	Mechanical Engineering	White	M	21	USA
19SP	George	Undeclared	White	M	23	USA
20SU	Larry	Undeclared	White	M	22	USA
21F	Tanner	Civil Engineering	White	M	57	USA
22F	Mindy	Associate of Arts	White	F	25	USA
23SU	Yuri	Electrical Engineering Tech	White	M	21	USA
24SP	Lina	Electrical Engineering Tech	Latina	F	47	Mexico
25SU	Bob	Civil Engineering	White	M	30	USA
26SU	Brayden	Undeclared	White	M	29	USA
27SU	Drew	Undeclared	Asian	M	24	Philippines
28SP	Mander	Associate of Science	Asian	M	29	Vietnam
29SU	Myra	Mechanical Engineering	White	F	26	USA
30SP	Tina	Engineering	Black	F	22	USA

Note. The letters listed after each case number signify the semester in which the student participated in the program; SP = spring semester, SU = summer semester, and F = fall semester.

4.3 Data Sources and Data Collection

Case study research is dependent on the use of multiple data sources to enhance data credibility [40,41]. To address the research questions of this case study, data were collected in the form of observations, written data, one multimedia recording, and artifacts, for a total of seven data sources, over the course of one calendar year. Data were assembled from participant observations and documents created by the students. Pre-presentation data were collected using a self-report instrument that included a question scale and space for comments (Appendix A). This self-report instrument was designed specifically for this project and consisted of five questions. Students rated their agreement to each question on a 1-7 scale, with 1 indicating not in agreement and 7 very much in agreement. Students were also able to add written comments to each question.

Post-presentation self-reflection data sheets (Appendix B) consisted of five open-ended questions to gather data on the perceptions students had about presenting their work to the public. Reflections, completed immediately after delivery of the presentation, allowed students to capture thoughts while the experience was still fresh in their mind.

Twenty-nine out of 30 total presentations were directly observed. Informal, descriptive notes were taken and emails collected. Occasionally photographs were taken to supplement the participant-authored post-reflection information. Observations and field notes recorded non-written and non-verbal communication and reactions between students and patrons during most presentations supplemental to students' written reflections. Written brochures created by students also comprised artifacts for analysis. These documents consisted of leaflets explaining the physics demonstrated in the participant's machine as it related to the K-12 state standard for that physics concept. One student (Craig, 13SU) requested that his presentation be video recorded. This video recording was then housed on his social media page and was reviewed by the research team with permission.

Most students worked on the project individually, with the exception of Earl (15SU) and Monty (16SU) who did their presentations together as a team during summer semester and Myra (29SU) and Lina (24SP). Lina (24SP) took classes in the spring semester and at that time didn't apply to be part of the project. Her friend Myra (29SU) later took a qualifying course and the two collaborated on a project during the summer semester.

All 30 students were mentored for one month. During any semester there was overlap among students when working with these mentors, depending upon the students' semester workload, however each student or student pair was assigned a unique date to make their presentation to the public. All but the two pairs of students were given individual attention by mentors. The two pairs of students who worked together on their projects, Earl (15SU) and Monty (16SU) and Myra (29SU) and Lina (24SP), worked with the mentors both individually and as a team.

Data in Table 2 were organized chronologically by the semester of collection and by the data type collected. The project began in the spring semester and continued into summer, finishing during the fall semester.

Table 2. Type and Amount of Data Collected by Semester

Semester	Spring	Summer	Fall
Interviews	8	16	6
Pre-Presentation Data Sheet	8	15	6
Brochures	8	16	6
Video	0	1	0
Observation Notes	8	16	6
Post-Presentation Reflection Data Sheet	8	15	6
Emails	5	6	4

Note. One presentation was video recorded by student request. Emails refer to number of students who corresponded with the professor, not actual number of email messages. Pre-Presentation and Reflection data sheets, shown in bold type, are primary data sources.

Table 2 contains two items worthy of notice. First, there were almost twice as many presentations done during the summer as there were during the spring and fall. This could be because students may have had more time to devote to an ancillary project during the summer. Second, there was only one instance of video data collection for the reason mentioned above. All data types were required with the exception of video and email correspondence. The single video data type was requested by the student to post on his/her social media account and was included as data for the study. Emphasis on data types was placed on pre-surveys and on reflections as primary data sources with interviews, brochures, video, observations, and emails as secondary data sources.

Interview data were collected during a one-hour orientation meeting with each student. These interviews were the first step in the data collection process. During these initial informal, non-recorded interviews, students completed the pre-survey and received instructions and materials to guide in the creation of their brochure. Each student selected a presentation date during this meeting and a model kit. Students selected from five different model kit types: catapult, mechanical drum, rolling tank, cart, and paddleboat. All of these kits contained plastic snap together pieces to assemble into a table top model. Presentations were scheduled for Friday or Saturday evening, from 5pm to 9pm, at the planetarium. These days and times were selected because that was when there was a flow of visitors to see the regularly scheduled planetarium programs.

The second required step was that each student or pair of students contact the professor to review the draft of their brochure. Students met with him during office hours, before or after class, via a telephone conference, or through email. Meetings via email were printed and examined as a secondary data source. The purpose of the second meeting was to receive feedback on the creation of their brochure. Figure 1 shows an example of Jim's (11F) brochure in progress with feedback notes on the rough draft.

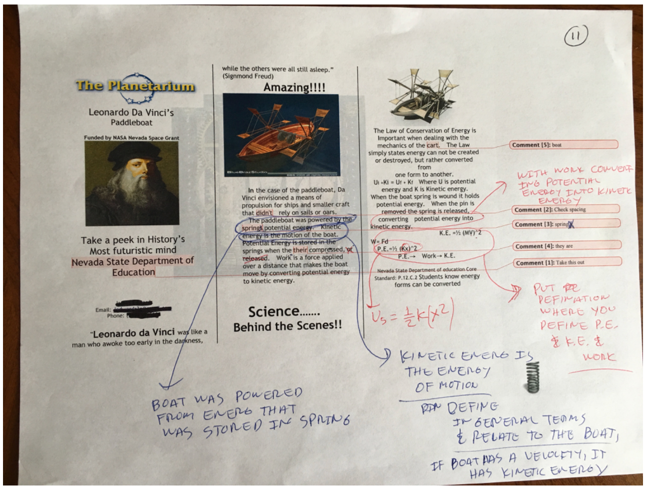

Fig. 1. The draft layout of a tri-fold brochure created by Jim (11F) describes the physics behind da Vinci's paddleboat. Feedback was provided by the first author as shown by inserted digital text comments and by the professor as indicated by written comments in red and blue ink.

