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A Scaffolded Approach to Active Learning in the Graduate Classroom

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A Three-Pronged Approach to Support Active Learning in the Graduate Classroom

Abstract:

Many graduate courses are the ideal size for active learning to take place, and although the literature has shown that students may be resistant to student-centered approaches, we propose that active learning can be effectively introduced with appropriate supports. To build trust within the class and reduce barriers to student participation, a three-pronged approach towards active learning was implemented: not-for-credit socialization activities including a field trip and snack breaks, game-based student response systems including Kahoot and Pear Deck, and small group collaborations. Here, we use an end-of-course survey to understand student perceptions of this approach in a graduate Structure and Diffraction course of 13 students. Overall, the results of the student survey provide some evidence to support the use of multiple strategies to facilitate a sense of community, comfort with active participation and knowledge of course material. However, there was variation in student perceptions by activity (socialization, GSRS, small group collaboration) and by gender. Given their ease of use and potential to impact community building, learning, and comfort with active participation, a multi-pronged approach merits consideration in all graduate courses.

Introduction

Studies of active learning in both graduate and undergraduate STEM courses have demonstrated a reduction of failure rates [1], [2], increased academic performance [3], [4], increased course satisfaction [5], and narrowed achievement gaps for students from minoritized groups in STEM [2], [6]. Despite these positive outcomes, instructors cite several barriers to the use of active learning in their courses including lack of time to prepare activities [7], lack of formal training on how to implement active learning [8], classroom setups that are not conducive to active learning [9], and student resistance to active learning at both the graduate and undergraduate level [10]–[12].

To reduce resistance to active learning, Finelli et al. recommend that instructors explain why and how the active learning activities will be carried out, and provide appropriate support for students as they engage in these activities [13]. Tharayil et al. found that setting expectations for active learning activities and creating an encouraging environment contributed to implementation success [11]. Sense of belonging has also been identified as a precursor for student engagement. Zumbrunn et al found that college students who reported a greater sense of belonging in the classroom also reported a greater sense of motivation and level of engagement in class [14]. A recent study of a graduate biology course found that implementing a varied set of community building activities during class time mitigated impostor syndrome and fostered a sense of professional identity for students [15].

In this paper, we describe a three-pronged approach to facilitate students' sense of community, comfort with actively participating in a graduate class, and knowledge of the course material, which implements the aforementioned evidence-based supports cited in the literature. First, informal socialization opportunities (e.g., field trip, in-class snack breaks) provided opportunities for students to get to know each other. Since active learning can require students to take risks and speak up, we hypothesize that experiences that contribute towards community building will also help students feel more comfortable with active learning. Second, Game-based Student Response Systems (GSRSs) such as Kahoot and Pear Deck provided a low-stakes entry into active learning and a check on understanding. We expect GSRSs to increase students' confidence in their knowledge and therefore help them feel more comfortable participating in class. Third, small group collaboration required students to work together and create knowledge independently from the instructor. We expect small group collaborations to contribute to both student learning and a sense of community.

An end-of-course-survey asked students the extent to which socialization activities, GSRSs, and small group problem solving impacted their sense of community, comfort level engaging in class, and learning the course material. Here, we address the following questions for the entire group and by gender:

> Which of the activities contributed to students' sense of community?
> In what ways did the small group collaboration and GSRSs impact students' comfort levels with active participation?
> To what extent did active learning activities (field trip, GSRSs, and small group problem solving) contribute to their understanding of the content?

Methodology

This study took place within a graduate Structure and Diffraction course at a small (~4,000 undergraduates and ~4,000 graduate students) engineering college on the East Coast. Students in the Masters or PhD program in Materials Science and Engineering take Structure and Diffraction as one of their four required core courses (out of five possible options). Students learn how X-rays are used to determine the structures of materials that take on a crystalline form such as metals and salts. Topics include crystal systems, crystallographic computations, point groups and space groups, collection and interpretation of X-ray diffraction spectra, and interpretation of electron diffraction patterns.

The course met for 2.5 hours one evening per week for 15 weeks, with a 10 minute break approximately halfway through each 2.5 hour session. A midterm exam was administered during week 8 and a final exam was administered during week 15. To facilitate students' sense of community, knowledge of the course material, and comfort with actively participating in class, instructor-led lectures were integrated with: (1) voluntary and not for credit opportunities to socialize, (2) GSRSs including Kahoot and Pear Deck, and (3) small group collaboration.

Socialization activities aimed to improve students' sense of community within the class. Nevertheless, these activities were voluntary and not for credit. To encourage students to spend some time during the 10-minute break getting to know their classmates, they were offered instructor-provided snacks about half the time. During week 5 of the course, the instructor organized an optional Sunday field trip to the Hall of Gems and Minerals at the American Museum of Natural History that was directly related to the content covered in the course. The date of the field trip was chosen based on a poll of student availability and was free of charge for students. Eight out of 13 students attended the Sunday field trip.

Game-based Student Response Systems (GSRSs) Kahoot and Pear Deck were implemented to: (1) elicit student responses to questions about concepts covered in class and (2) provide real-time feedback on student comprehension to both the instructor and the students. Kahoot is an online tool to create and host interactive quizzes [16]. Students enter a username (their real name or a nickname) and answer questions from their mobile device or laptop. Each question has a time limit, and when the time is up, the correct answer is displayed, and the instructor reviews the question with the class. Pear Deck is a slide-based interactive learning tool that allows instructors to create and integrate interactive activities on each slide during a lecture [17]. For example, students could be asked to draw a specific crystal structure on a certain slide. The instructor can then anonymously project all the drawings to discuss the correct answer. Across both GSRSs, the instructor facilitated a discussion once all the students had entered their responses. Students could "participate" anonymously and check their understanding without needing to speak up. GSRSs aimed to contribute to a sense of community, increase students' comfort levels with active learning, and improve their knowledge of the course material.

Small Group Collaborations of 2-3 students were used to promote learning and a sense of community. Eleven out of the 14 weeks included some small group collaboration, but the nature and duration of the collaboration changed over time. At the beginning of the course, small group work involved brief (15 minute) hands-on activities such as using lasers and diffraction gratings to exemplify the relationship between the structure of a material and its diffraction pattern; the use of marbles to demonstrate hexagonal close packing; and the use of molecular modeling kits to demonstrate the application of point groups to molecular structures. Small group work then transitioned into 15–20-minute group problem solving, in which students worked on a few problems together and then explained their work to the class. After the midpoint of the semester, 4 of the remaining 7 sessions had students working in small groups for more than ½ of the class time on case studies, during which students were given diffraction spectra to analyze in groups and directed questions to guide their analysis followed by a class discussion about these spectra. Small group collaborations aimed to not only create a sense of community, but also to improve students' content knowledge.

To assess student perceptions of the impact of various activities (socialization, GSRSs, small group collaboration) on their sense of community, comfort with actively participating in class, and knowledge of the course material, a five-minute online survey was administered during the last week of the course and was available to students from 12/15/2022 to 1/6/2023. IRB approval was obtained, under Protocol No. 2023-027 (N), and students were asked to provide active consent after reading about the purpose of the survey and the use of the data for research purposes.

In the survey, students rated the extent to which they agreed or disagreed with statements about course activities using a 5-point Likert Scale from 1 = strongly disagree to 5 = strongly agree. As appropriate, for each activity, students were asked to rate statements about community building (e.g., helped me connect with classmates), comfort participating in class (e.g., helped me feel more comfortable engaging in a class discussion), and knowledge of the course material (e.g., helped me feel more confident in my knowledge). Demographic information was also requested including semester at this university, race/ethnicity, international student status, and gender identity with the following options: a) male, b) female, c) non-binary, d) self-identify (students could type their response), e) decline to identify.

Sample. This study was conducted in the Fall 2022 semester, during which 12 students enrolled in the course for credit and 1 student audited the course (the survey was made available to all 13 participants). Response rate was 9/13 (70%). Of the 9 respondents, 4 identified as female, 4 male, and 1 declined to identify. Therefore, the sample size is 8 for all gender analyses. Further, although 8 students participated in the field trip, 6/8 responded to the survey (See table 1).

Table 1. Participation and response rates by activity.

Activity	Participants	Survey Respondents	Response Rate
Field Trip	8	6	75%
Game Based Student Response Systems	13	9	70%
Small Group Collaborations	13	9	70%

Results and Discussion

We first discuss student perceptions of the extent to which the optional socialization activities, GSRSs, and small group problem solving promoted a sense of community in the class. Then, we examine student perceptions of whether GSRSs, small group problem solving, and the field trip acted as a catalyst to encourage students to participate in class. Finally, we examine whether students felt that each active learning activity (field trip, GSRSs, and group problem solving) helped them to understand the course content. For each outcome of interest (sense of community, comfort with active participation, knowledge of course material) results are presented by activity for the total number of respondents and by gender given the large amount of literature on gender differences in STEM. Analysis by other potentially important demographic factors (e.g., years at this university, international student status, race/ethnicity) is not reported because of inadequate sample sizes by subgroups.

