Instilling professionalism and teamwork in the large Statics course

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1 Introduction

In today's rapidly evolving professional landscape, undergraduate engineering education increasingly emphasizes the development of self-regulated professional students equipped with the skills and competencies necessary for the field. Civil engineers play a vital role in creating a safer, more sustainable, and ethically responsible society, necessitating a strong foundation in professionalism. This principle is a core component of the ASCE Body of Knowledge [1], which highlights the importance of ethical and responsible practice. Similarly, the National Society of Professional Engineers [2] mandates integrity, honesty, and impartiality to protect public welfare, and the Accreditation Board for Engineering and Technology (ABET) [3] reinforces ethical responsibility as a key learning outcome for engineering programs. Thus, integrating professionalism into college curricula is essential for preparing engineers to execute their duties responsibly and maintain public trust.

To facilitate this integration, organizations such as ABET and the National Association of Colleges and Employers (NACE) have established criteria for student outcomes and competencies. ABET outlines seven Student Outcomes (SO), which emphasize professionalism-related aspects such as communication, ethical responsibility, teamwork, leadership, and lifelong learning alongside technical competencies [4]. NACE also defines eight career readiness competencies that include professional growth, including career and self-development, communication, equity and inclusion, leadership, and teamwork [5]. These frameworks ensure that engineering graduates meet industry expectations, adapt to technological advancements, and foster effective multidisciplinary collaboration. Given these factors, embedding professionalism into engineering curricula is widely recognized as critical to career success and long-term professional development. [7]-[9]

As an ABET-accredited institution, in our institution, professionalism is integrated into curricular and co-curricular activities including freshman design courses, senior capstone projects, professional seminars, and extracurricular activities such as ASCE student chapter events, mock interviews, and competitions. Project-based learning pedagogy has also been incorporated into junior-level design courses; however, a gap remains in the sophomore year, where students require continued professional development to sustain their learning trajectory.

Statics, the first required course for Civil Engineering students, presents an opportunity to bridge this gap. However, its large class size, extensive learning objectives, and limited instructional resources pose challenges in embedding professionalism. Recent course redesign efforts have prioritized accessibility and flexibility, accommodating rising enrollments driven by infrastructure investments and technological advancements [10][11]. Despite inherent challenges—such as increased workload for instructors and students, the necessity of clear communication, and limited teaching assistant support—the integration of professionalism in Statics offers significant benefits. Enhancing students' teamwork and communication skills can improve their academic success, research capabilities, and prospects for securing internships before graduation.

This paper proposes a targeted teamwork activity within the Statics curriculum to reinforce two critical aspects of professionalism: teamwork and communication. A key question arises—how can this be effectively implemented without imposing excessive grading and feedback burdens?

Nilson [12] emphasizes that higher education should cultivate lifelong learners who are proactive, independent, and self-directed. Active learning encourages students to take responsibility for their educational progress, yet younger learners often struggle with metacognitive skills, leading to passive engagement and external attributions for academic challenges. To address this, students must transition from perceiving learning as instructor-driven to recognizing their own role in the process. By fostering self-regulated learning and metacognitive development, students become more engaged and take initiative in their academic and professional growth.

Here, metacognition—the awareness and regulation of one's cognitive processes—is critical for engineering students' learning and problem-solving skills. [13] Research on integrating metacognition into engineering education has explored classroom instruction and project-based learning [14][15]. Interventions that promote self-directed learning and student ownership of the learning process have been shown to enhance academic performance [13][16]. The benefits of metacognition include improved performance [17]-[23], amount and depth of student thinking [24], sustained focus of learning [25], and the development of reflective and responsible professionalism [26]. With increased learning outcomes and confidence through academic performance, engineering students' self-efficacy might be positively correlated. [27][28] Consequently, multiple metacognitive interventions were integrated along with the teamwork activity to achieve the desired learning outcomes.

This paper details the implementation of professionalism and metacognition interventions in a large Statics course during Fall 2024. The study aims to address two research questions:

RQ1. How does participation in the Statics course with teamwork activities influence students' perspectives on professionalism?
RQ2. How does participation in the Statics course with metacognition activities affect students' self-efficacy?

Outcomes will be assessed through Student Evaluation of Teaching (SET) responses, Qualtrics survey questions, students' in-class semester reflections, and pre- and post-surveys using metacognition and self-efficacy instruments. Additionally, academic performance comparisons will be conducted, followed by an analysis of lessons learned.

2 Background and methodology

2.1 Motivation on professionalism education in Statics

The Statics course at the University of Connecticut is a large class with an annual enrollment of 400–500 students. Each section ranges from 120 to 180 students, primarily sophomores from various engineering departments, including Biomedical, Civil, Environmental, Mechanical Engineering, Management and Engineering Manufacturing, and Multidisciplinary Engineering. As a foundational course required for all Civil Engineering students, Statics undergoes continuous improvement to enhance flexibility and effectiveness in student learning. Various interventions, guided by the principles of Universal Design for Learning [29][10][11], have been implemented to support neurodiverse students and further benefit all types of learners. Examples include a hybrid class structure combining large lectures with smaller discussion sections, strength-based creative final project options as an alternative to the final exam, stretch breaks, extended time accommodations, and more. These efforts have received positive feedback from students [11], leading to the active adoption of similar interventions in other courses such as Design of Reinforced Concrete and Basic Structural Analysis.

However, implementing the UDL model in a large class has inherent challenges, including the preparation of teaching materials and resources, as well as increased workload for instructors, teaching assistants (TAs), and students without adequate preparation [11]. In the Fall 2023 semester, the number of final projects reached its maximum, 160, making it difficult to provide meaningful, personalized feedback despite the best efforts of the instructor and multiple TAs. This marked the practical limit for offering the project option in a large class. While it was the most impactful implementation for the Statics course, administering the project option becomes challenging when the number of projects exceeds 100. Nonetheless, this so-called 'high-cost' issue could be addressed with additional support from the department or institution, making it a feasible and sustainable approach moving forward.

A more pressing issue, however, is students' perception of UDL as overly lenient, leading to an increase in unprofessional behavior. On the positive side, more students are disclosing their neurodiversity to instructors and designing appropriate accommodations. However, there has also been a rise in students requesting extensions and alternative assignments or exams due to reasons such as forgetting deadlines, oversleeping, or failing to pay attention—despite the instructor providing all deadlines in the official course calendar, keeping assignments open for at least a week, and issuing multiple reminders during lectures and via email. This unintended consequence highlights a critical challenge: implementing UDL solely to enhance flexibility and accessibility without emphasizing professional responsibility can have negative effects. While UDL is essential for improving student learning, it must be complemented by professionalism education to better prepare students for their future careers and workplace expectations.

Professionalism has been strongly emphasized for inclusion in engineering curricula by multiple organizations, including ASCE, ABET, and NACE. To provide a comprehensive overview, such competencies are summarized and compared among the institutions as shown in Figure 1. Interestingly, while they use slightly different categorizations and terminology, their core components remain similar. The first category encompasses foundational competencies such as complex problem-solving and critical thinking. The second category focuses on technical proficiency, emphasizing the application of both traditional and advanced technologies for data analysis and design. The third category pertains to professional skills, including communication, teamwork, leadership, professionalism, ethics, and lifelong learning and development. These competencies collectively ensure that engineering graduates are well-equipped for the demands of their profession.

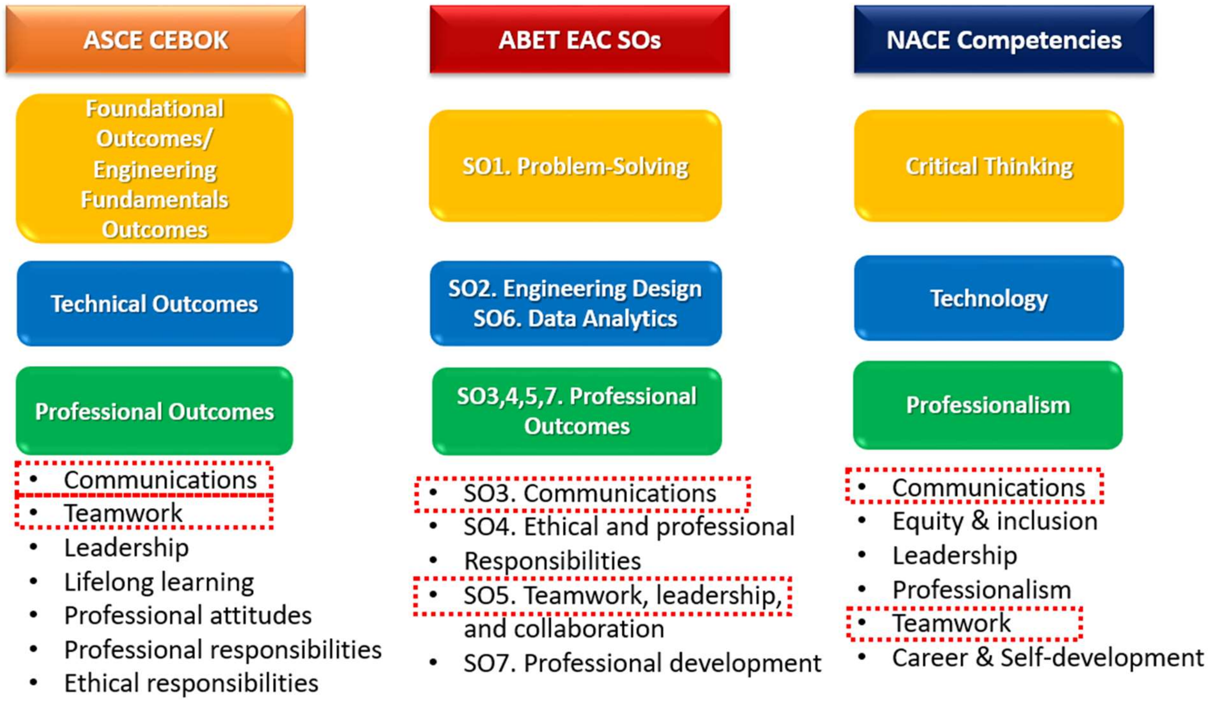


Figure 1. Professionalism outcomes defined by ASCE, ABET, and NACE

Among the various professional competencies, teamwork and communication were selected as learning objectives of the Statics course due to their alignment with course goals and the nature of the planned team activities. The primary objective of the Statics course is to develop engineering problem-solving skills through critical thinking, and the planned activity consists of weekly team-based exercises incorporating social interaction, problem-solving, and reflection. These activities directly enhance students' teamwork and communication skills while also indirectly strengthening their critical thinking and problem-solving abilities. Furthermore, engaging in teamwork activities fosters the development of other professionalism-related skills, such as leadership, responsibility, and self-improvement.

2.2 Statics course description

The Statics course covers the fundamentals of statics using vector calculus, including the resolution and composition of forces, equilibrium of force systems, analysis of forces acting on structures and machines, centroids, dry friction, and moments of inertia. The course grading breakdown includes three midterm exams (50%), ten homework assignments (20%), eleven pre-lecture quizzes (10%), teamwork activities (10%), and class participation with weekly reflections (10%).

The Statics course at our institution follows a flipped active learning model. Class meets for 75 minutes on Tuesdays and Thursdays, and all pre-recorded videos and learning materials for self-learning are provided ahead of time. All activities are structured and introduced to students at the beginning of the semester (see class slide graphic in Figure 2). Students are required to watch pre-recorded lecture and problem-solving videos and complete a pre-lecture quiz by Monday. On Tuesdays, students attend an in-person large class session where they review key concepts, participate in clicker activities, and solve additional problems in teams with guidance from instructors and TAs. On Thursdays, students work in assigned teams at designated tables to complete teamwork activities, problem-solving exercises, peer assessments, and self-reflections. Seating assignments are randomized weekly, and the updated seating chart is uploaded by Wednesday morning, allowing students to check their table assignment before Thursday's session. Each team consists of three students, with two teams sharing a table. The weekly homework assignment is due on Friday night, reinforcing concepts covered throughout the week.

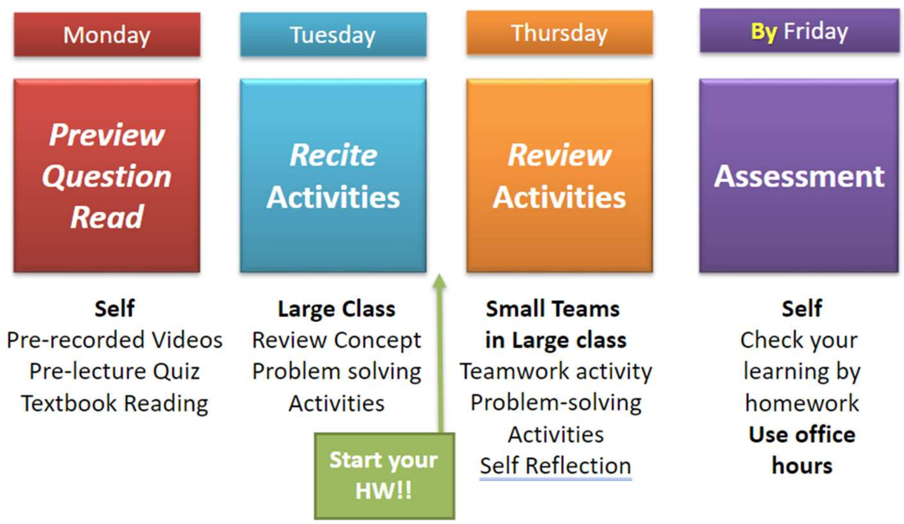


Figure 2 Weekly Course Activity Plan

For each the Statics section of 180 students, 20 hours of graduate teaching assistants (GTAs) are allocated to assist with instruction, along with one undergraduate teaching assistant (UTA) working nine hours per week to facilitate in-class activities and grading. Homework and pre-lecture quizzes are web-based and completed through McGraw Hill's Connect SmartBook, with automated grading. The GTAs support the course by moderating problem-solving sessions, facilitating teamwork activities, answering questions, and holding office hours and evening review sessions. Only one homework assignment requires manual grading—shear force and bending moment diagrams—where students submit scanned diagrams through the Connect website. The UTA is responsible for inputting participation grades from teamwork activities, summarizing student semester reflections, assisting with engineering education surveys, and holding office hours. The teaching team meets every Friday to reflect on the past week, plan for the upcoming week, and learn the problem-solving strategies by the instructor.

This course is recognized as one of the innovative courses at our institution, incorporating active learning strategies, Universal Design for Learning (UDL), and teamwork activities. Established instructional methods include iClicker activities, active problem-solving, and class discussions. All students have access to extensive support mechanisms, including 10~ hours of weekly office hours, evening exam review sessions, and various UDL-based interventions such as extended exam time, frequent breaks, extra credit opportunities, make-up activities, class recordings, instructor-provided class notes, in-class activities, and micro-assessments.

Starting in Spring 2024, the Statics course utilized a newly constructed active learning classroom in a state-of-the-art building. This large-scale active learning space features 34 individual tables, each equipped with six rolling seats and a dedicated whiteboard. Although the classroom has a fire marshal capacity of 293, enrollment is capped at 204 (= 34 tables × 6 seats) to ensure that all students have their own workspace. The classroom is equipped with a large projector screen, two front-facing TV monitors, and one rear-facing TV monitor. Additionally, a movable whiteboard at the front can be broadcast on the screens. The room features a full IT system capable of recording lectures, displaying multiple sources on screens and TVs, and utilizing an advanced microphone setup. This configuration allows students to collaborate effectively in teams while enabling instructors and TAs to move freely and provide support to all students. A snapshot of a teamwork activity from the Fall 2024 semester is shown in Figure 3, and the classroom table configuration is illustrated in Figure 4.

Figure 3 Teamwork Activity in BUILDING Active Learning Classroom: Fall 2024

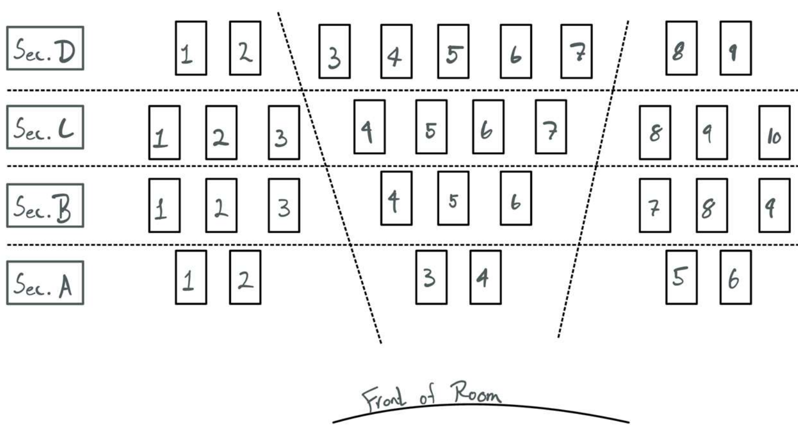


Figure 4 Table Configuration in the Classroom

A preliminary teamwork activity was piloted in the Spring 2024 semester, incorporating team-based problem-solving during Thursday meetings. The use of new active learning classrooms and teamwork activities had positive impacts; however, students needed training in metacognitive skills to effectively engage in self-reflection and assessment. Therefore, a teamwork activity incorporating metacognitive exercises was planned for the Fall 2024 semester.

2.3 Teamwork activity development in the Fall 2024

There are logistical requirements for developing course interventions to teach professionalism in a large classroom setting. The activity should:

1. Be interesting and meaningful to encourage student participation.
2. Provide proper feedback and incentives for students.
3. Be sustainable with a relatively low time commitment for instructors and TAs.

The purposes of these interventions and the accompanying professional learning objectives are clearly stated in the syllabus and communicated at the beginning of the semester, emphasizing their benefits.

The main teamwork activities were designed as weekly exercises with randomly assigned teams at each table, consisting of three parts and a peer assessment component (see Table 1).

Part 1: Socialization and Networking - The first part introduces students to socializing and networking to foster a sense of community. Since this course includes students from various engineering majors, this activity helps them get to know each other and practice communication skills. Students introduce themselves by sharing their names and majors, followed by a discussion on a given question or mission. The questions focus on self-regulated learning and metacognition, addressing topics such as goal setting, choosing effective study environments, and identifying positive distractions.

Part 2: Team-Based Problem Solving - In the second part, students collaborate with their assigned team members to solve a problem using open books and notes. Each student takes on a specific role—note taker, reference finder, or reviewer. This activity typically lasts 10 to 15 minutes, during which the instructor and TAs circulate the classroom, answering questions and assisting with problem-solving. Once approximately 50–70% of the tables have completed the problem, the instructor provides a reminder to finalize solutions and check answers within 2–5 minutes, depending on the problem's difficulty.

Part 3: Peer/Self Feedback - At the designated time, teams exchange their worksheets. Instead of simply announcing the final answer, the instructor or a TA demonstrates the problem-solving process. Students then review and correct their peer team's work, providing constructive feedback and encouragement. Following this activity, the class takes a three-minute break before continuing with additional problem-solving exercises.

Table 1 Structure of Teamwork Activity

Teamwork Activity	Description
Part 1: Social and Introduction	Introduce their name and major, and discuss one question such as: ▪ What is your goal in this course? ▪ Brainstorm ways to earn an A in this course ▪ What is your positive distractor?

Part 2: Team Problem Solving	Solve one problem with your assigned team, with your role as (open notes) ▪ Note taker ▪ Reference finder ▪ Reviewer
Part 3: Peer/Self Feedback	Switch the worksheet with your peer team and provide feedback

In addition, three special teamwork activities were scheduled one week before each midterm exam to help students create exam problems. Instead of the usual three-part teamwork activity, the entire session is dedicated to problem creation. A step-by-step guide is provided to students to assist them in developing and sharing problems with their classmates (see Table 2). First, students identify the three most likely topics to appear on the exam. They share their selections with the class using an iClicker poll featuring a Word Cloud option. Next, teams create one exam problem using open materials. The problem must meet three criteria: range adequacy, appropriate difficulty, and realistic time commitment. These criteria align with the instructor's standards for exam problems. While students work on creating their problems, the instructor and teaching assistants circulate through the classroom to provide feedback and answer questions. Once completed, one member from each team scans their problem and uploads it to a dedicated discussion board, allowing all students to view the problems created. The instructor may choose to adopt some of the problems from the discussion board and will communicate this decision to the class. Regardless, students can use the problems as additional practice material to check their knowledge and prepare for the exam. This process also encourages a sense of peer accountability, as students recognize the efforts of their classmates in exam preparation.

Table 2 Exam Creation Activity

Exam Creation	Description
Step 1. Choose 3 topics that could be in the exam	Provide all topics they learned for the exam coverage, for example: ▪ 2D resultant ▪ 3D equilibrium equation ▪ 3D moment ▪ Moment about an axis
Step 2. Draft one problem with your team (open book, open notes)	Criteria to create problem are provided: 1. Is this problem within the exam range? 2. Is this problem difficult enough for a sophomore level? 3. Is this problem suitable to solve in 15-20 minutes?
Step 3. Upload your problem on discussion board	Scan the created problem and upload it to Blackboard's Exam Creation discussion board as a response by 12:30 PM today.

2.4 Metacognition activities

To support professionalism activities and enhance student success, a series of metacognition activities were developed. These activities align with the foundational elements of metacognition, which include planning, goal setting, monitoring, and evaluating. As a result, metacognitive practices were seamlessly integrated into class assessments and teamwork activities.

Metacognition in weekly assignments and teamwork activities: First, pre-lecture quizzes included questions that required students to evaluate their confidence in answering each question. At the beginning of the Tuesday meeting, the overconfidence ratio from the pre-lecture quiz was shared along with other statistical measures, such as completion rates, completion times, and challenging topics. During the Fall 2024 semester, the overconfidence ratio ranged from 8% to 13%. Additionally, at the end of the Tuesday meeting, a "muddiest points" survey was conducted to identify areas where students needed further clarification, providing an opportunity to address weaknesses and reinforce learning. The results were announced at the beginning of Thursday's meeting to remind students of their areas of confusion and to guide discussions during Thursday's active discussion section.

Third, teamwork activities incorporated metacognitive elements through discussion questions focused on goal setting, brainstorming effective study methods and environments, and future planning. After Thursday's meeting, students were asked to reflect on their teamwork skills by completing the back of the worksheet and submitting it for credit. To support this reflection, a list of sample teamwork behaviors based on NACE competencies was provided on the worksheet.
A summary of the weekly reflections and teamwork activities is presented in Table 3 and Table 4, respectively. Throughout the semester, students were encouraged to monitor their progress, set new goals, and explore improved study strategies and environments through self-reflection or collaboration with peers.

Table 3 Weekly Reflection

Weekly Reflection	Description
Tuesday: The muddiest points	Clicker survey on the muddiest points Show the results on Thursday for motivation
Thursday: Teamwork skill reflection	Reflect on your teamwork skill by answering the following questions: ▪ What was the strength of your team? ▪ How did you deal with conflicts? ▪ How did you contribute positively to your team?

Table 4 Teamwork skill definition and sample behaviors [5]

Teamwork (NACE Competency)
Build and maintain collaborative relationships to work effectively toward common goals, while appreciating diverse viewpoints and shared responsibilities.
SAMPLE BEHAVIORS
▪ Listen carefully to others, taking time to understand and ask appropriate questions without interrupting. ▪ Effectively manage conflict, interact with and respect diverse personalities, and meet ambiguity with resilience. ▪ Be accountable for individual and team responsibilities and deliverables. ▪ Employ personal strengths, knowledge, and talents to complement those of others. ▪ Exercise the ability to compromise and be agile.

▪ Collaborate with others to achieve common goals. ▪ Build strong, positive relationships with team members.

Metacognition activities using exams: Metacognition activities were also integrated into the preparation and follow-up processes for major exams. One week before the exam, a teamwork activity focused on exam creation was conducted. This activity encouraged students to review the material, identify key concepts, and engage in higher-order thinking processes to create new problems based on Bloom's taxonomy. The problems created were shared with peers as study materials and were also incorporated into the actual exam.

During the exam, the last page of the exam paper was reserved for a metacognition exercise to facilitate post-exam analysis. Students were asked to evaluate their problem-solving process, predict their scores, and answer two additional questions: how they prepared for the exam and which topics were most difficult and why (see Table 5). Graded exams were returned to students within one week, allowing them to compare their expected scores with their actual performance.

Table 5 In-exam Metacognition Activity: Exam 1

Problem	1	2	3	4	Total
Expected Score	/20	/40	/20	/20	/100
Score	/20	/40	/20	/20	/100
1. How many hours did you study for Exam 1?					
2. Which topic was the most difficult? Why?					

The in-exam data collected during the metacognition activity are later used for post-exam self-reflection through a separate survey on Blackboard. The survey consists of six questions (see Table 6), and students are required to scan and upload the last page of their exam, which contains their metacognition activity responses, as proof of completion.

Table 6 Post-Exam Self Reflection Questions

#	Question	Question format
1	Compare your expected scores and actual scores. Which of the following statement is true?	Multiple Choice among higher, lower, same
2	Based on your answer to the first question (how many hours did you study), was this enough time to get the grade you wanted, or should you have spent more time preparing?	Short answer
3	How do you feel about your exam grade? Are you surprised, pleased, relieved, disappointed, or what?	Short answer
4	Examine the items on which you lost points and look for patterns. To what extent did these items come from a specific set of class materials? To what extent did they focus on certain topics? Did you tend to misread the questions? Were you careless? Did you run out of time?	Essay
5	How did you spend your time preparing for the exam? How effective were these study strategies?	Essay

6	Set a goal to get a certain percentage correct in the next exam. What study strategies and schedule will enable you to earn that score?	Essay

Extra credit and other supportive activity: To encourage students to improve their professionalism, two Career Readiness modules were integrated into the course as extra-credit opportunities on the Blackboard site. These modules, developed by our institution's Center for Career Readiness and Life Skills, include the *Career & Self-Development* module and the *Networking and Elevator Pitch* module. