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Optimizing Co-Teaching Strategies for Success in a Neuroinclusive Large Mechanics of Materials Class

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Abstract

The Mechanics of Materials course is a core offering at the University of Connecticut, catering to students majoring in civil, mechanical, manufacturing, and biomedical engineering. Delivered in a flipped classroom format, students engage with video materials that cover the theory outside of class. In class, students focus on developing problem-solving skills, exploring real-life applications of mechanics concepts, and participating in multiple active learning activities. In 2020, the course underwent a redesign to align with inclusive teaching standards, aimed at providing support to neurodivergent students.

For the Spring 2023 semester, the course was co-taught by two instructors, one a teaching faculty member and the other a tenure-track faculty member. The course was hosted in an active learning classroom, equipped with 34 spacious tables and 204 rolling chairs, fostering dynamic interaction between instructors and students. In contrast to traditional auditorium-style classrooms, this environment allowed for more-effective engagement during class time.

While higher education faculty members frequently collaborate on research, most courses are taught by one faculty member [1]. Co-teaching typically involves instructors dividing the course content equally, with each instructor individually covering half of the classes. However, potential conflicts may arise in this approach due to differences in teaching styles and philosophies [2]. These differences may, in turn, affect the consistency of instruction and lead to a less satisfactory learning experience for students, potentially influencing student evaluations of teaching [3]. This study aims to assess the effectiveness of different strategies employed by the instructors to enhance inclusive teaching, and minimize potential challenges associated with co-teaching.

In this course, both instructors attended all lectures, with one leading the lecture and classroom activities while the other engaged with students, promoting interaction and discussion. The class featured diverse active learning methods, including teamwork-based problem-solving, hands-on stress analysis with physical models, think-pair-share activities using real-world examples, polling on mechanics concepts, and strength-based projects. Classroom activities were carefully crafted to align with neuroinclusive teaching practices, aiming to empower every student, with particular emphasis on supporting those who are neurodivergent. Instructors and the three teaching assistants provided consistent support during these activities, while students had the opportunity to explore the application of mechanical concepts in topics of personal interest through strength-based projects. Having a tenure-track faculty member as one of the instructors enriched the experience, providing interested students with the opportunity to participate in research-focused strength-based projects using their knowledge from the Mechanics of Materials course.

This paper delves into the benefits, challenges, and practical details of implementing these strategies in a large, inclusive, classroom setting. To gauge the effectiveness of these strategies, two anonymous surveys were conducted at the end of the semester, soliciting student feedback

on class activities and co-teaching practices. The results highlight student feedback on the course content, assessments, active learning strategies, and overall course management and suggest that the employed co-teaching style was perceived as harmonized and well-coordinated, with clear expectations. This paper aims to share best practices for co-teaching in a large engineering course while incorporating inclusive teaching strategies to enhance the learning experiences of students.

Introduction

Co-teaching was utilized in the large class of Mechanics of Materials in the Spring 2023 semester. A variety of class activities and teaching strategies were designed and offered. The objectives include incorporating neuroinclusive teaching best practices, utilizing unique features of the active learning classroom, employing instructional resources effectively and minimizing potential challenges with co-teaching. Co-teaching in, college classes is an innovative instructional approach where two or more teachers collaborate to deliver instruction to a diverse group of students [4]. In certain higher education institutions, co-taught courses are reduced to a mere division of duties or roles, where teaching faculty alternate in delivering classes or divide the course credit load based on specific weeks or assignments [4]. This method does not maximize the potential of coteaching, which should enable instructors to interact with each other in class be used to leveraging the collective knowledge and expertise of multiple teachers within the same classroom to enhance student learning outcomes [1], [5]. This collaborative teaching model fosters a dynamic learning environment, addresses the varied learning needs of students, promotes active engagement, and provides differentiated instruction. Furthermore, co-teaching encourages shared responsibility, reflection, and professional growth among teachers, ultimately enhancing the overall quality of education in college classrooms [5]. However, co-teaching in a large classroom presents several unique challenges which can impact the effectiveness of instruction and student engagement. One challenge is coordinating and synchronizing teaching approaches and strategies between co-teachers to ensure cohesive and consistent instructional delivery [6]. This requires effective communication, planning, and flexibility among co-teachers. Moreover, assessing and providing timely feedback to many students can be overwhelming and may require additional resources and strategies to accurately gauge individual progress.