Community Building

All respondents were either positive or neutral towards the impact of Kahoot, Pear Deck, group problem solving, and the field trip on their sense of class community (Figure 1a). A higher percentage of students were neutral for Kahoot than for the other activities, perhaps because of its competitive nature (a scoreboard is displayed in between each question and at the end of the game). In contrast, a higher percentage of students strongly agreed or agreed for group problem solving than for other activities– this activity necessitated interaction between students, likely contributing to a sense of community. More than 80% of the students felt positively towards the field trip (Figure 1b), perhaps because this activity had no assignment attached. While the content of the field trip was related to the course learning objectives, the purpose was for students to have fun and get to know each other. Pear Deck was not competitive and allowed students to type free response answers, which resulted in some shared humor and feelings of community.

Female students responded more positively than male students in terms of the effect of Kahoot and the field trip on their sense of community (Figure 1b). Notably, all female students “strongly agreed” that the field trip contributed to their sense of community. However, a higher percentage of male students than female students “strongly agreed” that group problem solving contributed to their sense of community (Figure 1b).

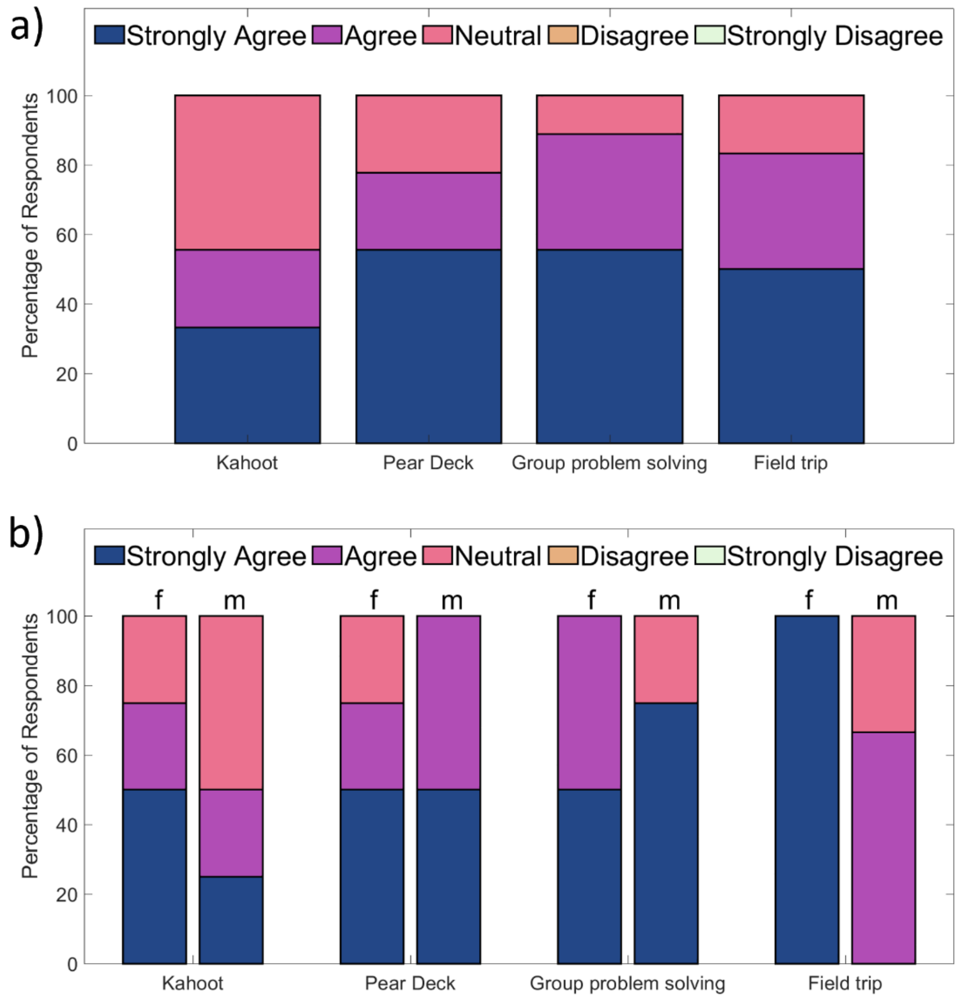

Figure 1: This activity helped me feel a sense of community among my classmates. (a) All responses. (b) Responses by gender.

We asked students to what extent they agreed or disagreed that the snack break, field trip, and group problem solving helped them connect with their classmates (Figure 2). These three activities were chosen for this analysis because the snack break and field trip were implemented for the purpose of helping students form connections with each other, and group problem solving required interaction between students.

The break may not have had an impact on students' sense of community (Figure 2a), as more than 50% indicated they neither agree nor disagree that the break helped them form connections with their classmates, with one student even disagreeing. There are a number of activities students may need to accomplish during the break such as checking their phones, using the bathroom, and getting up and stretching, so perhaps ten minutes is not long enough to accomplish these urgent tasks as well as talk to other students in the class. Or, perhaps students are simply exhausted in the evening after 70 minutes of class with another 70 minutes ahead of them.