The final step was to borrow a piece of laboratory equipment from the college physical science laboratory. This piece of equipment was used to demonstrate the physics involved in the function of the model. Students were responsible for bringing all of these materials to the planetarium an hour before they were scheduled to present. Students set up their presentation display on rolling carts in the planetarium lobby. They had an opportunity to receive additional feedback on their presentation after set-up. Finally, they presented to patrons as they came in to the planetarium lobby on their way to the planetarium astronomy store box office.

4.4 Data Analysis

Qualitative analysis: Case study research answers "how" and "why" questions [42]. In this case the "how" describes the perspectives of 30 pre-engineering and calculus-based physics students and how they presented science concepts to the public at a planetarium. This "how" was the phenomenon of creating a brochure and presenting a physics concept to planetarium patrons. This task was influenced by the situated context of presenting complex material at a planetarium in a way that enabled lay patrons to understand a concept presented using simple language [43,44]. The "why" in this case study is addressed by examining themes that emerged from the perspectives students had with experience working with mentors toward their final presentation. These were the different perspectives students revealed while working with this professor on their projects and doing their presentations. This is a descriptive case study [41], designed to understand the intervention of creating an explanatory brochure for the general public and presenting a physics concept to a population in the real-life context of the public planetarium where it occurred.

Written comments were transcribed from hand-written data sheets to a word-processed document. Seven data types were collected (see Table 2). These data types were divided into primary data and secondary data. Primary data sources were the initial data collection instruments created by during the structuring of the study. Appendix A and B are pre-presentation data sheets surveys and post-presentation self-reflection sheets [4,5,12]. Secondary data sources were collected were interviews, student created brochures, one video, observations, and emails. Using the transcribed primary data sources and the secondary data sources, data were reduced to five salient themes.

Data were reduced by identification of inchoate themes and subthemes [45]. Searching for patterns across all data sources, salient themes emerged and were grouped together. Data were examined again in an iterative process to find dominant themes. Appendix C presents an example of the coding of select post-presentation Self-Reflection sheets. According to Creswell [44] and Strauss and Corbin [46], this iterative method uses students' experiences and self-reported data from primary and secondary data sources to group and organize emerging themes and interpret the raw data into useable parts that can be analyzed. When transcribed data texts revealed the same themes over and over, the cycle of this portion of data analysis was considered complete [47]. The five themes that continued to come up in the data and that are further discussed in the next section are: nervousness; recognition of the need for public speaking as part of the engineering and scientific profession; hesitancy to give out incorrect information when giving a presentation; explaining science to a lay audience, especially to children; and confidence.

After data were reduced by transcription and themes identified, passages in the transcribed data were coded and grouped according to theme categories. The process of coding and grouping organized the data. Coding enabled associations to be made within the data and helped draw conclusions [48]. After coding was completed, narrative analysis was used to look at the data in units.

Narrative analysis uses narratives or stories that emerged when students reflected on their presentations. In this case study the post-presentation reflection sheets provided a source of stories for analysis. Narrative analysis was also applied to responses on the pre-presentation self-reports. In analyzing a narrative, Bernard and Ryan [49] treat data as means for developing explanations of how things work. Narrative analysis technique applied to the narratives within each category helps to discover and put a human face on nascent themes [50].

Quantitative analysis: In addition to the qualitative analysis described here, simple descriptive statistics were calculated for the Pre-Survey. On this, students rated each question on a scale of Likert-style scale of 1-7. Other data collection instruments did not include quantitative measures, so direct comparison (e.g., pre-to-post change) is neither possible nor appropriate. The raw data for the Pre-Survey can be found in Appendix D.

5 Results

The data captured perspectives of 30 pre-engineering and calculus-based physics students at a large urban two-year college after they presented science concepts to the public. These data were analyzed to examine themes that emerged from the perspectives students had on their experience working with their mentors toward their final presentation. Results obtained from data collected and analyzed provided insight to answer the "how" and "why" questions in the purpose statement. We first describe the perspectives students had on "how" they presented science concepts to the public, then examine themes that emerged (the "why") from the perspectives students had on their experience working with their mentors toward their final presentation.

5.1 Results from Primary Data Sources

Of the seven data sources collected, the Pre-Survey and post Self-Reflection survey (Appendices A and B) are considered primary because they were created when the study was designed. Primary data sources are the main source of direct student comments. Five other sources (see Table 2) were collected; these are considered secondary data sources.

Narrative analysis: Narrative analysis uses artifacts, field notes, and other data collection instruments to understand the way people create meaning from an experience. In this case primary data source instruments were examined and narrative analysis occurred after looking at the data in transcribed form. Themes that occurred in the text were highlighted using different colored markers. Colored highlighting helped group the themes that emerged when looking at the experiences of students before and after working on their project presentations. Quotations from the written narrative component of the primary data—the pre-presentation self-report data sheet and the post presentation self-reflection data sheet—revealed information concerning the lived experience implementing the project had on this group of student scientists and pre-engineers.

According to Nikitina [51], "[the] tension when introducing personal narrative is much more pronounced in the hard sciences, where analytical stance towards knowledge has been given supreme value" (p. 252). In this study, tension can be a contributing factor to hesitation toward speaking to the public because students were in the midst of their training as scientists and engineers. As such, an analytical stance toward knowledge was valued and because these students were undergoing training they may have been unsure of their skills in being able to transfer what they know to a lay audience. This may have created tension that led to their hesitation.

Selected quotations from students' relay some of the concerns they had before embarking on the project. Blocks of annotated text were analyzed to draw out broader themes coming from selected student quotations. These quotations were then grouped into the above mentioned thematic categories. These quotations or points of narrative analysis were derived from written comments by students collected on the pre-presentation self-report data sheets and post-presentation reflection data sheets. These written comments were analyzed and informed the understanding of students' experiences with the project. Below are five salient themes that emerged from data analysis.