In Fall 2020, the course underwent a transformation to better serve neurodivergent students and encourage inclusive teaching methodologies. This initiative was a part of "INCLUDE, Beyond Accommodation: Leveraging Neurodiversity for Engineering Innovation" project funded by the National Science Foundation (NSF). Truly inclusive educational environments in engineering studies entail educators adopting a perspective that recognizes the inherent value in neurodiversity, going beyond basic provisions for accommodations and accessibility [7]. Using the Universal Design for Learning (UDL) framework, the course structure was adapted to address the varied requirements of the increasingly neurodiverse student body in higher education [8] – [11]. UDL guidelines offer a set of concrete suggestions to ensure that all learners can access and participate in meaningful, challenging learning opportunities [11]. While UDL offers an excellent foundation for creating courses accessible to a wide range of learners, there is a need for additional criteria to help neurodivergent students leverage their unique talents within the realm of engineering [12]. Embracing inclusive teaching signifies an appreciation for diverse learning modalities, leading to richer, more engaging educational experiences. It involves integrating a variety of viewpoints and fostering active engagement, thus providing every student with the chance to excel and realize their potential.

Teaching in an active learning classroom offers numerous ways to support inclusivity by promoting student-centered and participatory learning experiences, where students actively engage with course content and collaborate with peers. Additionally, active learning classrooms often utilize technology and flexible seating arrangements, which create a dynamic and adaptable learning environment. Peer interaction fosters critical thinking, problem-solving skills, and a deeper understanding of the material. This active participation enhances student motivation and encourages a sense of responsibility, sense of belonging and increases retention [13], [14].

Student reflections on the co-teaching approach will be presented and discussed in this paper. The course structure and class components provided to students to promote accessibility, flexibility, and strength-based approach in this course will be presented. Students' feedback will be shared about effectiveness of the class components and if the class activities supported the inclusive environment.

Neuroinclusive Course Structure

The Mechanics of Materials is a core course, serving about 400 undergraduate engineering students annually, teaches how to compute stresses and strains in structures like beams, columns, and shafts. Adopting a flipped classroom model since 2014, students watch a concept video before class and then follow-up with problem-solving videos that guide them through 2-3 examples. Class time is dedicated to a short recitation of concepts followed by different active learning activities such as problem solving, teamwork, interactions with physical models, and discussion.

In Fall 2020, the course was updated to better serve neurodivergent learners by integrating neuroinclusive teaching best practices. Research indicates that those with ADHD, dyslexia, autism, etc., often possess strengths like visualization, spatial thinking, and hands-on activities [15] - [17]. Guided by Universal Design Learning (UDL) [11], additional teaching strategies were added to enhance the distinct talents of neurodivergent students. The revised course focuses on three key areas: accessibility, flexibility, and a strength-based approach.

In Spring 2023, the Mechanics of Materials course enrolled 130 students and took place in an active learning classroom. The course was co-taught by two instructors. This section discusses the course components, policy and class features which supported neuroinclusive teaching.

Accessibility

The course content, catering to various learning styles, was presented through diverse methods. From the outset, captioned videos (99% accurate) facilitated a self-paced learning experience, immediately accessible to the students. Accompanying the videos, an electronic file with course lectures and practice problems was provided for those who learn best by reading or note-taking. During in-class sessions, instructors reviewed the material with a focus on practical examples and guided students through additional problem-solving, aiding those inclined towards lecture-driven learning. Adopting the smart book gave audio learners the option to study effectively.

Access to instructors and teacher assistants was facilitated via multiple office hours in both in-person and online modalities were offered to students. Students could meet with the instructors outside of office hours by previous appointment.

The active learning classroom's unique design fosters easy interaction among peers and the instructor. In contrast to traditional classrooms, where students in center seats may be cut off from interaction, the setup here ensures every student is reachable. The classroom houses thirty-four rectangular tables, each surrounded by six rolling chairs, allowing for a maximum of 204 students (see Figure 1). With an enrollment of 130 students for this class, it averaged about four students per table. Each table features a small whiteboard, encouraging teamwork and idea sharing. The room's four-tiered layout guarantees an unobstructed view of the podium and main screen from any seat.

Figure 1. Peers and instructor's interaction in the active learning classroom

<u>Flexibility</u>

The course incorporated flexibility through various options in class policy, active learning methods, assignments, and the class project.

Students could self-assess their understanding with a non-graded "Test yourself problems" assessment after each video. In these tests, students tackled real-world problems applying mechanics concepts and could compare their answers to provided solutions.

Students were given a series of graded team problem-solving activities during class to motivate them to watch lecture videos and come prepared. It also allowed them to practice with a simulated mini exam, mimicking the difficulty and time constraints of an actual test [18]. Neurodivergent students, who may face challenges with social communication, had the option to work alone or in groups to accommodate their needs. Furthermore, students could make up the activity up to twice per semester if they missed it.

Online assignments via smart book (McGraw-Hill Connect) were implemented. Online assignment platform offers algorithmic, auto graded homework assignments. Students were able to check their work before submission and get access to the textbook resources. Students are allowed to request a deadline extension up to two times per semester. This policy is intended to provide support for students who may encounter occasional distress. Students earned extra points by completing supplementary assessments, including concept comprehension exercises (via SmartBook) and online quizzes.

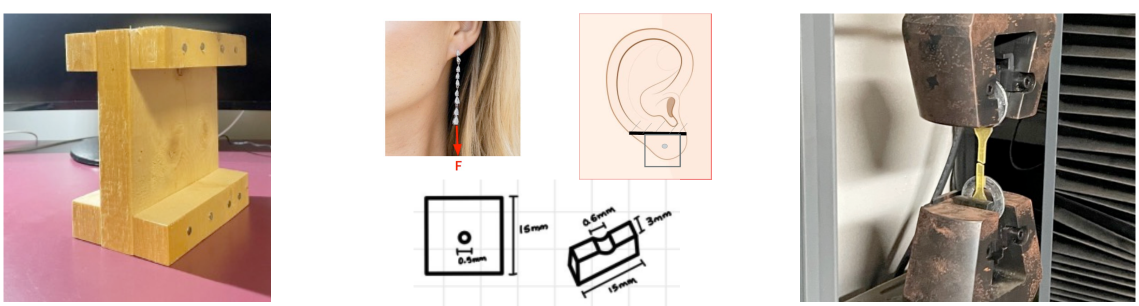
In Spring 2023, a new policy was offered allowing students to retake midterms. This aimed to remedy poor exam performance. Retakes were scheduled within 10 days of the initial exam, and roughly 40% of students opted for this chance to boost their grades. The policy also alleviated exam anxiety, as reported by students.

Students completed a mini project (Strength-Based Project) for the course wherein they applied mechanics concepts in a real-world example [19]. They had the flexibility to select their topic and the modality, using video, poster, slides, written report, and/or illustrations to complete their project.

<u>The Strength-Based Approach</u>

Multiple activities were utilized in this course to reinforce some of the leaning preferences such as visualization, hands-on activities, and world class learning experiences.

A graded mini project called "Strength-Based- Project" was offered to students [19]. Students completed individual projects in which they had the choice to create a physical model or analyze an object from their areas of interest by using mechanics concepts. Students were asked to submit a short proposal on a topic from area of interest, such as photography, drawing, filming, sports, programming, game design, comedy, woodworking, cooking, planting, and/or human body. Instructors provided feedback to confirm the correct alignment between the suggested topic and the mechanics concepts. Another set of feedback was provided to students after submitting the final project. In Spring 2023, one of the instructors (a tenure-track faculty member) offered a new research track that enabled students to visit the structural laboratory to test and analyze samples of materials under different loadings. Approximately 8.5% of students participated in the research track. Figure 2 shows a sample of projects from creative, analytical, and research tracks.



(a) (b) (c)

Figure 2. Students' strength-based projects in a) Creative track, wooden built-up beam, b) Analytical track, modeling the ear pursing as discontinuous plate under axial loading c) Research track, axial load testing on a resin dog-bone sample.

Student teams were provided with cut pool noodles for an ungraded, interactive exercise in the classroom. They were tasked with computing stress and strain for specified loads or determining the noodle's load capacity under axial, twisting, bending, and buckling forces. Figure 3 illustrates students analyzing a noodle subjected to a buckling load.

Figure 3. Students interacting with a pool noodle to analyze element under buckling.

