Board 384: Setting the Stage for Co-Creation: Using Workshops to Scaffold Interdisciplinary Research, Collaboration, and Community Building

Dr. Trina C. Kershaw, University of Massachusetts, Dartmouth

Trina Kershaw earned her PhD in Psychology from the University of Illinois at Chicago in 2006. She is a Professor of Psychology at the University of Massachusetts Dartmouth. She conducts multidisciplinary research in education and creativity under the broad umbrella of cognitive science. Recent work includes using co-creation to develop curricular materials in graduate engineering education; devising training to help undergraduates comprehend research articles; and conducting research about creativity in computer programming, engineering design, and within classic psychology paradigms.

Dr. Susan Thomson Tripathy, University of Massachusetts, Lowell

Dr. Susan Thomson Tripathy is a Research Associate at UMass Lowell who specializes in qualitative research methods. She received her doctorate in Anthropology from Harvard University.

Dr. Hong Liu, University of Massachusetts, Dartmouth

Hong Liu is a Professor of Electrical and Computer Engineering at the University of Massachusetts Dartmouth. She received PhD degree in Computer Science /w Math minor from New York University - School of Engineering. She is an IEEE Senior Member.

Prof. Kavitha Chandra, University of Massachusetts, Lowell

Kavitha Chandra is the Associate Dean for Undergraduate Programs and Professor of Electrical and Computer Engineering in the Francis College of Engineering at the University of Massachusetts Lowell. She directs the Research, Academics and Mentoring Pathways (RAMP) to Success program that aims to establish successful pathways to graduate school and interdisciplinary careers for new engineering undergraduates. Dr. Chandra's research interests include design of data-driven stochastic models for applications in acoustics, communication networks and predictive analytics in education, model-based systems engineering and communications network traffic and performance modeling.

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Abstract

Co-creation in academe can take multiple forms. In this research, the co-creation focus is on collaboration between faculty and graduate students to develop educational modules. This activity is designed to improve graduate education and prepare students for conducting graduate research. In previous work presented at ASEE 2022, we discussed benefits and challenges of participating in the co-creation process. This current paper focuses on how we took lessons from our first year and transformed them into a structure to better support interdisciplinary research, collaboration, and community building.

We will discuss how we supported the process of co-creation by developing a series of workshops to scaffold student learning. Scaffolds are instructional methods and interventions that are designed to foster skill development by allowing for interactions between what students already know and what they have yet to learn. These workshops were designed using the tenets of the gold standard project-based learning (PjBL). The PjBL framework is itself a scaffold that is designed to build research competencies.

Specifically, to introduce a challenging problem or question, we created multiple technical overviews of the cyber-physical system theme of interest that would constitute the eventual educational modules. We scaffolded sustained inquiry by developing a workshop using techniques from the Right Question Institute, and also through a workshop about crafting your message for different audiences. To support the PjBL idea of authenticity, we developed a workshop about core values to help students connect personally to their project topics. To further support collaboration and community building, we developed a workshop to introduce ideas of interdisciplinary collaboration, including developing community agreements and recognizing and responding to microaggressions. Periodic reinforcements of these topics were incorporated as students progressed in their co-creation project. We assessed how students applied these topics through student reflections.

Scaffolding students' learning helped to address co-creation challenges that were expressed by our pilot group, including not understanding the goals of the project and not feeling connected to the research. Observational data of the current groups suggests that students have better understanding of the co-creation process and are collaborating more effectively than our pilot group students, and focus group data confirmed these observations. We also collected feedback from students about the workshops to evaluate what is effective about them and what can be improved. Students felt skills taught in the workshops such as how to prioritize research questions, construct messages for specific audiences, and perform literature searches and reviews, were all effective and useful as they worked on their projects. For improvement, they suggested clearer objectives and more workshops that focus on technical aspects of the project work would be helpful.

1.0 Introduction

Graduate education in engineering has the goal of developing future engineers with strong technical and human interaction skills to succeed in the workplace. Yet, employers find that graduates are lacking skills in leadership, collaboration, communication, and critical thinking [1]. Likewise, graduate students often experience limited opportunities to develop these skills [2]. A goal of our NSF Innovations in Graduate Education project, entitled Graduate Education in Cyber-Physical Systems Engineering, is to provide support for graduate students to become more effective leaders, communicators, and contributors in a collaborative interdisciplinary team. These teams, composed of graduate students and faculty, are engaged in the co-creation of educational modules about cyber-physical systems (CPS). In this paper, we focus on the ways in which we support teams as they navigate the co-creation process.