Theme of nervousness: The following quotations illuminate students' views toward public speaking as manifested in worry and nervousness.

Joe (8SP): "I prefer not to do it [public speaking, but]…I perform well if I thoroughly know the subject."

Edgar (12SU): "[Before the presentation] I learn the material inside and out."

Earl (15SU): "I worry about it [public speaking]…but it is necessary/unavoidable."

Monty (16SU): "I speak well when I am required to do it."

Dan (18SP): "I am nervous before [speaking]."

Larry (20SU): "It [public speaking] is nerve racking (sic)."

Mindy (22F): "It is tough to public speak in front of a group."

This nervousness can be interpreted in two ways. First, by looking at the profile matrix (Table 1) we see that the mean age of students indicate that they may not have experience sharing their knowledge with the public. All students are in the first two years of their pre-engineering and scientific training and may not have had opportunities to present technical information to the public before this experience.

The second way nervousness is interpreted is through the area of content. These students were engaged in a field of technical study and hesitated because their audience was unknown and may have little background knowledge to understand the technical subject matter presented. At the same time, these students have not had the scaffolding or training to be able to speak plainly about technical information. The conclusion we make from the theme of nervousness is that specific training in speaking to lay audiences is needed as part of pre-engineering and scientific preparation in order to alleviate the natural nervousness that comes with a lack of experience.

Theme of recognizing that public speaking is part of the profession. Students understood the importance of the public speaking aspect of this project and its value toward their careers. Mander (28SP) described the importance of public speaking and engaging a group by relating it to popular culture: "No one wants to be a mad scientist like Dr. Frankenstein." This comment illustrated the need to communicate in the field of science in a way that is relevant to consumers of informal science education. Mander (28SP) also indicated that the need for public speaking increases when seeking a terminal degree, thus linking this second comment back to the first with the assumption that speaking would be done more as training advanced. "If you plan to pursue a Ph.D. it [public speaking] would be important."

Students were aware that part of their job would be difficult as it involved oral presentations to unknown audiences. Not knowing the audience or what to expect makes the task more difficult. Students were preparing for their presentations blind, another reason for hesitation to commit to the oral part of the project as seen in the previous theme.

Students also realized that they would be called upon to orally convey complex ideas and information to various groups during their training and later in their careers. From this expressed need there is a gap in the traditional way engineers and scientists are trained. As programs in science and engineering move away from a reliance on solely lecture to more interactive and active learning methods, oral expression and project presentation become a more natural part of the curriculum.

Theme of being hesitant to give out the wrong information. Written comments from students included "fear of coming off as foolish" (Tanner, 21F) and fear of "giving out wrong information" (Thane, 5SU). This latter participant used the strategy of putting himself in an audience perspective to gain confidence. Students in this study are developing their early professional identities by showing concern for high standards. Concentration on deep core content knowledge and understanding of the topic could alleviate some of these fears. Students stated that iterative practice helped alleviate presentation concerns as illustrated in this statement made by Jim (11F), "…now the next time will be easier." This was a recurring theme as exemplified in this quote by Charlie (6F), "This exercise has actually helped my public speaking skills and made me realize how confident I was when explaining the physics concepts" since the exercise allowed him to practice within the structure of the grant reinforcing what he already knew about speaking to unknown audiences. Larry (20SU) felt that a "low pressure situation helps to alleviate any fears" of public speaking and that this informal situation coupled with scaffolding and support helped him relax with the patrons and helped him to explain the scientific concepts with confidence.

Theme of explaining science to a lay audience, especially children. Myra (29SU) talked about the need to connect with her audience. She worked with a partner on the project and stated, "We had to create a system that could be explained to a five-year-old and maybe someone who did not speak English very well. We kept our experiment (project) basic and our definitions concise." Her partner Lina (24SP) reported, "It was difficult to paraphrase the (scientific) definitions and bring the terminology to a very basic level." Myra (29SU) further stated that explaining the material to "people of all ages and backgrounds was a challenge." The students who did the projects had a more advanced understanding of physics and pre-engineering than the children to whom they presented and the situation was a new experience. Tony (4F) felt that it was difficult to "overcome the challenges of explaining physics to children." Despite that challenge, students reported that presenting to children is valued, as noted in this comment by Monty (16SU): "If students [children] learned more science I believe technological advances would occur more rapidly." Mander (28SP) reported that the professor stated, "Kids who are the most curious are the ones who love science."

Other comments about getting the message across include: "presenting difficult topics in a friendly way to the public was the most difficult part" (Mick, 7SP) and "I need to be simple and straightforward with how I explain…it is important to show and inspire" (Edgar, 12SU). These students understood that they needed to adjust their method of presentation for diverse audiences by being accessible, approachable, and motivational in their delivery of the content. They also understood the concept of simplification when presenting to a non-technical audience that involved children. For Brayden (26SU), "making [the] handout helped me practice" and he further stated, "people do not like being talked down to and the use of Science Greek doesn't help." Similarly, James (17SU) said that it is important to "use examples that the public can relate to." Dan (18SP) noted, "It is difficult to explain some things in language that a normal everyday person can understand." These comments further suggest that being open and accessible increases the ability to convey ideas and this is an important attribute to learn.

Theme of confidence. Students felt that they gained confidence after completing the project as illustrated by their post-presentation written comments. "[I gained] more confidence in speaking by drawing on previously learned physics information…I have more confidence in my intelligence" (Mindy, 22F). Joe (8SP) stated, "It required me to focus on the principles of work energy and conservation of energy to fully understand the material and to be able to give a clear demonstration." Jim (11F) reinforced this idea when he said, "if I can understand it I can explain it." Lina (24SP) sought advice from instructors in other disciplines, stating, "I asked my speech professor for some tips on how to overcome fears."

Quantitative results. A statistical analysis of Likert data from each of the five questions shows the number of participants that answered each question as well as the mean score and standard deviation of the responses. The mean scores for all five questions were above the middle of the score (i.e., 4 on a scale of 1-7), demonstrating some level of agreement or positive orientation toward each question, as indicated by the scale anchors (scale anchors are included in Appendix A).

Table 3. Pre-Survey Questionnaire Results

	Questions	N	μ	σ
1	What do you know about learning transfer from theory into practice?8	30	4.5	1.58
2	What are your perceptions about public speaking?8	30	4.8	1.79
3	What are your attitudes towards the integration of Physics and History as courses of study	30	6	1.58
4	As a student how important do you think the delivery of public service and speaking in Science content areas will be to your career?	30	6.6	0.76
5	As a student how important do you think your perceptions of public service and speaking may or may not have on your career?	30	6.3	1.16

Note. The Pre-Survey Questionnaire is shown in detail in Appendix A. Response options ranged from 1-7.

5.2 Further Insights from Secondary Sources

The five secondary data sources of initial one-hour interviews with each student participant, the brochure each student or student team created, the single video, direct observations, and student/professor email correspondences provided ancillary insights to the research questions. The initial interviews and the observations were recorded as field notes in student files set up to organize management of the project. Student/professor interactions through the mode of email correspondence provided thick description of how each student or student pair was helped to understand the science described in each brochure.

Student/professor interactions. Email correspondence between the students professor showed attention to detail with concern that physics concepts be presented correctly. Note the team effort exemplified in this email exchange:

Hello, my name is Thane [5SU] and I was in your Physics 180 and Statics class last semester. I am doing the NASA space grant ME project with [the researcher]. She told me to forward you the handout that I will give to the kids and their parents. Yes, she told me to make it as simple as possible for the kids to understand it. I think she said the age range was between 6-10 years of age. The attachment is in PDF format. Please give me some input on how I may make it better for kids to understand. Thank you, Thane [5SU]

The professor answers this email by going over the physics concepts then defers the logistical details to another mentor as shown in this reply:

You had said that power is delivered when the spring is released, and it is actually work that is being done. Power is the rate at which work is done. The spring is released, the spring goes through a distance so the spring is doing work, the work is changing the potential energy into kinetic energy of all the moving parts. I hope I didn't just make this harder for you or confusing. You should consult with [the first author] a bit more with what I said in this email as she has worked with kids a lot. Let me know if you have some other questions as I will be on-line all summer.

Data email exchanges were not formally collected during the course of the project and these artifacts are samples of exchanges that occurred. There are 15 email artifacts between these mentors, and students: five from spring semester taken from exchanges with Dalia, Joe (8SP), Dan (18SP), George (19SP), and Lina (24SP); six from summer semester with Thane (5SU), Craig (13SU), Earl (15SU), James (17SU), Lonnie (10SU), and Myra (29SU); and four taken in the fall semester from Charlie (6F), Jim (11F), Roy (14F), and Mindy (22F). Exchanges were similar to the above dialog and informed the case study by providing detail on another "how"— in this case, how the students worked with the professor.

Activity record. The activity record shown in Figure 2 details a scaffolded support process and outlines the steps used in the project from beginning to end. The activity record created here details the degree of complexity of the activity and the order of activity components for each participant to complete their project. According to Werner [52], an activity record shows that a process or activity can have more than one interpretation. If students skipped a step or completed the steps out of order, the finished presentation was not as successful in the minds of the student as determined by comments on the post-presentation self-reflection data sheet and by direct observations.

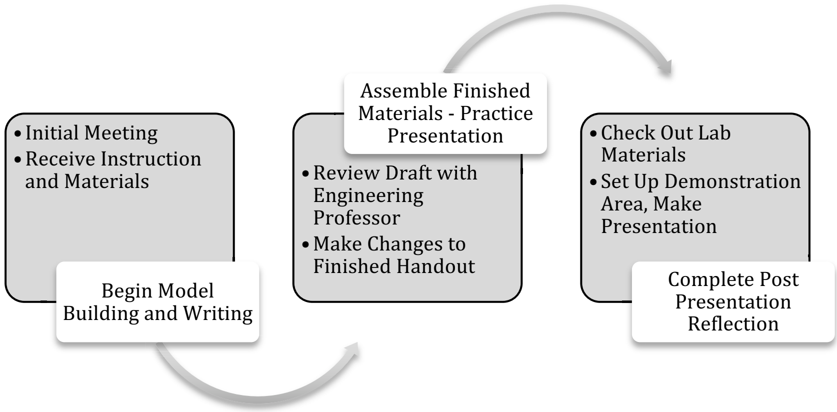

Fig. 2. Activity record describing students' actions in chronological order, including steps taken by students to complete their project from start to finish. Gray boxes represent scaffolding by the researcher and/or professor. White boxes represent student independent work time.

An example of a skipped step in the activity record occurred when Earl (15SU) found himself unsupported during the actual presentation. He expressed distress and frustration over his final presentation at the planetarium and over the self-reflection in a telephone conversation with one of the mentors. When he was offered the opportunity to do his presentation again he declined saying he just wanted to get the experience over with and put it behind him. Tanner (21F) and Mindy (22F) had difficulty meeting with the professor because of travel time to different campuses to finish their flyer. This caused a degree of stress until a physics professor on that campus was called to review the brochure. Tanner (21F) and Mindy (22F) were able to get their brochure finished before the presentation but the experience rattled them to the point where their presentations were affected.

6 Discussion

Use of a profile matrix (Table 1) confirmed that our students were drawn from a relatively narrow demographic, in line with previous studies of STEM demographics [39,53]. According to a meta-analysis done by Springer, Stanne, and Donovan [54], undergraduates in underrepresented groups prefer instruction through active learning or in project-based teams doing hands on study linked to real world problems. Given that the majority of students self-selected were from a narrow demographic, uncertainty about giving the presentation part of the project could be explained because use of real world problems is not a preferred learning style for this group.

After analyzing data, we formulated a pedagogic model [47] to explain student participant experiences, the "why" and the "how" of the research questions. This model explains why pre-engineering and calculus-based physics students have the experiences they do with creation of a brochure and explanation of their project to a lay audience. The constructed model (Figure 3) consists of three elements of preparation as signified by the horizontal boxes. The boxes are in the order in which steps are taken to identify factors as well as opportunities for practice with the top box the first step. The larger left-side box indicates the evaluation iteration cycle, which is particularly important in helping further identify and refine our understanding of the student participant experiences.