Anonymous polls via Slido were utilized to improve student participation and engagement during class. Students were given five minutes to complete polls on their cellphones with their live responses then displayed. The questions on Slido were designed to assess student understanding of mechanics concepts and their ability to connect these concepts to real-world scenarios. The Think-Pair-Share method was endorsed by instructors for students to contemplate independently, discuss with tablemates, and submit their answers through the Slido app.

A variety of physical models made of foam, wood, and cardboard were utilized by instructors to illustrate mechanics concepts. These models were constructed by the instructor or the course's former students to enhance learning through visualization. A model employed to demonstrate buckling in columns with varying end conditions is shown in figure 4.

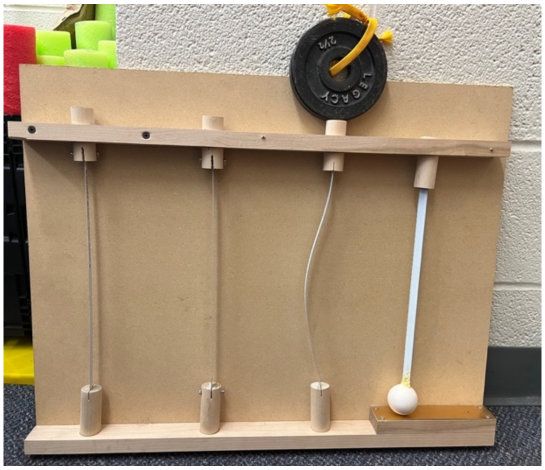


Figure 4. Demo model for buckling in columns with different end conditions.

Table 1 presents the options for implementing an approach based on accessibility, flexibility, and strength within the course, categorizing these under course contents, assessments, and active learning methods.

Table 1. Mechanics of Materials course components

Contents delivery	Assessments	Engagement-Active learning
• Lecture • Sample solving videos • Video captions • PDF of video content • PDF of class notes • Smart book Connect • Real-world examples • Visualizations • Physical models	• Weekly homework with unlimited attempts • Optional quizzes • Optional "Test yourself problems" • Optional Smart book reading • In-class teamwork problem solving • Optional final exams • Re-take midterm exams • Hands-on projects	• Think-Pair-Share • Slido polls • Teamwork problem solving • Physical models analysis • Strengths-based projects

It is understood that including course components that emphasize visualizations and hands-on activities, such as strength-based projects, Slido problems, and physical models, can benefit neurodivergent students with ADHD or dyslexia who possess strong 3-dimensional visualization skills. By offering the option to work in groups or individually on teamwork problem-solving tasks, it acknowledges and accommodates the preferences of students with autism characteristics. Integrating resources like smart books and captioned videos can provide support for dyslexic students who may prefer audio-based content. It is important to mention that the impact of inclusive teaching on students with neurodiversity is currently under investigation in a separate study, which has obtained approval from an Institutional Review Board (IRB). The findings from this study will be shared in forthcoming publications.

Co-Teaching Strategies

Co-teaching strategies were integrated with neuroinclusive teaching practices to ensure a satisfactory learning experience for all students.

Rather than following common co-teaching methods where each instructor teaches half of the course materials, co-instructors decided to be present for all lectures, each assuming varied roles during class. Responsibilities included one instructor delivering lectures every other session, while the other focused on engaging with students, circulating the room to respond to questions, and facilitating interactions with physical models at each table. This alternating of lecturing roles resulted in a more cohesive teaching approach and allowed for seamless transitions between the two instructional styles for students. Previous research indicated that mid-semester instructor changes can disrupt student learning [20]. By having both instructors present for the duration of every class, any potential disruption to class expectations and routines was minimized. The initial 10 minutes of each session were dedicated to revising key concepts, followed by various activities, including instructor-led problem-solving, Slido questions, hands-on model interactions, and collaborative group exercises.

Lecture attendance was mandatory for all teacher assistants. Teamwork problem solving and pool noodle model activities involved both instructors and teacher assistants circulating the classroom, monitoring students' work, and providing immediate feedback.

The midterm exam designs, and grading were collaboratively handled by the faculty, ensuring consistent difficulty and evaluation standards across assessments, thus preventing any comparison between the two faculty members' assessment methods. The possibility of retaking the midterm exam was made feasible by having two instructors present, thereby managing the increased grading load for the large class effectively.

The research track for strength-based projects was designed and managed by the tenure track faculty. Students were given opportunities to visit the structural lab, construct samples, use the universal machine, and test samples under axial and bending loads, attracting 8.5% of students to the track. Extended and flexible office hours were offered by both faculty members, with numerous students utilizing this chance for one-on-one discussions about homework, strength-based projects, and post-graduate possibilities. Specifically, office hours were available from 4-5 pm twice a week and by appointment up to 9pm.

Assessment Objectives and Methodology

This work assesses the impact of class activities and co-teaching strategies on students' learning experiences, excluding consideration of learning outcomes. Data was collected through anonymous surveys and instructors' observations. As the process involved solely the systematic gathering of program-related information for assessment, improvement, and future planning, IRB approval was not required by the authors [21]. Analysis was performed on open-ended responses from the Student Evaluation of Teaching (SET) concerning co-teaching, inclusivity, and beneficial learning components, with the findings presented in this report. The response rate was 31%.

Results

Feedback on co-teaching practices, course components facilitating learning, and class features promoting inclusive teaching and belonging was provided by students through three questions. Instructors were each awarded a perfect score of 5 out of 5 in the final student evaluation of teaching survey conducted by the university. Students were asked:

Q1. How did having two instructors impact the class for you? Do you have any suggestions for future professors who may co-teach?

The students' responses were analyzed, and the significant findings are presented. Overall, students had a positive response to having two instructors in the course. The two-instructor model was seen as enhancing the educational experience, offering multiple teaching perspectives, and ensuring readily available assistance for students. They appreciated the additional support available both during lectures and outside of class. The presence of a second instructor walking around during lectures was valued for providing instant clarification on doubts without interrupting the class. The physical examples provided by one instructor while the other was teaching, particularly in demonstrating concepts like buckling beams, were well-received. One of the students mentioned:

> *"Having two instructors was very good to me, combined with the TAs there was always someone around to answer questions. I think it was effective and allowed for questions to be asked without interrupting the professor that is teaching."*

The diversity in teaching styles and explanations was highlighted as beneficial in understanding the material. The different perspectives and problem-solving strategies offered by two instructors were seen as refreshing and helpful for smooth course delivery. A student expressed:

> *"Having two instructors was a positive and refreshing experience. Having the instructors trade off ideas and problem-solving methods offered variety to the learning environment."*

Students appreciated the approachability and availability of both instructors, often comparing it to having two resources or friends to consult with without feeling pressured. The dual-instructor format was seen as contributing to a warm, welcoming, and less strict atmosphere that facilitated learning. One comment reflected:

> *"It was really nice because we have access to both and were able to get a fast response, I felt that it was a very warm and welcoming atmosphere and because it was two professors, it didn't feel so strict in a way, it was as if I could go to either of them for help or advice almost as a friend and not feel the pressure of messing up etc."*

Students noticed an effective co-teaching dynamic and did not feel that one instructor outperformed the other. The change of pace and the additional opportunities for help during office hours or class were seen as advantageous. Here is a comment from one of the responders:

> *"I was unsure how I felt about having two professors at the beginning of the semester, but I felt instructors worked really well together and had the co–teaching down to a science. There was never a point where I felt one instructor was doing particularly better than the other."*

Nonetheless, a few students felt indifferent about the two-instructor setup, with some expressing that it could occasionally be overwhelming, and one even stated that it made no significant difference to their learning experience. However, these were minority views in the otherwise overwhelmingly positive feedback. Students' suggestions for future co-taught classes included maintaining an equal level of engagement and visibility by both instructors to instill confidence in all students.

In the 2^{nd} question, students were asked:

Q2. Did you feel comfortable and confident to participate in all class activities? Please indicate the class features that support the feel of belonging. What features of the class do not support inclusive learning environment?

Student feedback about the class features suggests a largely positive response, with many emphasizing comfort and support from both peers and instructors. The use of group tables and whiteboards was highlighted as a beneficial component for fostering a collaborative learning environment. One student remarked:

> *"I felt very comfortable participating. I feel like the teamwork activities really promoted the feeling of belonging. I can't find a feature in this class that didn't support inclusive learning."*

Technology like Slido was mentioned as a helpful tool for engaging more students, especially in larger classes, with one student commenting,

> *"The classroom used was comfortable and spacious promoting a good learning environment. The later use of Slido to allow anonymous questions during lecture was a good addition."*

Teaching in the active learning classroom was highlighted as a helpful component for sense of community and belonging,

> *"Even though the class was over 100 people, the classroom and group tables made it feel small and brought with it a sense of belonging."*

On the other hand, there were concerns about the size of the class impacting the sense of inclusivity and the ability to participate fully, leading to suggestions such as rotating assigned seats for better interactions with different classmates. Despite the overall sense of belonging and a supportive learning environment, some students expressed discomfort with certain practices, such as being called upon unexpectedly to answer questions in front of the class. One student shared this sentiment candidly:

> *"This makes me never want to show up to class again, what if she calls on me? what if I do not know the answer? embarrassing."*

However, the feedback generally indicates that the class structures in place are conducive to creating an inclusive and participative atmosphere, with room for minor improvements based on individual comfort levels.

For the third question, students reflected on helpfulness of the class components in their learning.

Q3. What components of the course helped your learning the most? (Lecture videos, sample solving videos, Lectures by the instructor, Strength-Based Projects, class discussion, Instructor class notes, Connect HWs, Quizzes, Demo, Test yourself problem, models, Teamwork activity, office hours)? Please suggest activities that can be removed or should be added to this course to improve the course quality.

Student responses regarding the most helpful class components are summarized in Figure 5.

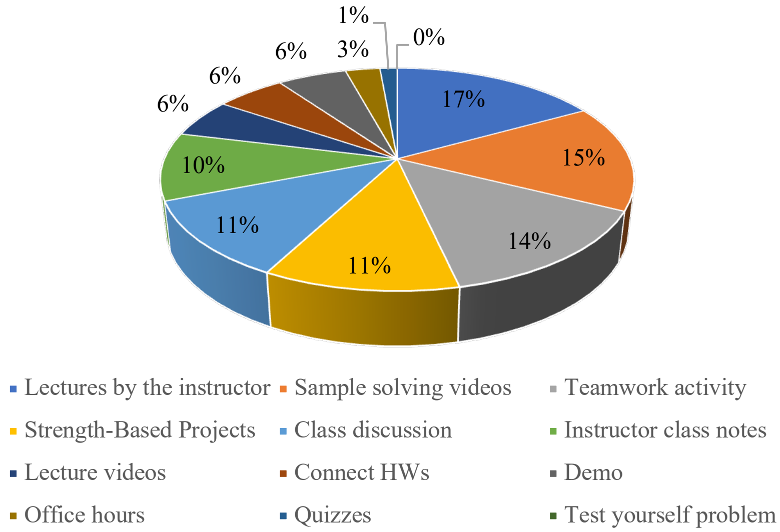


Figure 5. The course components in order of helpfulness

Lectures by instructors, sample solving videos followed by teamwork activity, strength-based projects and class discussions were repeatedly ranked as the most useful course components of the class. Students expressed that lectures by instructors and class discussion were opportunities to actively engage with problems during class to solidify their understanding of the material.

The office hours, quizzes, and test yourself problems were rarely expressed as helpful learning components of the course. Some students stated that office hours were a crucial support component for personalized help and clarification for them.

Conclusion

Diverse active learning methods were featured in the class, incorporating teamwork-based problem-solving, hands-on stress analysis with physical models, think-pair-share activities utilizing real-world examples, polling on mechanics concepts, and projects focusing on strength. The class components were selected based on neuroinclusive best teaching practices to promote accessibility, flexibility, and a strength-based approach. To optimize the benefits of having two instructors and to mitigate potential challenges, such as inconsistent teaching styles or expectations, various co-teaching strategies were employed.

The instructors' approachability and availability were appreciated by students. The diversity of teaching styles and explanations was recognized as aiding material comprehension. Feedback from students regarding the inclusive features of the class indicated a generally positive reaction, with many citing a comfortable and supportive atmosphere fostered by peers and instructors. Collaborative learning was enhanced with group tables and whiteboards. However, the practice of being called on unexpectedly to answer questions in front of the class was not favored. The top three aspects of the class that facilitated learning, as reported by students, were problem-solving demonstrations by instructors, the provision of sample solving videos, and teamwork problem solving activities. Only a minority of students indicated that office hours were a helpful resource.

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