Our interdisciplinary teams are involved in projects with two major outcomes. In addition to developing educational modules, the first major outcome, teams also plan a study related to their CPS topics with the goal of writing and presenting an academic paper, the second major outcome. During the 2022-2023 academic year, we have three teams composed of students and faculty from three universities: the University of Massachusetts Lowell (UML), the University of Massachusetts Dartmouth (UMassD), and the University of the District of Columbia (UDC). Each team is conducting research into their own CPS topic, all of which are novel in some way to the members of the team and extend beyond their current research areas. One team is focused on developing wireless sensor networks for bridge health monitoring, the second team is exploring the problem of human balance and postural control, and the third team is addressing the human vestibular system and its role in helping maintain balance. All three topics broadly address the problem in the context of CPS, where the physical system is either an engineered system as in the bridge or the human ear in the case of postural balance topics. The cyber components include the sensors, algorithms, and neurons that enable the physical system to be monitored and controlled.

To help team members accomplish the multiple project requirements of conducting research in a new area, collaborating in an interdisciplinary team, and communicating knowledge to different audiences, we have created a workshop series to support teams as they work towards the outcomes of co-creating educational materials and writing and presenting an academic paper. In section 2.0, we discuss past literature on co-creation and how we are defining this concept in our current work. Section 3.0 summarizes the findings from our first year of the grant. Section 4.0 explains how scaffolds can be used to support co-creation and other collaborative activities. In section 5.0, we explain how we used the workshop series as a scaffold, along with following the tenets of gold standard project-based learning (PjBL). Section 6.0 presents outcomes from our implementation of the workshop series in Fall 2022 based on survey and focus group data. Finally, section 7.0 summarizes our conclusions and section 8.0 outlines the next steps for our work.

2.0 Defining co-creation

Co-creation in educational settings can take many forms. Its general goal is to improve teaching and learning. This can occur when student voice is incorporated into the design of educational materials [3], when students contribute to curriculum design (e.g. [4]), or when students partner with faculty in teaching and research efforts (for examples, see [5]). Co-creation allows for students' growth within their zones of proximal development and also scaffolds learning through collaboration among members with varying levels of technical expertise [6]. It also leads to increased knowledge gain and deep learning due to elaborative processing of curricular materials through collaborative learning [7]. Co-creation results in greater academic engagement, feelings of belonging, and increased confidence and empowerment for students [4] [8]. At the same time, faculty members benefit from increased classroom engagement and improved teaching experiences [5]. On the other hand, Bovill et al. [4] [9] report several challenges that can be experienced during the co-creation process, particularly due to traditional expert-novice power relationships encountered during the initial stages. Faculty have reported concerns about meeting professional requirements, losing pedagogical responsibilities, and navigating institutional norms.

3.0 Our past findings in co-creating educational materials about cyber-physical systems

Our first year of the project (2021-2022) included two teams comprised of engineering faculty and graduate and upper-level undergraduate engineering students [10]. The participants were diverse in terms of gender, ethnicity, and academic background, with representation from two universities and five fields of study. To avoid conflicts of interest, students did not receive course credit or any financial incentive. Participants were given the option to join or decline research and assessment activities.

The teams' curiosity in NASA's design of deployable space structures sparked their desire to study the structure deployment and lifetime management of light-weight flexible material in the physical world. One team (the CPS team) focused on the dynamics of a simple and accessible physical system, a tape-measure, to understand how it buckles during its extension. The second team focused on product lifecycle management (PLM) to understand how airplane manufacturers maintain their planes through their lifecycle. Both teams produced a final product, academic papers that were presented at the ASEE 2022 Northeast Regional Conference (see [11] [12]).

The students had positive feedback about the teamwork process based on the focus groups conducted in Fall 2021 [10]. Their comments included benefits such as good communication and collaboration between team members. They reported learning new skills such as formulas, theories, and academic writing. The Friday afternoon group meetings were appreciated as being encouraging. The most common challenge faced by students was connected with time management, including scheduling meetings and balancing the project with their classes. Faculty interviews from Fall 2021 also indicated difficulties with time management. Students also reported challenges with academic writing, understanding complex derivations, and understanding the objective of the project. When asked for suggestions for improvement, students mentioned both personal changes within their teams, such as staying engaged and

meeting deadlines, and changes in the overall organization of the project, such as time for reflection and clearer connections between the team activities and the learning module they were creating. They also wished they had a better understanding of the project at the beginning.

Based on what we learned during the first year of the project, we made changes to the organization of the project to better explain its goals. We also addressed challenges about and desires to have more opportunities for improving academic writing, gaining technical knowledge, and reflecting on the process. Overall, we worked to support teams through the co-creation process by providing better scaffolds. The benefits of scaffolds are addressed in Section 4.0, and our application of them via a workshop series is addressed in Section 5.0. Section 6.0 discusses the changes we have observed in the current 2022-2023 teams vs. the 2021-2022 teams.

4.0 Supporting the co-creation process through scaffolding

4.1 The benefits of scaffolds

Scaffolds are instructional methods and interventions that are designed to support student learning [13] [14]. They help students bridge the gap between what they already know and what they have yet to learn, thus allowing instructors to simultaneously provide challenging tasks yet make the tasks manageable for learners [15]. Although one-to-one scaffolding is ideal because it is designed for an individual student's needs, scaffolding can be effectively implemented in classroom or other group settings [13]. Scaffolding has been shown to support science learning in classroom settings by teaching procedural and strategic skills [16] such as problem solving, interpreting data, and communicating results [17]. Much of this research on science learning scaffolds has been focused at the high school or beginning undergraduate levels [17] [16] but graduate students would still benefit from the scaffolding of skills that they have limited opportunities to practice [1] [2].

4.2 Incorporating the gold standard PjBL framework

Scaffolding should be designed to create and sustain student motivation, emphasize key points, model expert processes, and provide opportunities for questions and feedback [13]. Project-based learning (PjBL) is an effective way to scaffold learning because it engages students in solving real-world problems that are similar to what professionals work with [18]. PjBL is a method that incorporates key learning environment features [19] along with opportunities for collaboration and scaffolds that support the project process [18]. Several studies have shown that PjBL has led to improvements in students' content knowledge, learning strategies, and motivation [20], but a recent review also suggests that educational research is more focused on the implementation of PjBL rather than its impact on student learning outcomes [20].

PjBL has multiple key features, shown in Figure 1, that make up what the Buck Institute for Education [19] calls gold standard PjBL. The first feature is a driving or challenging question. Throughout the time working on the project, group members should engage in the second key feature, sustained inquiry, which involves asking questions and collecting evidence in relation to

the driving question. The third feature is that the project should be authentic, in that it is connected to real-world topics and has personal relevance for the group members. A fourth feature is that PjBL should incorporate student voice and choice, such as group members choosing project topics and believing that their thoughts and opinions matter to the group. A fifth feature involves reflection on the project experience, including what, how, and why the group is learning through the PjBL process. As group members work on the project, they should also engage in critique and revision of their work, the sixth feature. This can include constructive peer feedback, formative assessment, and periodic revision as group members work towards the seventh feature, a public product that showcases the results of the project.

5.0 Using workshops to support PjBL and the co-creation process

To help team members accomplish the multiple project requirements of conducting research in a new area, collaborating in an interdisciplinary team, and communicating knowledge to different audiences, we created a workshop series to support teams as they work towards the outcomes of co-creating educational materials and writing and presenting an academic paper. Our workshops were influenced by challenges that students reported in the first year of the project regarding academic writing and technical knowledge [10], as well as our desire to bolster collaboration skills. Further, these workshops are aligned with the tenets of gold-standard PjBL [19] and scaffold knowledge and skills [18] that teams need to acquire as they progress through the project. Alignment between the workshops and PjBL is shown in Figure 1.

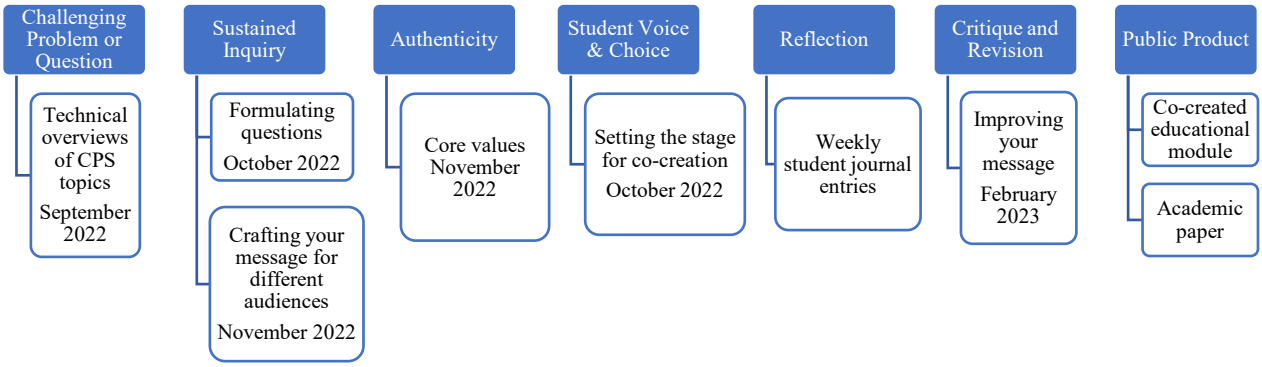

Figure 1: Alignment between workshop topics and gold-standard PjBL.

Nine workshops were presented during the Fall 2022 semester, all of which had the goal of supporting the co-creation process. Our first workshops introduced a challenging problem or question, the first feature of PjBL. Specifically, we presented multiple technical overviews of the cyber-physical system topics of interest -- human postural balance, the vestibular system, and bridge health monitoring with wireless sensors -- that would constitute the eventual co-created educational modules. Other early workshops supported collaboration and community building by introducing ideas of interdisciplinary collaboration, including developing community agreements and recognizing and responding to microaggressions. These early workshops supported the fourth PjBL idea of student voice and choice. We scaffolded sustained inquiry, the second

feature of PjBL, by developing a workshop using techniques from the Right Question Institute [21], and also through a workshop about crafting your message for different audiences using the Message Box tool from COMPASS Science Communication [22]. To support the third PjBL idea of authenticity, we adapted a core values exercise to create a workshop to help students connect personal values to their project topics [23]. A workshop near the end of the semester introduced key concepts for beginning to plan the educational module, one of the public products, including writing learning outcomes, deciding on content to be included, and generating methods for assessing learning.

6.0 Assessment of workshops

During Fall 2022, eleven students participated in the IGE program and workshops: three from UMassD, two from UDC, and six from UML. Seven of these students are women, including two who identify as Middle Eastern (both Iranian), one as South Asian (Indian), one as Black (African), two as White (European and North American ancestry), and one as East Asian (Japanese/Filipino). Three students are White men of European ancestry (2 Portuguese, 1 Polish), and one student is an East Asian man (Korean/Filipino) who was born and grew up in Jamaica.