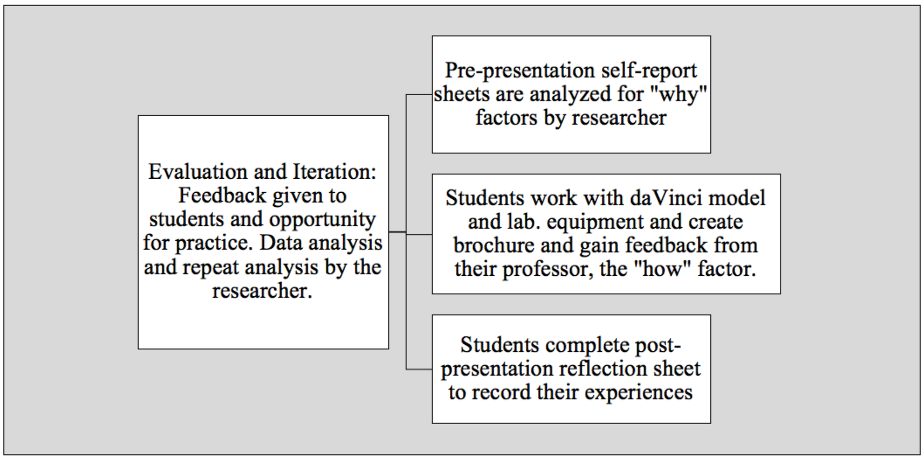

Fig. 3. The pedagogic model illustrates the three elements of preparation and data analysis with opportunities for feedback and evaluation as well as practice.

Pre-presentation self-report data sheet results inform the first box of the model. Typical "why" factors include being nervous interpreting their knowledge to groups they were unfamiliar with and to a certain extent how these unfamiliar groups would perceive them. Nerves, even natural nervousness due to normal brain function [55], were reported. As mentioned before, Brayden (26SU) said that scientists and engineers often come off as speaking "Science Greek." This type of comment could be perceived as students having a fear of being associated with science, which may make them seem eccentric or obsessed with intellectual pursuit to the point of being unlikable. Another factor in hesitancy to go forward with their presentation was lack of deep core content knowledge on the subject. Students expressed value that public speaking was a necessary part of becoming an engineer or scientist but also mentioned that unless they were prepared with a deep knowledge of the content they were less likely to have the confidence to go forward. One factor of being prepared was to know the audience and do preparation on a topic targeted to their audience. They were concerned about giving out misinformation.

Concerns about language coming from these future scientists and engineers is also worth mentioning. Student data sheets mentioned lack of confidence in the ability of the public to for basic understanding of science concepts. Perceived lack of ability of the public to understand basic science caused hesitation to present because the students were unsure how to proceed with explanations that were simple enough for the audience to understand. Similar concerns had to do with themselves being perceived as overly intellectual if they were not able to connect with their audience.

The second or middle box of scaffolded support in the pedagogic model represents support that can be given to student students in their preparation of materials and talking points prior to the presentation date. Support came in the form of writing and editing the brochure as well as presentation practice and presentation display support in setting up beforehand. Referring back to the activity record described by Figure 1, this support and the sequence in which it was provided helped students with presentation success.

The final box on the model suggests that students need to reflect on the influence of a scaffolded presentation experience. From our post-presentation data, the theme of nervousness in particular was mentioned by students as being alleviated or lessened by another experience at public speaking. Explicit reflection is a component of critical thinking and metacognition [56], which can in turn lead to greater success in STEM fields.

Themes of nervousness, the need for public speaking, concern for giving out misinformation, and concern for explaining science to the public and to children contribute or enhance confidence in giving a presentation. According to Phelps [55], nervousness is part of brain function. For high achievers like these students, nervousness comes from internal high demands such as thoughts that they must not appear nervous or that they must cover everything.

Creation of the printed materials ranked low on importance as career preparation. When giving a compelling presentation well thought out and documented visual and print materials are often key components. The fact that these students were dealing with the subject of K-12 education may have contributed to their low rating of this activity as important to a future career.

7 Limitations

This study was limited by the absence of formal post-presentation student interviews. The types of activities included one-hour meetings with each student for orientation (these meetings were labeled interviews in Table 2), observations by the researcher, and the pre- and post-presentation written instruments. Data analysis focused on written responses, student observation notes, and email correspondence between students and the professor. Post-presentation interviews were difficult to schedule due to time constraints for the students, who were in their last year of study at the institution. Some students completed their studies with the two-year Associates of Science degree conferred from the college and began to work in their profession, often moving out of the area for employment in their field, whereas others transferred to a four-year university to pursue a Bachelor's degree. Both scenarios meant that scheduling follow-up interviews were difficult.

The students self-selected and they received a stipend upon completion of their project and presentation. The work they did on the project was not part of a required class or assignment. This tended to attract motivated and curious students to participate who were interested in science and engineering and positioning themselves for a later career, in addition to completion of a class toward their degree as opposed to a random sample that could have been recruited from a cross section of a typical engineering or science course.

8 Conclusions and implications for future research

Further studies with use of the pedagogic model (Figure 3) to understand more details of student experiences with situated learning using a real-life project experience are potential areas for further research. Such future studies using the model ideally would be performed using a larger sample size. Testing the model with students doing either an in-class project-based learning unit or an out-of-class project similar to this project would further situate the "how" and "why" of the case study. As identified in the meta-analysis by Springer et al. [54], project-based learning and connecting theory to real life experiences is the preferred way for some students to learn, particularly those not traditionally represented in STEM fields. Creation of experiences for students to practice explaining their knowledge in a supportive environment helped students go forward with oral presentations of their knowledge. Taking time to evaluate the speaking experience afterward and engage in another follow up experience gave the students confidence.

Efforts to increase opportunities for students to present complex material orally to groups provide possibilities for students to practice engineering process skills [4,15]. Data from this study revealed that scaffolded, iterative experiences as well as preparation can help student scientists and engineers hone their communication skills. Students need training in the professional skills of public speaking to overcome perceptions that they may be giving out incorrect information. The need to avoid closure might be particularly strong when there are costs associated with being wrong

[57]. Students with low prior knowledge would be unlikely to engage in cognitive activity when they are also trying to avoid closure. Further research with continued testing and refinement of the pedagogic model will add more to this preliminary understanding. This information can inform the practice of training students for careers in physics and engineering.

