Incorporating Teamwork Elements into a Course to Improve Learning Outcomes

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Abstract

The use of teamwork in courses has many benefits for students beyond simply the development of collaboration skills. When compared to individual learning alone, teamwork can support deeper understanding of the material, a more interactive class environment, and improved knowledge retention. Therefore, the senior-level design course Coastal Engineering was modified in 2022 with the addition of teamwork elements in two course components: homework assignments and in-class quizzes. The homework assignments were completed in small groups, with teams submitting a joint homework solution. The objective of assigning homework to groups rather than individuals was to have students work together and discuss the problems and course concepts. To discourage "divide and conquer" approaches and hold students accountable for understanding the full homework assignment, students were required to participate in one-on-one homework chats with an instructor. During the chats, students were asked to briefly explain the concepts behind an instructor-selected part of the homework assignment. Teamwork was also added to in-class quizzes, focused on conceptual type questions. The in-class quizzes were closed-book and closed-note, but "open-classmate," meaning the students were free to interact with other students in the class in any manner they chose prior to submitting their own quiz solution.

Multiple assessments tracked how effectively students were working on teams. The assessments included surveys, administered to students after teamwork activities, to identify both perceived benefits of teamwork and common issues that the students had encountered. Survey responses indicated that team activities greatly enhanced opportunities for developing skills for working cooperatively; students learned to listen to each other's opinions to solve problems together but were also held individually accountable for understanding the team's final product through the one-on-one homework chats. After the first two surveys, common teamwork issues reported in the responses were addressed with an in-class session on maximizing team effectiveness. Additionally, direct assessments were conducted by comparing student performance on individually-completed conceptual exam questions between the 2022 cohort and prior cohorts that took the class without the new teamwork elements. The 2022 cohort showed significant improvement in mastery of the course concepts relative to cohorts from several previous semesters.

Introduction and Literature Review

The need for engineering undergraduates to learn performance skills – particularly the ability to function effectively on a team – has been well documented, most notably in the National Academy of Engineering's 2004 publication of *The engineer of 2020: Visions of engineering in the new century* (2004). Since the Engineer of 2020 was published, leadership programs for undergraduate students have proliferated (Compton-Young et al., 2010; Donald & Jamieson, 2022), numerous pedagogical strategies have been discussed in the literature and at academic conferences, and there has been formal acknowledgement of the importance of performance skills through ABET requirements and the ASCE's Code of Ethics. See Chowdhury and Murzi's (2019) literature review for a more thorough account of the historical calls and strategies to incorporate performance skills education into the engineering curriculum.

Engineering educators and industry employers agree that graduates need communication and interpersonal skills, collaborative and conflict management skills, and a cultural understanding (Seat et al., 2001) to function effectively as an engineer. What has also been agreed upon is that simply having a leadership program and/or incorporating teamwork into classes is not enough to sufficiently teach and develop these skills. Vik (2001) addressed this concern when she discussed the classic "sink or swim" (Vik, 2001, p. 112) method often utilized by faculty – forming teams, stepping back, and expecting performance to follow. Lingard and Barkataki (2011) went further by identifying specific team dynamics issues that can stem from little guidance or interaction. In their systematic review of teamwork pedagogy in higher education, Riebe, Girardi, and Whitsed (2016) acknowledge the challenges faculty face in finding the most effective strategies and pedagogical tools across a sea of disciplines, student and faculty variables, and organizational assumptions and contexts. These phenomena have contributed to a continued gap between graduate preparation and employer-perceived readiness (Ellis et al., 2018).

The coastal engineering class presents an excellent opportunity to close that gap. Most students in the course are senior undergrads or graduate students, nearing their entry (or re-entry) into their professional careers, so the authors decided to hone in on the professional aspect of collaboration, as a way to move from simple team projects to what Ellis, Han, and Pardo would refer to as "productive collaboration" (2018, p. 130). When developing the course interventions discussed in this paper, the authors focused less on which skills needed to be taught, and more on shifting the context from undergraduate education to a setting more akin to professional environments. The aforementioned gap between graduate preparation and employee readiness is exacerbated by the difference in organizational and learning environments graduates experience upon entering the workforce (Lingard & Barkataki, 2011; Lutz & Paretti, 2021). The course interventions described in this paper were designed to better simulate a real-world, professional environment.

The team effectiveness session was intended to provide experiential team exercises, which have been shown as an effective teaching method for teaming education (Seat & Lord, 1998). These exercises centered around team structuring, building a culture of psychological safety, and conflict management, further aligning with students' development of their professional identities and responsibilities. The team homework assignment was designed to have students working collaboratively on a single assignment, and it required them to review each other's work and provide feedback. This not only helps increase engagement and learning (Mora et al., 2020), but also better prepares them for the engineering profession. To complement the students' peers' feedback, but to also ensure ample mentoring was still being offered (Vik, 2001) the instructors held one-on-one homework chats. Perhaps the most professional-like intervention was the introduction of open-class quizzes. Students were free to confer with any classmates during the quizzes, simulating a professional environment and allowing the students to focus on the task at hand without the ceremony of a formal presentation (Lingard & Barkataki, 2011). The authors were also influenced by Segalas, Ferrer-Balas, & Mulder's (2010) work in identifying community learning as an effective pedagogical method for teaching sustainable development, and Chen, Hernandez, & Dong's (2015) paper on collaborative projects leading to increased engagement, interpersonal skills and professional identity development, and deeper learning.

Methods

Course Structure

"Coastal Engineering" is a three-credit senior technical elective that has been taught every spring semester with the same instructor from 2014 to 2023. It is cross-listed with a graduate version of the course and over the past several years has had a robust total enrollment of thirty to forty students, typically two-thirds undergraduate and one-third graduate. The graduate students are required to complete several additional assignments individually. For all students, the course introduces basic coastal engineering topics, including wave mechanics, nearshore hydrodynamics, large-scale hydrodynamics, sediment transport, shoreline change, wave forces, and coastal structures. The course also includes a multi-week team project focused on developing a shoreline protection plan.

Changes to the course aimed at increasing teamwork elements were implemented in Spring 2022. In this semester, student enrollment was 36, and the instructor was joined by a co-instructor participating in a teaching certificate program who assisted with the course modifications. The purpose of the changes was two-fold: first, to help the students develop teamwork effectiveness skills, and second, to support deeper learning of the material through active team interactions. The course has traditionally been taught in the standard lecture format with individually-completed assessments: about five homework assignments, closed-book quizzes with conceptual questions, and open-book exams with problem solving questions. In the 2022 revised version of the course, homework assignments were instead completed in small teams and supplemented with individual "homework chats." Individual quizzes were replaced with "open-classmate" format quizzes. In all semesters including 2022, exams were completed individually.

Group Homework Assignments

For each of the first three homework assignments, students were randomly placed in teams of three to four. The teams were re-randomized for each homework assignment. When determining teams, there was no distinction between students enrolled in the undergraduate versus graduate versions of the course, so the resulting teams were mixed. The teams were given one week to complete each homework assignment, consisting of two to four problems. The problems themselves contained multiple parts and a mix of problem-solving and open-ended discussion. Students were instructed to work as a team on the full assignment and submit a single written solution to be graded for accuracy. Every member of the team received the same grade on the submitted solution.

After the first three homework assignments, students were allowed to select their own teams. Students who needed help finding team members were, upon request, placed into a team by the instructor. All students stayed with these teams to solve the final two homework assignments and the term project. As before, they submitted a single solution for each assignment.

Individual Homework Chats

To hold students accountable for understanding the full homework assignment and discourage "divide and conquer" approaches, students were required to participate individually in

a “homework chat” for each assignment. The chats were five-minute one-on-one Zoom calls with either the instructor or co-instructor aimed at assessing conceptual understanding a completed homework assignment. The chats were conducted during four different time blocks, each spanning 45 to 60 minutes, over the two days following assignment submission. An online signup sheet was provided for students to schedule their own five-minute time slots, with a few more slots than students to ensure availability. If a student missed the time slot they had scheduled, they were allowed to sign up for a new time slot, but with a 50% chat score deduction. To maintain smooth and timely transitions between student chats, a single Zoom call was used with a waiting room so that each student could join the call early and wait until the instructor admitted them for their chat. At the beginning of each chat, the instructor asked the student to describe their solution process for one of the homework problems, selected randomly by the instructor and varying student to student. Students were allowed access to their submitted solution during the chat, and the vast majority chose to share it with the instructor via screen-sharing during the chat to facilitate their explanation. Discussion during the chats centered around the problem-solving process and the interpretation of the results rather than the mathematical solution. If a student’s solution contained errors, the instructor asked leading questions to give them an opportunity to identify and begin correcting their mistakes. A full chat score could be earned if they were able to do so and/or demonstrate full mastery of the relevant concepts. Each homework chat was worth ten points, assigned according to the rubric in Table 1 and was included as 10% of the overall course grade.

Table 1: Rubric for grading homework chat participation.

0 points	Student did not participate in the homework chat.
5 points	Student showed up for the chat but was unprepared and unable to demonstrate understanding of the material.
7 points	Student had some elements of the solution correct but had some significant misunderstanding of fundamental concepts.
9 points	Student had the majority of the solution correct. They needed some prompting, but they were able to verbalize the majority of the concepts correctly.
10 points	Student correctly explained the solution. They were able to demonstrate full mastery of the concepts, even if some prompting was required.

To help students prepare for the expectations of the homework chats, the instructor and co-instructor performed a series of mock chats for the class at the beginning of the semester. They acted out four example chats illustrating different levels of student performance. After each example, the students were asked to vote by hand-raising on the score they thought the example student should receive. Agreement between the results of the students’ voting and the intended score for each example demonstrated that students understood the expectations.

Open-Classmate Quizzes

There were several unannounced ten- to fifteen-minutes quizzes throughout the semester. They consisted of conceptual questions using multiple choice and short answer formats. The quizzes were closed-book and closed-note, but "open-classmate," meaning the students were free to collaborate with anyone in the classroom during the duration of the quiz. At the end of the quiz, all students were required to turn in their own solution to be graded for accuracy.

Assessment

After each of the first four team homework assignments, students were asked to complete a short online homework survey regarding their experience working with their team. The survey questions spanned the following topics: the team's strategy for completing the homework, how the team performed with respect to student expectations, the level of engagement of team members, student satisfaction with the team, conflicts encountered, and the impact of the teamwork on student understanding of course content. The surveys also asked students to provide a short description of their teamwork experience and their satisfaction or dissatisfaction with the team. Students earned a quiz grade for completing each survey, and most students participated with response rates of 100%, 97%, 92%, and 97% for the four surveys. At the end of the semester, a fifth and final survey was issued that used five-point Likert scale questions to assess which aspects of the course students felt best supported their learning.

The effectiveness of teamwork was directly assessed through individual student performance on closed-book conceptual exam questions. These exam questions consisted of multiple choice, short answer, and simple sketching formats to assess the conceptual understanding of course topics. Student scores on these questions were compared between the 2022 semester and preceding semesters without the new teamwork elements.

Results

Group Homework and Homework Chats

For the first three homework assignments, teams were assigned but students could decide how they wanted to work together to complete the assignments. The homework survey results describe how teams functioned and indicate there were three predominate strategies: complete fully collaboratively, complete individually then compare, or separate and consolidate. The distribution of strategies by homework assignment is shown in Table 2. Survey responses describe that teams choosing to do the homework fully collaboratively scheduled a specific time to meet (either in person or virtually) and solved the problems together. For teams using this strategy, some students reviewed the assignment on their own before the meeting to familiarize themselves with the topic, but the majority of problem-solving occurred during the team meetings. Other teams decided to complete the entire homework assignment individually and use team meetings to compare and correct answers. With this approach, meetings focused on only the aspects of the problems that confused students. The third common teamwork strategy was essentially "divide and conquer," separating the assignment and later consolidating answers during a team meeting. Occasionally, teams using this strategy would meet early to overview the homework and assign

individual problems. Regardless of whether this first meeting took place, a separate meeting was later used to collect the solutions and explain them to the other team members. Only twice did a student admit to completely copying an assignment from, or allowing their assignment to be copied by, another teammate.