More than 80% of students "strongly agree" or "agree" that group problem solving and the field trip helped them form connections with classmates, suggesting that more focused interactions between students lead to increased connections. All female respondents strongly agreed that the field trip and group problem solving helped them to form connections with their classmates.

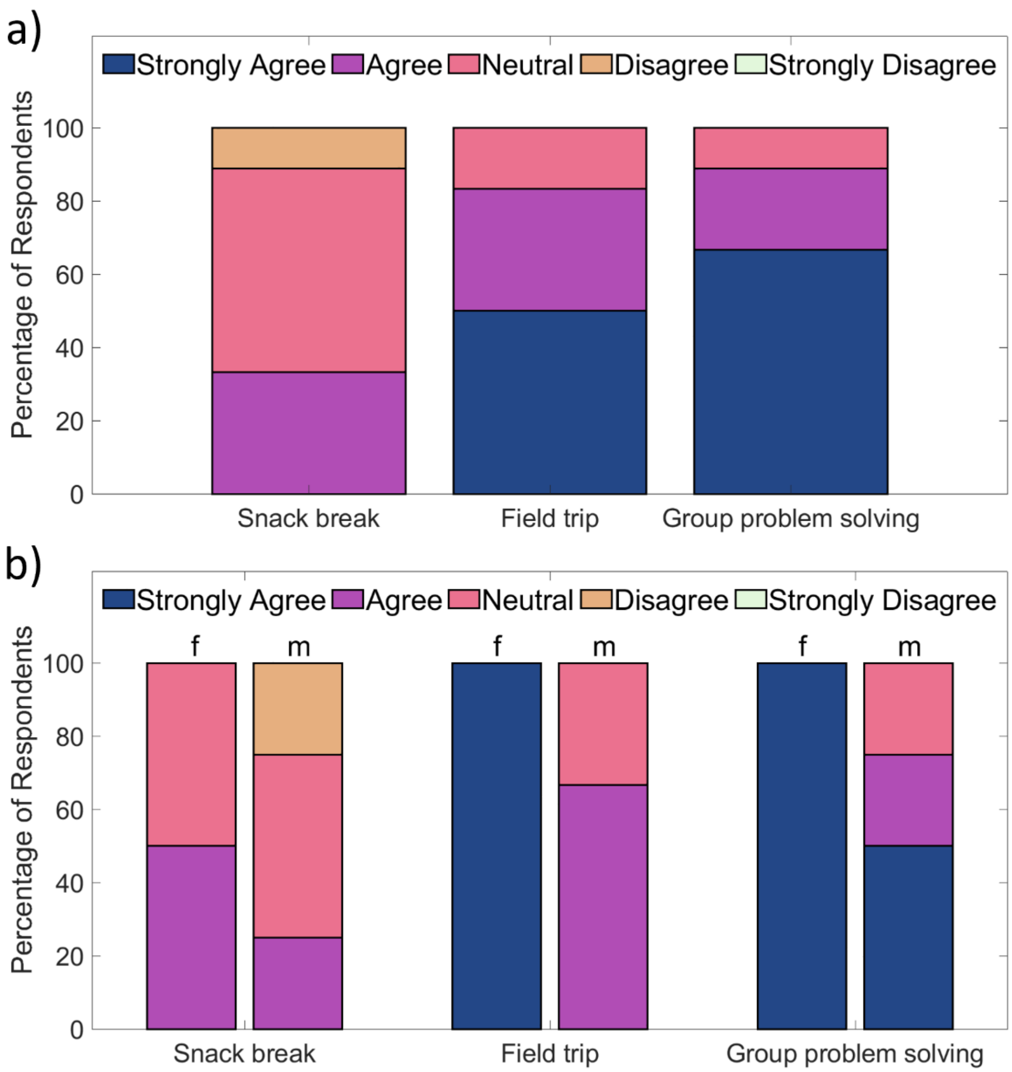

Figure 2: This activity helped me form connections with my classmates. (a) All responses. (b) Responses by gender.

As an additional metric of community building, students were asked to what extent they agreed or disagreed that participating in the field trip and small group problem solving made them more likely to reach out to their classmates for help with the content. Seventy five percent of respondents either “strongly agreed” or “agreed” that group problem solving made them more likely to reach out to their classmates for help, compared to 65% of respondents for the field trip. We again see an indication that more focused and structured interactions among students lead to increased connections.

Comfort with Active Participation

It was hypothesized that GSRSs would serve as low-barrier-to-participation forms of active learning that would ease students into the idea of class participation and make them more likely to subsequently engage in activities that required class discussions and problem solving. The two GSRSs used, Kahoot and Pear Deck, are both anonymous forms of participation, so we predicted that students would increase their confidence using GSRSs and ultimately feel more comfortable speaking up in class. To compare the impacts of Kahoot, Pear Deck, group problem solving, and the field trip on students’ likelihood to actively participate in class, students were asked the extent to which they agreed or disagreed with the following statements:

> This activity helped me feel more comfortable engaging in a class discussion.
> This activity helped me feel more comfortable solving problems in small groups.

Group problem solving was left out of the second question, since it is a requirement of the activity.

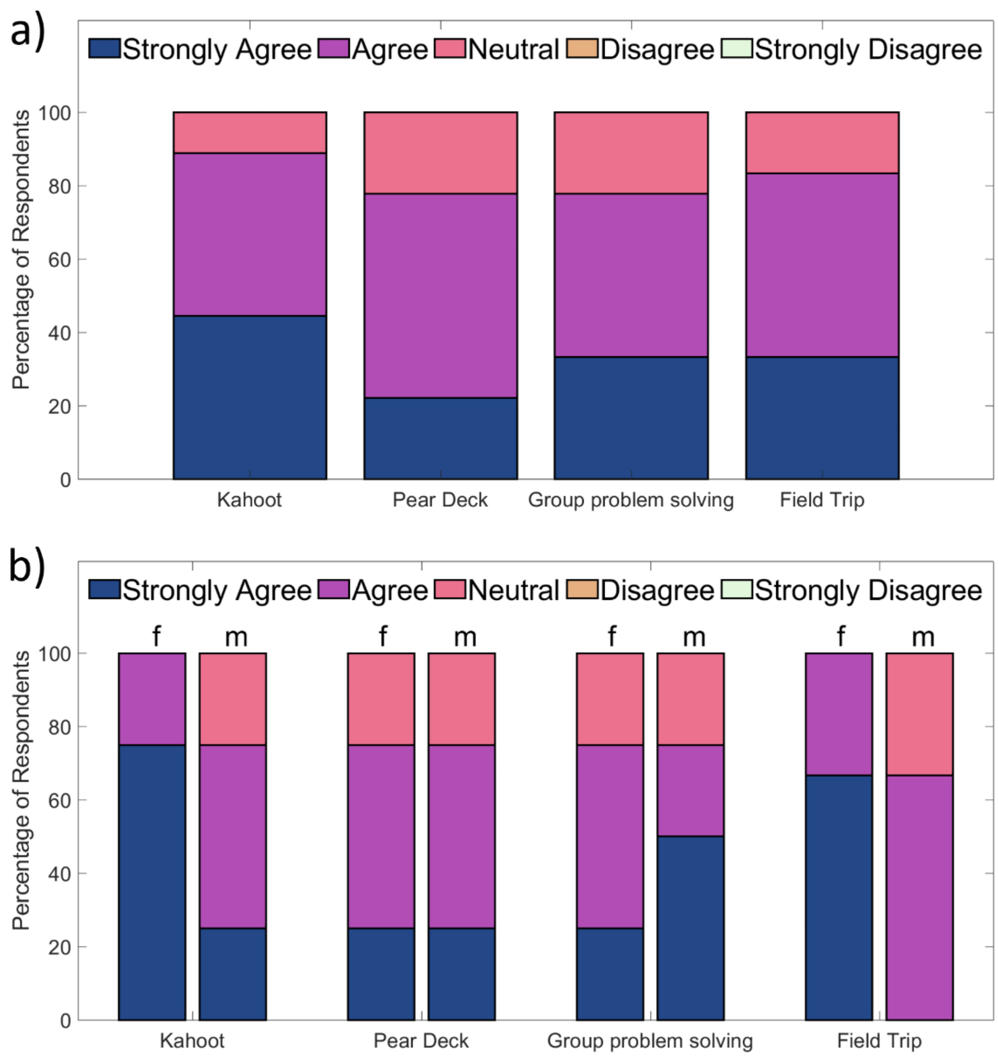

Figure 3: This activity helped me feel more comfortable engaging in a class discussion. (a) All responses. (b) Responses by gender.

Figure 3 shows the extent to which students agreed or disagreed that each activity "helped me feel more comfortable engaging in a class discussion." Of the respondents, 80% or more "strongly agreed" or "agreed" that each of the activities contributed to their comfort in a class discussion. For Kahoot, that number rose to 90%. Kahoot provides immediate feedback on whether the student's submitted answer was correct, which perhaps made them feel comfortable engaging in a class discussion given that they knew they had responded correctly. Like the trend shown in Figure 1b, female students responded more positively to Kahoot and the field trip than male students did. However, male students were more positive towards group problem solving, also in alignment with the data in Figure 1b.

More than 75% of students "strongly agreed" and "agreed" that Kahoot and Pear Deck increased their comfort levels solving problems in class whereas less than 40% did so for the field trip (Figure 4a), which is expected because there was no assessment attached to the field trip. The distribution of responses was the same for male and female students for this question.

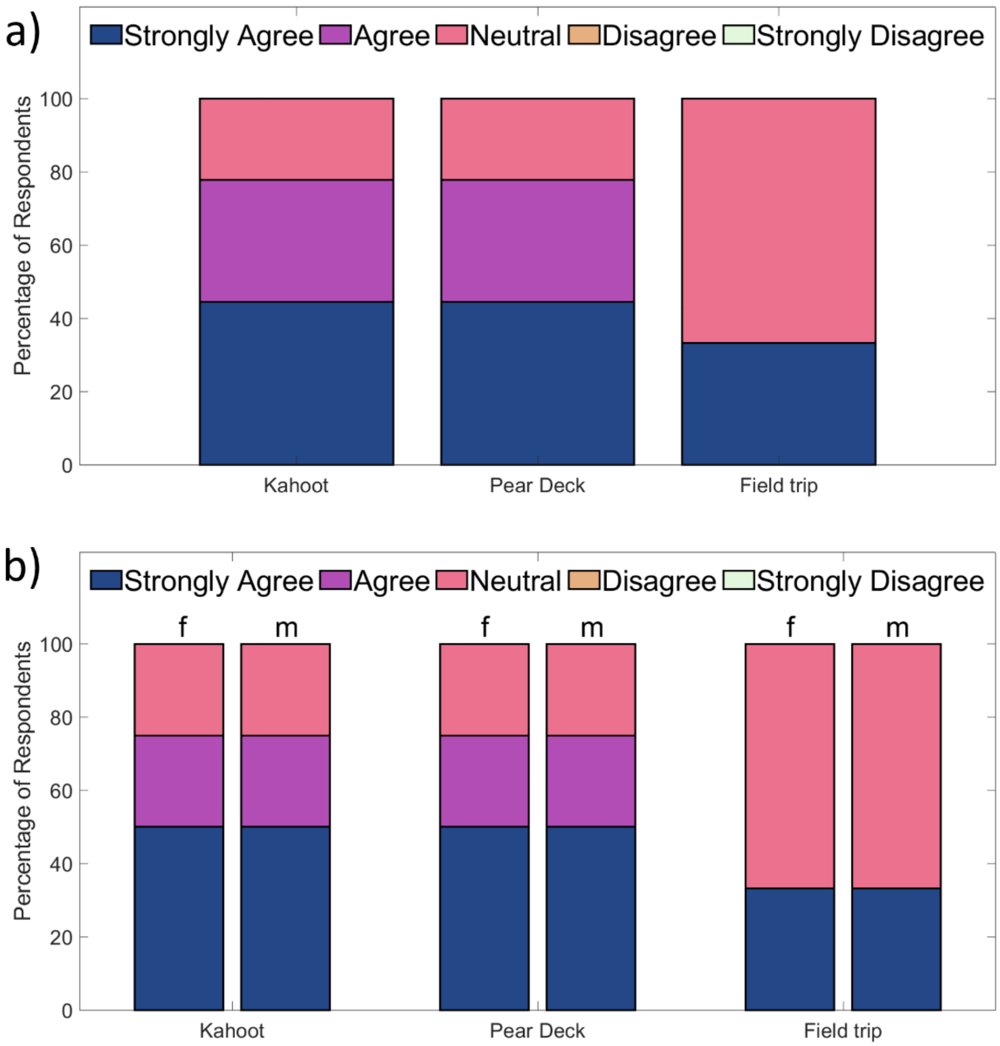

Figure 4: This activity helped me feel more comfortable solving problems in groups. (a) All responses. (b) Responses by gender.

Knowledge of Course Material

To determine the impact of each active learning activity on students' perceptions of their understanding of the course content, we asked students to rate the following statements:

This activity helped me learn the course material.
This activity helped me feel more confident in my knowledge.

Eighty percent of respondents strongly agreed or agreed that the field trip helped them learn the course material (Figure 5). Although the content was not directly assessed, the field trip did provide an opportunity for students to link some of the museum displays to the topics they had covered in class. Consistent with other findings reported above, female students perceived the field trip as contributing to their knowledge more so than other activities, not so for male students.

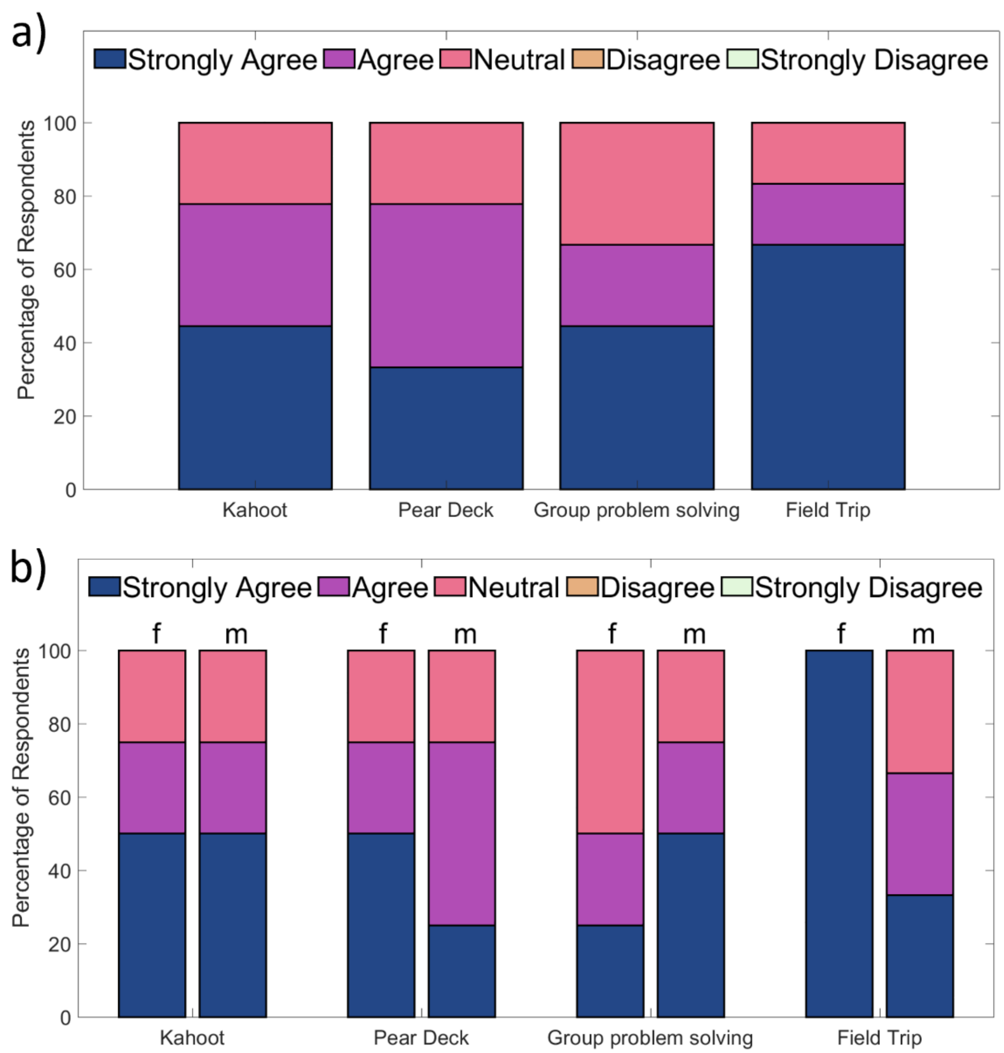

Figure 5: This activity helped me learn the course material. (a) All responses. (b) Responses by gender.

For all activities except group problem solving, students were positive or neutral towards the activity helping them feel more confident in their knowledge (Figure 6a). Perhaps students who struggled with the content felt discouraged by peers who appeared to solve the problems more easily. Female students again responded more positively to the field trip than male students, and more male students “strongly agreed” that group problem solving helped them feel more confident in their knowledge (Figure 6b). Female students responded more positively than male students to both Kahoot and Pear Deck as well (Figure 6b).

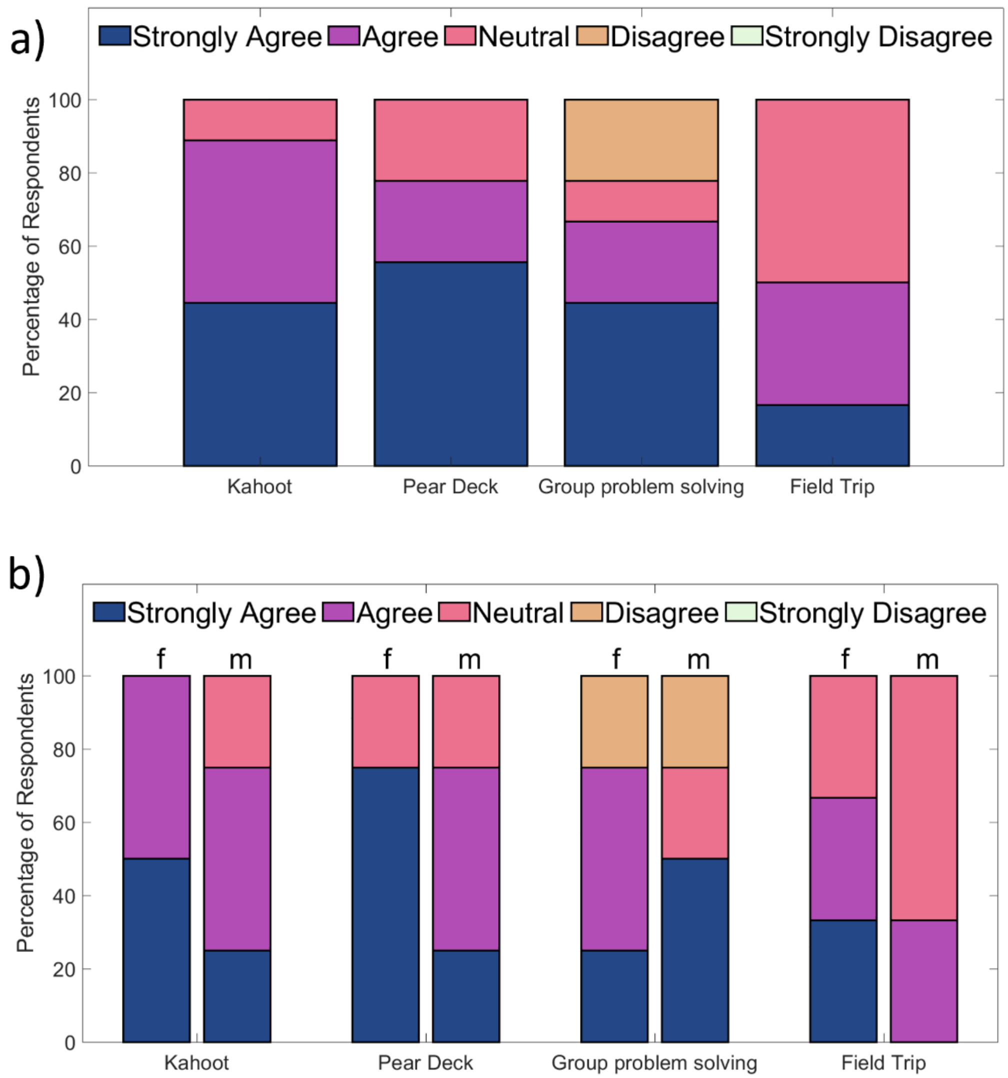

Figure 6: This activity helped me feel more confident in my knowledge. (a) All responses. (b) Responses by gender.

Conclusions

Overall, the results of the student survey provide some evidence to support the use of multiple strategies (or activities) to facilitate a sense of community, comfort with active participation, and knowledge of course material. However, perceptions varied by activity (socialization, GSRS, small group collaboration) and by gender. Snack breaks did not have a noticeable impact on students' sense of community. Perhaps increasing the length of time of the break or adding structure to the break would increase its impact as a community building activity, but our results show that there are content-focused methods that act as better community building strategies. Field trips seem to be a good tool for building community and knowledge. Their effectiveness in encouraging students to engage in active learning could perhaps be increased if there was an assignment attached to the field trip experience to help students assess their own understanding of the content. Responses seem to confirm our hypothesis that Kahoot helps students feel more comfortable with both speaking up in class and participating in problem solving, perhaps because they can generate their answer anonymously and immediately receive feedback. In contrast, perceptions of Pear Deck were mixed – a lower percentage of students strongly agreed that Pear Deck made them feel more comfortable engaging in a class discussion and helped them learn the material relative to the other activities, but more students strongly agreed that Pear Deck helped them feel more confident in their knowledge. While Kahoot only allows for multiple choice questions, Pear Deck allows for free responses and drawings, so the types of questions presented on Pear Deck could have been perceived to be more difficult than the Kahoot questions. Perhaps students were responding to the level of difficulty of questions when considering Pear Deck.

Variations in perceptions by gender suggest that female students perceived the field trip more positively than did male students in terms of its impact on their sense of community, connections with classmates, comfort engaging in a class discussion, learning the material, and confidence in their knowledge. However, male students perceived group problem solving more positively than female students with respect to helping them feel more comfortable engaging in a class discussion, learning the material, and feeling more confident in their knowledge. Female students responded more positively than male students to nearly every question regarding community building except for whether group problem solving helped students feel a sense of community.

All activities described in this study are easy to integrate into lectures, and given their potential impact on community building, learning, and comfort with active participation, they merit consideration in all graduate courses. Consistent with other studies of a graduate level course, small sample size limits the generalizability of the findings and precludes disentangling factors which may impact student responses such as gender, time at this university, and international student status. We plan to continue to collect data during each semester in which the course is offered. In future iterations of the course, student performance on course assessments can be correlated with implementations of active learning and community building strategies.

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