9 Acknowledgements

Although the research study was unfunded, it was possible because the da Vinci project was supported by the National Aeronautics and Space Administration under Grant/Contract/Agreement No. NNX10AN23H, Nevada NASA Space Grant Consortium. The authors would like to thank Dr. Qingmin Shi for review of the grounded theory model and assistance with qualitative research theory and method.

10 References

[1] Giles, D. E., & Eyler, J. (1994). The theoretical roots of service-learning in John Dewey: Toward a theory of service-learning. Michigan Journal of Community Service Learning, 1(1), 7.
[2] Powell, K. C., & Kalina, C. J. (2009). Cognitive and social constructivism: Developing tools for an effective classroom. Education, 130(2), 241-251.
[3] Bairaktarova, D. & Eodice, M. (2017). Thermodynamics in high rhythms and rhymes: Creative ways of knowing in engineering. Advances in Engineering Education, 6(2), 1-16.
[4] Ferrero, F. J., Lopez, A., Valledor, M., Campo, J. C., Blanco, C., & Vershinian, Y. A. (2015). An ECG lab project for teaching signal conditioning systems in a master's degree in mechatronic engineering. Advances in Engineering Education, 4(3), 1-16.
[5] Fries, R., Cross, B., Zhou, J., & Verbais, C. (2017). How student written communication skills benefit during participation in an industry-sponsored civil engineering capstone course. Advances in Engineering Education, 6(1), 1-14.
[6] Kirkman, R., Fu, K., & Lee, B. (2017). Teaching ethics as design. Advances in Engineering Education, 6(2), 1-17.
[7] Moskovitz, C. (2017). Volunteer expert readers: Drawing on the university community to provide professional feedback for engineering student writers. Advances in Engineering Education, 6(1), 1-31.
[8] Pfatteicher, S. K. A. (2001). Teaching vs. preaching: EC2000 and the engineering ethics dilemma. Journal of Engineering Education 90(1), 137–142. https://doi.org/10.1002/j.2168-9830.2001.tb00581.x
[9] Shuman, L. J., Besterfield-Sacre, M., & McGourty, J. (2005). The ABET "professional skills"—Can they be taught? Can they be assessed? Journal of Engineering Education, 94(1), 41-55. https://doi.org/10.1002/j.2168-9830.2005.tb00828.x
[10] Kumar, S., & Hsiao, J. K. (2007). Engineers learn "soft skills the hard way": Planting a seed of leadership in engineering classes. Leadership and Management in Engineering, 7(1), 18-23. doi: 10.1061/(ASCE)1532-6748(2007)7
[11] Darling, A. L. & Dannels, D. P. (2013). Practicing engineers talk about the importance of talk: A report on the role of oral communication in the workplace. Communication Education, 52(1), 1-16. https://doi.org/10.1080/03634520302457

[12] Fox, G. A., Weckler, P., & Thomas, D. (2015). Linking first-year and senior engineering design teams: Engaging early academic career students in engineering design. Advances in Engineering Education, 4(3), 1-14.
[13] vom Brocke, Jan, Simons, A., Niehaves, B., Niehaves, B., Reimer, K., Plattfaut, R., & Cleven, A. (2009, June). Reconstructing the giant: On the importance of rigor in documenting the literature search process. Paper presented at European Conference on Information Systems, Verona, Italy.
[14] Galvan, J. L. & Galvan, M. C. (2017). Writing literature reviews: A guide for students of the social and behavioral sciences. Abingdon, United Kingdom: Routledge.
[15] Chuchalin, A., Minin, M., & Vyuzhanina, N. (2014). Practice-oriented learning as a way to meet employers' requirements to graduates. International Journal of Engineering Pedagogy, 4(2), 31-35. https://doi.org/10.3991/ijep.v4i2.3440
[16] Agan, D. (2011). The hitchhiker's guide to public presentations, a companion guide. National Science Foundation Workshop, Science: Becoming the Messenger. University of Nevada, Las Vegas.
[17] Villanueva, I., Jones, S., Putney, L., & Campbell, B. (2018). Puzzling the pieces: Conceptual blocks of engineering student ideas in a service learning project. The International Journal of Engineering Education, 34(1), 56-68.
[18] Whitman, L., Reynolds, K., & Toro-Ramos, Z. (2011, June). Service learning in engineering. Paper presented at the 2011 ASEE Annual Conference & Exposition, Vancouver, BC, Canada.
[19] Roth, W. M., & Roychoudhury, A. (1993). The development of science process skills in authentic contexts. Journal of Research in Science Teaching, 30(2), 127-152. https://doi.org/10.1002/tea.3660300203
[20] Danielewicz-Betz, A. & Kawaguchi, T. (2014). Preparing engineering students for global workplace communication: Changing the Japanese mindset. International Journal of Engineering Pedagogy, 4(1), 55-68. doi: 10.3991/ijep.v4il.3297
[21] Hrmo, R., Mistina, J., & Kristofiakova, L. (2016). Improving the quality of technical and vocational education in Slovakia for European labour market needs. International Journal of Engineering Pedagogy, 6(2), 14-22. doi: 10.3991/ijep.v6i2.5369
[22] Moore, D. J., & Voltmer, D. R. (2003). Curriculum for an engineering renaissance. IEEE Transactions on Education, 46(4), 452-455. https://doi.org/10.1109/TE.2003.818754
[23] Henneman, R. L. (1999). Design for usability: process, skills, and tools. Information Knowledge Systems Management, 1(2), 133-144.
[24] Padilla, M. J. (1990). The science process skills. Research Matters-to the Science Teacher, 9004.
[25] Lave, J., & Wenger, E. (1991). Situated learning: Legitimate peripheral participation. Cambridge, MA: Cambridge University Press. https://doi.org/10.1017/CBO9780511815355
[26] Clancey, W. J. (1995). A tutorial on situated learning. Proceedings of the International Conference on Computers and Education (Taiwan) Self, J. (Ed.) Charlottesville, VA: AACE. 49-70, 1995.
[27] Shor, I. (1987). Critical teaching and everyday life. Chicago, IL: University of Chicago Press.
[28] Stein, D. (1998). Situated learning in adult education. ERIC Digest No. 195.
[29] Brown, A. L. (1994). The advancement of learning. Educational Researcher. 23(8), 4-12. https://doi.org/10.3102/0013189X023008004
[30] Jacobson, W. (1996). Learning, culture, and learning culture. Adult Education Quarterly. 47(1), 15-28. https://doi.org/10.1177/074171369604700102