Table 2: Distribution of homework strategies.

	Homework 1	Homework 2	Homework 3	Homework 4
Complete Fully Collaborative	49%	55%	33%	40%
Complete Individually and Compare	46%	39%	57%	40%
Separate and Consolidate	6%	3%	7%	20%
Copied a Teammate	0%	3%	3%	0%

When asked how team performance compared to students' expectations, the results, shown in Figure 1, were generally positive. For Homework 1, 2, and 4, over half of respondents said the team performance greatly or slightly exceeded their expectations. Satisfaction was lowest for Homework 3, with the most commonly selected response being "met expectations" and 21% reporting that the teamwork "almost met expectations."

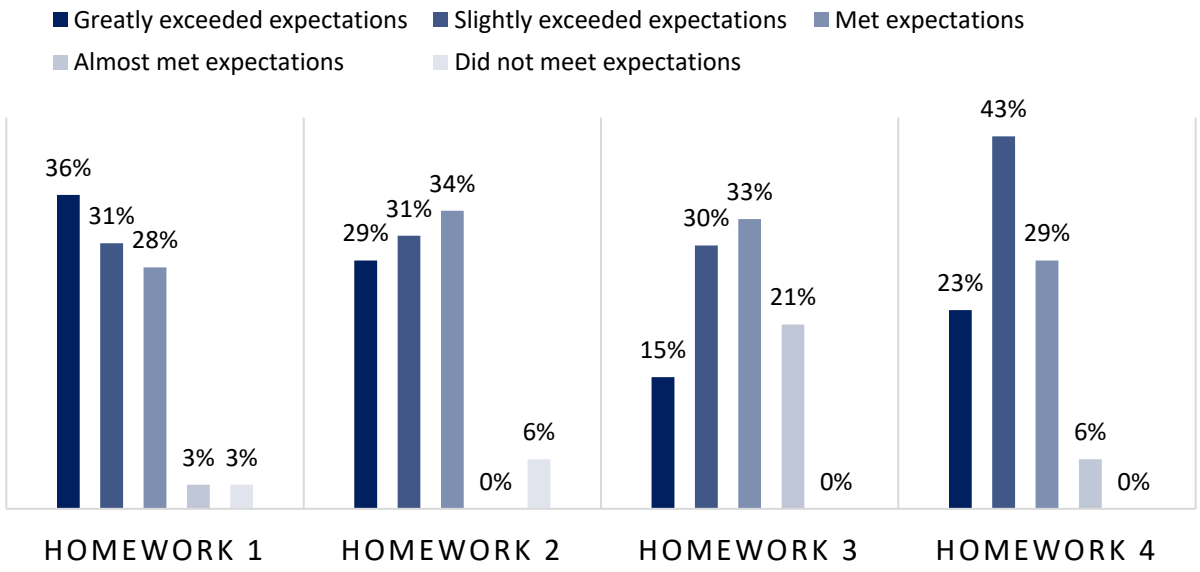

Figure 1: How well did your team perform compared to your expectations?

Difficulties surrounding teamwork during Homework 3 were also reflected in the level of engagement of teammates reported in the homework surveys, shown in Figure 2. The percentage of students who felt all of their teammates were engaged when completing the homework decreases between Homework 1, 2, and 3, and compared to the other assignments, Homework 3 has the lowest percentage (42%) of students reporting that all team members were engaged.

However, for Homework 4, engagement is improved, with 80% of students reporting all team members were engaged for that assignment.

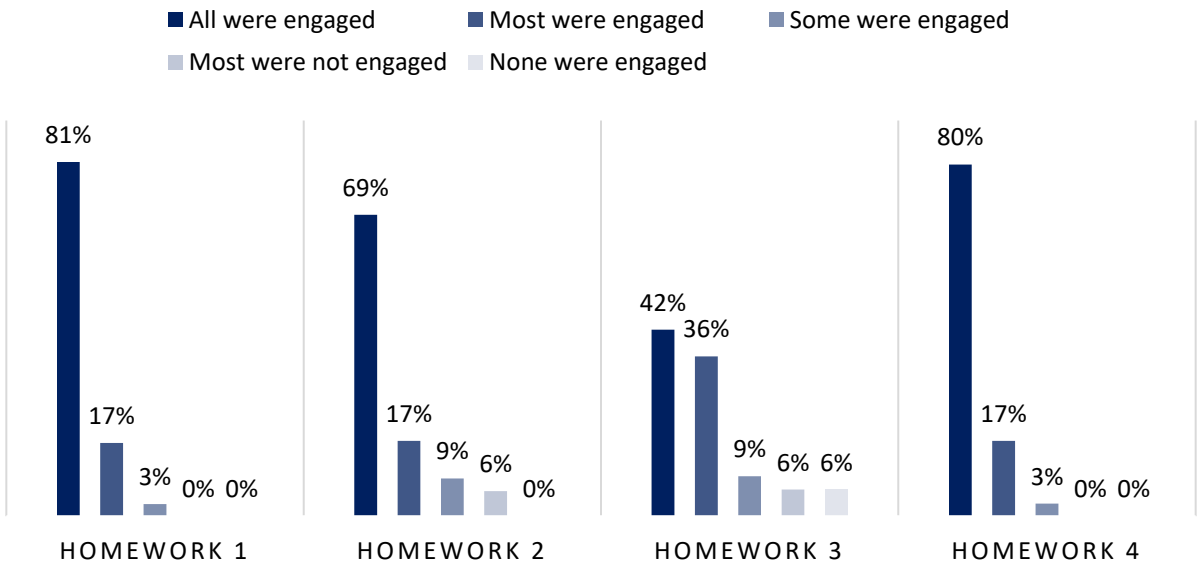

Figure 2: What was the level of engagement from all team members?

Students were also asked in the homework surveys if they experienced any conflicts while working with their team and if they were satisfied with their experience on that team. Conflicts increase consistently across the four assignments. The percentage of students who reported experiencing conflict within their teams increased from 6% for Homework 1, 9% for Homework 2, 18% for Homework 3, and 20% for Homework 4. These conflicts were predominantly miscommunication and limited availability when scheduling meetings. Team satisfaction was high in Homework 1 and 2, with both having 89% of respondents reporting they were satisfied. However, that value decreased to 73% for Homework 3. As with engagement, perceived team performance improved in Homework 4, with 100% of respondents reporting satisfaction with their team.

Table 3: Responses to "were there any conflicts on your team?" and "were you satisfied with your experience on this team?"

Were there any conflicts on your team?				
	Homework 1	Homework 2	Homework 3	Homework 4
Yes	6%	9%	18%	20%
No	94%	91%	82%	80%
Were you satisfied with your experience on this team?				
	Homework 1	Homework 2	Homework 3	Homework 4
Yes	89%	89%	73%	100%
No	11%	11%	27%	0%

The final question of the homework survey asked students if completing the homework as a team helped them understand the material, and if so, how it did so. Those who reported that working in a team helped their understanding explained how it did so in ways that could be grouped into three categories, shown in Table 4. The results show the first and most common way the teams supported understanding was through team members' explanations when there were points of confusion. If a student was confused about a homework question or concept, they found their teammates explanations' helpful. Students also found that providing explanations to their teammates furthered their own understanding. For instance, by explaining their homework approaches to others, students were forced to think carefully about why they did each step, reinforcing what they learned in class. One student's response exemplifies this in particular: "It helped me think about how to explain the topics and get a better understanding of what the equations actually mean in terms of their real applications." Finally, students found the group homework assignments helpful because it was a natural way to debate and validate their problem-solving process. The phrase "bounce ideas off of" was common in the responses of students describing this benefit. They also reported that learning and working in a team increased their confidence because their team provided a safe space in which to debate problem solving approaches.