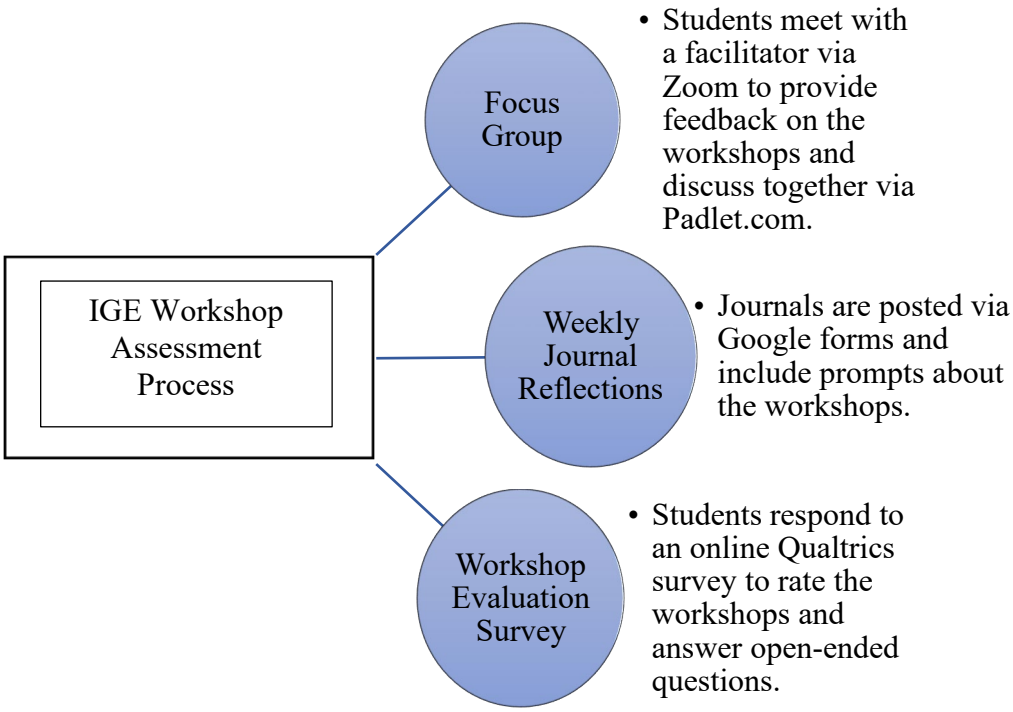

Figure 2: Workshop assessment process

To assess the nine workshops we conducted during Fall 2022, students responded to an online survey including both closed and open-ended questions about the workshops and participated in an end-of-semester focus group that included a series of discussion questions about the project as a whole (see workshop assessment process in Figure 2). Out of eleven students, nine participated

in the online survey and ten participated in the focus group. In late November 2022, we also began asking students to complete weekly online journal entries, commenting on what they learned each week, what they enjoyed, challenges they experienced, and suggestions for improvement. Considering the small number of students and considerable diversity (i.e., the number of students in any particular race/ethnic group is not more than 3), we did not include an intersectional analysis of the assessment data because for the quantitative data, it would not be possible to show statistical significance, and for the qualitative data, we would not be able to reach any meaningful generalizations.

For the online survey, students were asked to rate each of the nine workshops regarding how helpful it was for making progress on their team projects. On a scale of 1 to 5 with 1 representing "very unhelpful" and 5 "very helpful," the mean responses for individual workshops ranged from 3.89 to 4.56, with an overall mean of 4.17 (*SD* = .25) for all 9 workshops. The highest ranked workshop was "Generating Questions and Finding and Reviewing Literature," which had a mean response of 4.56 (*SD* = .68). The lowest ranked workshops, each of which had mean responses of 3.89, were "Overall Project Introduction" (*SD* = .74), "Introduction to Wireless Sensor Networks for Bridge Health Monitoring" (*SD* = 1.10), and "Identifying Core Values" (*SD* = .87).

In an open-ended question on the online survey, students were also asked, "what were the most important things you learned from this semester's workshops?" "Co-creation" was mentioned specifically by two students. In one student's words, "Creating a co-creational work helped me to discuss my ideas with other people with the same or opposite opinion and come up with the solution." While not using the word co-create, two other students' comments about what they learned in the workshops connected strongly with this process: "How to collaborate with a diverse team with different skill sets," and "In spite of not knowing anyone personally in the beginning and meeting in a hybrid manner, [the workshop] was surprisingly interactive and has improved my confidence to express my opinions without the fear of being judged." Students also mentioned "learning how to formulate questions" and "how to craft questions for an audience," as well as "structuring an educational plan" and "how and what to think about when creating an educational module." Finally, "defining the objectives and goals of the projects" was also appreciated as an outcome from the workshops.

In the second weekly online journal, students commented specifically about the workshop on designing an educational module, mentioning that it provided "different perspectives on teaching vs. understanding" and "answered a lot of my questions," which was greatly appreciated because most of them did not have previous experience with making a curriculum.

In the focus group, in response to the question, "have you been able to apply what you learned in the workshops to your projects," some students went into detail about additional specific workshops. One student mentioned that "the question design workshop was very helpful for defining our paper objectives," and "learning how to identify the difference between objectives and outcomes was helpful to begin thinking about different assessments." With regard to the workshop titled "Crafting your Message for your Audience," one student commented: "It helped me understand to look at the project from a different perspective. More specifically, understanding the audience might not be at the same level of experience/knowledge." Students also felt topics and activities in the workshops such as building literature review skills, learning

about the co-creation process, and "gaining confidence to interact and speak with a crowd" were all directly applicable to their project work.

When asked about possible improvements for the workshops, students suggested "more clear objectives" and a stronger focus on technical aspects of the project such as engineering models and providing information about the types of equipment/methods relevant to their project topics. Students also said they would be interested in having future workshops focused on communication, how to plan tasks for co-creation work, writing, doing multipurpose tasks, curriculum building, and summarizing multiple ideas. While no one suggested that we have a future workshop on time management and scheduling meetings, these were the most frequently cited challenges that students are experiencing, as they were during the first year of the project (2021-2022; [17]).

Overall, a comparison of student comments made during the Fall 2021 end-of-semester focus group with those made during the Fall 2022 end-of-semester focus group reveals greater confusion about the project's goals and objectives in 2021 than in 2022. In 2021, several students (3) expressed feeling uncertain about "what they were doing," especially at the start of the project [10]. In 2022, none of the students expressed this uncertainty, but one student commented that they would like to know more about "the importance and effects of our volunteer work."