[31] Orner, M. (1996). Teaching for the moment: Intervention projects as situated pedagogy. Theory into Practice. 35(2), 72-78. https://doi.org/10.1080/00405849609543705
[32] Lave, J. (2009). The practice of learning. In K. Illeris (Ed.), Contemporary theories of learning: Learning theorists… in their own words, (pp. 200-208). New York, NY: Routledge.
[33] Klopf, D. W., & Cambra, R. E. (1979). Communication apprehension among college students in America, Australia, Japan, and Korea. The Journal of Psychology, 102(1), 27-31. https://doi.org/10.1080/00223980.1979.9915091
[34] Sallinen-Kuparinen, A., McCroskey, J. C., & Richmond, V. P. (1991). Willingness to communicate, communication apprehension, introversion, and self-reported communication competence: Finnish and American comparisons. Communication Research Reports, 8(1), 55-64. https://doi.org/10.1080/08824099109359876
[35] Young, D. J. (1990). An investigation of students' perspectives on anxiety and speaking. Foreign Language Annals, 23(6), 539-553.https://doi.org/10.1111/j.1944-9720.1990.tb00424.x
[36] Dannels, D. (2002). Communication across the curriculum and in the disciplines: Speaking in engineering. Communication Education, 51(3), 254-268. https://doi.org/10.1080/03634520216513
[37] National Science Board. (2014). Higher education in science and engineering. Science and Engineering Indicators 2014. Arlington VA: National Science Foundation (NSB 14-01).
[38] Aikenhead, G. S. (2002). Cross-cultural science teaching: "Rekindling traditions" for aboriginal students. Canadian Journal of Science, Mathematics and Technology Education, 2, 287-304. https://doi.org/10.1080/14926150209556522
[39] Leggon, C., & Pearson, W. (2009). Assessing programs to improve minority participation in the STEM fields: What we know and what we need to know. In R. G. Ehrenberg & C. V. Kuh (Eds.), Doctoral education and the faculty of the future (pp. 160-174). Ithaca, NY: Cornell University Press.
[40] Patton, M. Q. (2002). Qualitative research and evaluation methods (3rd ed.). Thousand Oaks, CA: SAGE Publications.
[41] Yin, R. K., (2003) Case study research: Design and methods (3rd ed.). Thousand Oaks, CA: SAGE Publications.
[42] Stake, R. E. (1995). The art of case study research. Thousand Oaks, CA: SAGE Publications.
[43] Baxter, P. & Jack, S. (2008). Qualitative case study methodology: Study design and implementation for novice researchers. The Qualitative Report, 13(4), 544-55
[44] Creswell, J. W. (2013). Qualitative inquiry and research design: Choosing among five approaches. Thousand Oaks, CA: SAGE Publications.
[45] Charmaz, K., & Belgrave, L. (2003). Qualitative interviewing and grounded theory analysis. Thousand Oaks, CA: SAGE Publications.
[46] Strauss, A. & Corbin, J. (1994). Grounded theory methodology. In N. K. Denzin & Y. S. Lincoln (Eds.), Handbook of qualitative research (pp. 217-285). Thousand Oaks, CA: SAGE Publications.
[47] Schraw, G., Wadkins, T., & Olafson, L. (2007). Doing the things we do: A grounded theory of academic procrastination. Journal of Educational Psychology, 99(1), 12-25. https://doi.org/10.1037/0022-0663.99.1.12
[48] Miles, M. B., & Huberman, A. M. (1994). Qualitative data analysis: An expanded sourcebook. Thousand Oaks, CA: SAGE Publications.
[49] Bernard, H. R., & Ryan, G. W. (2009). Analyzing qualitative data: Systematic approaches. Thousand Oaks, CA: SAGE Publications.

[50] Boje, D.M. (2001). Narrative methods for organizational and communication research. Thousand Oaks, CA: Sage Publications. https://doi.org/10.4135/9781849209496
[51] Nikitina, S. (2003). Stories that stayed "under the skin." International Journal of Qualitative Studies in Education. 16(2), 251-265. https://doi.org/10.1080/0951839032000060581
[52] Werner, O. (1992). Short take 7: How to record activities. Field Methods, 4(2), 1-3. https://doi.org/10.1177/1525822X9200400201
[53] Maple, S. A., & Stage, F. K. (1991). Influences on the choice of math/science major by gender and ethnicity. American Educational Research Journal, 28(1), 37-60. https://doi.org/10.3102/00028312028001037
[54] Springer, L., Stanne, M. E., & Donovan, S. S. (1999). Effects of small-group learning on undergraduates in science, mathematics, engineering, and technology: A meta-analysis. Review of Educational Research, 69(1), 21-51. https://doi.org/10.3102/00346543069001021
[55] Phelps, E. A. (2004). Human emotion and memory: Interactions of the amygdala and hippocampal complex. Current Opinion in Neurobiology, 14(2), 198-202. https://doi.org/10.1016/j.conb.2004.03.015
[56] Schraw, G., Crippen, K. J., & Hartley, K. (2006). Promoting self-regulation in science education: Metacognition as part of a broader perspective on learning. Research in Science Education, 36, 111-139. https://doi.org/10.1007/s11165-005-3917-8
[57] Kruglanski, A. W. (1989). Lay epistemics and human knowledge: Cognitive and motivational bases. New York, NY: Plenum. https://doi.org/10.1007/978-1-4899-0924-4

11 Authors

Pamela A. Maher is an independent researcher on issues of science education with a concentration on using simulations for informal science education and for teaching college astronomy. She earned her Ph.D. at the University of Nevada, Las Vegas and worked at the Planetarium at the College of Southern Nevada as the NASA Nevada Resource Center Coordinator.

Janelle M. Bailey is an Assistant Professor of Science Education at Temple University, where she works with preservice science and mathematics teachers. She researches student learning, particularly in Earth and space science, at the secondary and tertiary levels, as well as preservice teacher education. She earned a B.A. from Agnes Scott College, a M.Ed. from the University of Georgia, and her Ph.D. from the University of Arizona.

Allan M. Tucka began his teaching career at the College of Lake County in Illinois teaching machine technology while simultaneously pursuing a four-year tool and die apprenticeship. After this training he earned a degree in mechanical engineering at the University of Illinois at Chicago and a master's at Portland State University in Oregon. He founded the pre-engineering program at the College of Southern Nevada.

Article submitted 13 June 2018. Resubmitted . 20 August and 08 September 2018Final acceptance 09 September 2018. Final version published as submitted by the authors.

Appendix A

Name____Date_________________

Pre-Survey – Understanding Physics Using the Machines of Leonardo da Vinci

Please answer all questions, be as complete as you can, record all thoughts you have about the questions as well as circling a point on the Likert Scale:

1. What do you know about learning transfer from theory into practice?

I know very little **----1------2------3------4------5------6------7----** I know a lot

Comments:

2. What are your perceptions about public speaking?

I have no fixed perceptions **----1------2------3------4------5------6------7----** I have set perceptions

Comments:

3. What are your attitudes towards the integration of Physics and History as courses of study?

My attitudes are negative **----1------2------3------4------5------6------7----** My attitudes are positive

Comments:

4. As a student how important do you think the delivery of public service and speaking in Science content areas will be to your career?

Not important **----1------2------3------4------5------6------7----** Very important

Comments:

5. As a student how important do you think your perceptions of public service and speaking may or may not have on your career?

Not important **----1------2------3------4------5------6------7----** Very important

Comments:

Appendix B

Name____Date__________________

Self-Reflection – Understanding Physics using the machines of Leonardo da Vinci

Please answer all questions, be as complete as you can, record all thoughts you have, there are no right or wrong responses.

1. What do you know about explaining hard science to the public? How was it helpful to do this exercise?

2. What was the most valuable experience you had being a part of this research project? Will you be encouraged to continue studying hard science?

3. What challenges did you have to overcome in order to do this project? What did you learn?

4. As a program participant tell me about your experience with the state standards. Did this change the way you view science as a course of study?

5. Did participation in this program have any influence in your career choice? Tell us about this. Did this increase your confidence in ability to talk about physics? How?

Appendix C

Self-Reflection sample with color coding page 1 of 11. Student responses (labeled by letters a-i) are included verbatim; no edits were made for grammatical, spelling, or style issues.

Theme of Nervousness – Pink
Theme of recognizing that public speaking is part of the profession – Green
Theme of being hesitant to give out the wrong information – Yellow
Theme of explaining science to a lay audience, especially children – Blue
Theme of confidence – Gray

1. **What do you know about explaining hard science to the general public? How was it helpful to do this exercise?**

a. I don't know much about hard science or about talking in public. I could be helpful because you can get to explain what have been learned in class to other people, and it also helps on getting more comfortable talking to the public.
b. I knew about the conservation of energy which forms the basis of my discussion. It was helpful to explain how the projectile can be fired. Projectile motion was a little harder to explain, the lab equipment confused some people.
c. I like science and so I feel it is somewhat easy to explain it to the general public and so the exercise was mostly easy for me.
d. It is often difficult to give specific details on the way physics work (sic), therefore a concept is a better way of getting a point across rather than details.
e. At first, I had my doubts about explaining hard science to the general public. I took my physics courses and I could understand the work, but explaining it is a little tricky. You don't want to give out the wrong information to the people or else they might develop bad habits in the future. After getting myself deep into the project I came to be a lot more aware of my education and I got more confident towards the understanding of the material.
f. I know that it wasn't that hard. I explained the general physics principles that were informative to the audience and myself. This exercise has actually helped my public speaking skills and made me realize how confident I was when explaining the physics concepts.
g. To explain difficult science topics to the general public, the best first step is to begin with the basics. For example, In Da Vinci's armored car, there are physical properties and equations at work but the simplest topic is conservation of energy. By using a prop and the car, I can easily present these ideas to the public in a friendly manner. In the pamphlet, the more in-depth workings of the machine are listed for those who are interested.
h. I know very little about explaining hard science to the public as I have only taken one semester of chemistry and one semester of physics. This exercise was helpful in that it required me to focus on the principles of work energy and conservation of energy to fully understand the material to be able to give a clear demonstration.
i. This was my first experience explaining hard science to the public. It was very helpful to experience the question that the public has. respond well to hands on display.

Appendix D

Raw data from Pre-Survey (Appendix A)

Pre-Survey Likert Questions	Participants by participant number																														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	24A	25	26	27	28	29	30
	Likert 1-5 scale; 1 being less favorable, 5 being more favorable																														
Question 1	1	4	4	4	7	2	6	3	4	4	5	7	6	6	4	6	3	5	5	3	5	4	7	5	5	3	3	5	6	3	4
Question 2	6	3	2	4	6	5	7	4	5	5	7	4	7	1	6	7	4	6	5	4	5	6	6	7	3	4	4	6	1	2	6
Question 3	6	7	7	7	7	6	5	7	7	6	1	7	4	7	2	7	5	6	6	6	5	7	7	7	7	4	7	6	7	7	5
Question 4	7	7	7	7	7	6	6	7	7	7	6	7	7	6	7	7	6	6	6	7	5	7	7	7	7	6	6	5	7	7	7
Question 5	6	7	7	7	7	6	6	5	7	5	7	7	6	7	7	7	6	7	5	2	5	7	7	7	7	4	6	7	7	7	7

Pre-Survey Likert Questions	Participants by participant number																														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	24A	25	26	27	28	29	30
	Likert 1-5 scale; 1 being less favorable, 5 being more favorable																														
Question 1	1	4	4	4	7	2	6	3	4	4	5	7	6	6	4	6	3	5	5	3	5	4	7	5	5	3	3	5	6	3	4
Question 2	6	3	2	4	6	5	7	4	5	5	7	4	7	1	6	7	4	6	5	4	5	6	6	7	3	4	4	6	1	2	6
Question 3	6	7	7	7	7	6	5	7	7	6	1	7	4	7	2	7	5	6	6	6	5	7	7	7	7	4	7	6	7	7	5
Question 4	7	7	7	7	7	6	6	7	7	7	6	7	7	6	7	7	6	6	6	7	5	7	7	7	7	6	6	5	7	7	7
Question 5	6	7	7	7	7	6	6	5	7	5	7	7	6	7	7	7	6	7	5	2	5	7	7	7	7	4	6	7	7	7	7