Table 4: How did the working on the homework as part of a group help with you understanding of the material?

	Homework 1	Homework 2	Homework 3	Homework 4
Teammates helped when confused	36%	37%	39%	31%
Explaining to teammates solidified learning	33%	20%	15%	9%
Debate and validation	11%	20%	18%	37%
Did not find group HW to help understanding	19%	23%	27%	23%

In the final feedback survey at the end of the course, 61% of students found the group homework assignments to be the most valuable activity in the course, and 77% said that the group homework assignments supported their learning more than a typical homework assignment. The homework chats were used to discourage "divide and conquer" teamwork methods, and while some teams still split the assignments, the chats encouraged them to come together as a group and explain their solutions. The chats themselves however were more controversial in the final feedback survey. 18% of students said the chats were the most valuable activity in the class, and another 18% said they were the least valuable activity. Even still, 78% of students said that the chats supported their learning more than a typical course activity.

Open-classmate quizzes

The open-classmate quizzes were unannounced quizzes in which students were asked concept questions related to the course content. No notes or textbooks were allowed, but students

were allowed to talk with each other to answer the questions. During the quizzes, students generally met in small groups initially, frequently their homework team, and would then begin to talk with the groups seated near them. Eventually groups would send a single student as an "ambassador" to check with other groups in different parts of the classroom. The discussions would get very active as students had to defend their viewpoints if they were getting different answers. A third of students found these quizzes to be the most valuable aspect of the course. One was especially honest about the process: "The group quizzes were kind of painful at times but also very useful in terms of talking to people about the content especially realizing what I didn't know too well." 15% of students found the quizzes to be the least valuable activity, with most of the dissension due to the quizzes being unannounced nature rather than the teaming aspect. Despite this, 74% of students said that the open-classmate quizzes supported their learning more than traditional quizzes.

The additional emphasis placed on understanding course concepts via the homework chats and open-classmate quizzes manifested in the final exam. Closed-book conceptual questions on the exam were used to directly assess the students' ability to learn the pertinent concepts, When comparing to years past, shown in Table 4, there is a clear increase in the average score for these questions in 2022.

Table 5: Scores on concept questions on final exam compared to years past. 2020 and 2021 class did not have group homework, homework chats, or open-classmate quizzes.

	2020	**2021**	**2022**
Max points	25	40	32
N	34	41	33
Mean	56%	75%	81%
std	3.97	6.85	4.48

Discussion

Tense team dynamics and conflict is seemingly unavoidable in teams, and small, short-term teams like those assigned for the group homework assignments are not exempt. However, not all conflicts are detrimental to the health of the team. Task conflicts, or disagreements surrounding the appropriate approach to solving a problem, have the potential to improve team performance as it encourages innovation (O'Neill et al., 2013). In one instance of task conflict a student said "Some of us got different answers for the questions, so we all went back, double checked our notes, and made corrections where they were necessary. We were all open to critique and listened to what the others had to say." This student, while admitting experiencing conflict within their team, also rated their team as greatly exceeding their expectations and felt that all members were engaged in the problem-solving process. Unfortunately, most of the students who experienced conflicts in their teams reported relationship or interpersonal conflict with team members. This predominantly manifested as difficulty scheduling meetings or the occasional instances of "social loafing," meaning a member of the team for one reason or another is disengaged from the team activity

(Borrego et al., 2013). Fortunately, feedback in the surveys between homework assignments and the reassignment of teams for each homework help to prevent instances of social loafing from becoming a compounding issue. Even so, halfway through the course (between Homework 3 and Homework 4) a focused in-class session on "maximizing team effectiveness" was given by a faculty member who specializes in team development. The results of the session are seen most clearly by examining the number of students reporting conflicts alongside those reporting satisfaction with their team. The number of students who reported experiencing conflict in their team increased consistently as the course progressed, but after the team effectiveness session, all students reported being satisfied with their teams for the next assignment (Homework 4). Furthermore, the perception of team performance and team member engagement also increased. The percentage of students who felt all members of their team were engaged increased from 42% in Homework 3 to 80% in Homework 4.

Another potential issue common in teamwork is the reliance of the team on just one member to complete a task. Teams who used the strategy of separating the homework and consolidating the answers were the most at risk for developing this habit. The homework chats were employed to counteract this by requiring that all students be familiar with all solutions in the assignment; since students did not know ahead of time which problem they would be asked to discuss in the chat, they needed their teammates to effectively explain their solutions to them. The "separate and consolidate" approach was most prevalent in Homework 4, which is likely because one question required modeling with a coastal engineering software program. Some students were more familiar with the software than others, so the member of the team most comfortable with the software typically completed the relevant problem independently before demonstrating the process to their team. In these instances, the students who did not attempt the software problem were fully dependent on the teammate who completed it.

The homework chats mostly fulfilled their purpose but did not fully eliminate the copying of homework assignments, and there was disagreement among the students regarding the chats' value in the course. In the final feedback survey, student rated it as significantly supporting their learning, but the question was phrased in relation to a similar aspect in a typical course, i.e. a 3 on the Likert scale was oriented as "supported my learning an average amount (compared to a typical course aspect)." The positioning of this question makes sense when considering the changes to homework assignments and quizzes because there is a "typical" homework or quiz that students expect to provide the comparison. But in the case of the homework chats, students have no framework for a "typical homework chat" and instead likely compared it to no intervention whatsoever. This aspect of the course was also the most time intensive change for the instructor and co-instructor, requiring them to set aside a significant amount of time after each homework assignment to conduct a five-minute chat with each student. The feasibility of implementing this activity in future courses depends on the number of students, the availability of the instructor, and the experience level of any teaching assistants. Since this course contained both undergraduate and graduate students, only a more senior graduate student with strong familiarity of the course content can effectively conduct the chats. Alternatives include discussion boards, in-class activities related to the homework assignments, and fewer required homework chats. Regarding the latter, reducing the number of extra time slots available for each homework assignment would ensure a more even

distribution of students attending a particular time block of chats across the various assignments; in other words, there would be fewer unused time slots and possibly fewer blocks altogether.

While the homework chats demonstrated students' conceptual understanding of topics in a setting they could prepare for in advance, the unannounced open-classmate quizzes served as an effective feedback tool for more recent material. The communal nature of the activity meant that while the students may have begun the quiz with many different ideas of the correct answer, they would eventually settle on similar answers as a class. This activity served as a way for students to teach each other and engage deeper with the concept, as students were forced to thoroughly explain their reasoning if it did not align with another student's answer. By observing this process, the instructor gets valuable feedback on common misunderstandings among the students. In one case, the entire class performed poorly on a particular quiz because there was a fundamental misunderstanding of the concept in question. Students discussed possible answers and eventually convinced themselves to adopt an incorrect interpretation. Because the instructor could easily observe the misunderstanding during the quiz and related discussion, they were able to revisit the topic and effectively clarify the specific points of confusion. This misunderstanding may have been missed in a traditional individual quiz because some students did start with the correct answer but were eventually convinced to adopt the wrong answer by the reasoning of their peers. This particular concept was reassessed on the final exam with the vast majority of the students demonstrating strong understanding.

Near the end of the semester, the instructors held an open discussion with the class about the course changes that were implemented along with the motivation for them. The students appreciated the frank dialogue and provided additional feedback which allowed for real-time discussion resulting in some modifications to the incorporated changes for the Spring 2023 course offering, including changes to the logistics of the homework assignments and the addition of more in-class team activities.

Conclusion

The team-centered innovations to a Coastal Engineering course effectively supports students' understanding of difficult concepts in the course. Not only did students find the reformatted homework assignments and quizzes to be valuable in supporting their learning, but these activities also supported increased scores on traditionally difficult conceptual questions on the final exam. Future implementations of these changes may require a reevaluation of the logistics for the homework chats, as they serve an important role ensuring participation from all team members but are time intensive for the instructors.

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