7.0 Conclusions about supporting co-creation

Past research indicates that co-creation has benefits for students and faculty [4] [5] [7] [8], but also presents challenges [4] [9]. The first year of our grant project indicated that while participants were excited about collaborating and learning new skills, they were also lacking support in transparency about the direction of the project and science process skills [10]. Although we incorporated elements of gold-standard PjBL [19] in the choice of project topics and public products during the first year of the grant, we only had two workshops to support scientific inquiry and writing skills. In the second year of the grant project, we have combined the elements of gold-standard PjBL [18] [19] and best practices in scaffolding [13] to better support our co-creation teams.

There are multiple ways to provide support for the co-creation process. We developed a workshop series to increase technical knowledge, provide opportunities for science process skill development and practice, and promote effective collaboration. As summarized in Section 6.0, student feedback on the workshop series was generally positive, with students appreciating learning about co-creation, getting practice in asking questions, and gaining knowledge about structuring online educational modules. Compared to student comments from focus groups conducted during the first year of the project [10], the current student group was less confused about the overall goals of the project and felt more prepared to carry out their two public products, creating an online educational module and writing and presenting an academic paper.

Overall, this research on integrating co-creation as a model in graduate education for improving technical and professional skills of graduate education has demonstrated that it has potential in

addressing the project goals. For this model to be successful, several requirements are critical. As demonstrated above, teams are more successful when effective scaffolds are employed to support the co-creation process. These scaffolds need to come from supportive and engaged research advisors of graduate students who can work collaboratively with an agreed-upon set of goals and objectives for their students' success in this effort. Throughout the project, mechanisms for maintaining and exercising acquired skills need to be provided. We also believe that it is important to identify the specific product(s) that co-creating teams are to produce early in the process. Further, it is also important to ensure that this product provides sufficient incentive for students to work towards. A challenge expressed by all participants in both years of this grant project is finding time to work within their teams while balancing demands of other classes and research projects. Due to the constraints of the IGE program, students cannot be paid for their participation. But, a graduate credit-based framework for students to commit the time and effort needed for success of PjBL is an option. Our incentives have been supporting students to produce public products which can be added to their CVs, but other co-creation implementations have occurred within the context of a course [4] [9].

8.0 Next steps

During the Spring 2023 semester, we continued to support students as they progress on their projects. As of May 2023, we conducted three workshops to support students as they work on one of their final products, writing and presenting an academic paper. The first workshop was focused on tools to organize the literature review, such as summary tables and synthesis matrices (cf. [18]). The second workshop revisited the Message Box [22] to help teams think of their audience for the academic paper, and also provided an opportunity for peer review, which allows for critique and revision of their work, the sixth feature of gold-standard PjBL [19]. The third workshop focused on effectively presenting research via spoken presentations and posters. Two of the teams have submitted papers to the 2023 ASEE conference, and the third team is submitting a paper to *IEEE Sensors Letters* and will submit to the IEEE International Symposium on Technologies for Homeland Security in the summer.

We also developed additional workshops to further support teams' construction of their respective educational modules. An overview workshop about designing online educational modules was delivered in December 2022. Three follow-up workshops focusing on presenting content, writing learning outcomes, and assessing learning were conducted in February and March 2023. In addition, to further promote collaboration and community building, we conducted a workshop about effective collaboration in February 2023 and a workshop about intercultural communication and collaboration in March 2023.

To assess the effectiveness of these workshops, we again conducted a focus group and surveyed students near the end of the spring semester. We also continued to collect weekly journal entries that asked students to discuss what they have learned, what they have enjoyed, what they have found to be challenging, and their other thoughts. As this year's project comes to a close, analyzing these journal entries along with the survey and end-of-semester focus group data will provide further understanding of student perspectives regarding the co-creation process.

Beyond the data collected through focus groups and surveys about the workshops, we have also planned a quantitative analysis of what students have learned about their CPS topics. Specifically, after teams were formed but before embarking on the project, students were asked to write a one-page summary of their project topic based on an assigned reading and their own research. Students were instructed that these summaries should be written for a non-specialist audience, such as readers of a newspaper article or Wikipedia entry. This writing exercise will be repeated at the end of the semester, once students have largely completed the two outcomes for their projects: developing an educational module and writing and presenting an academic paper. Their writing will be analyzed for use of technical terms, clear examples, and overall clarity.

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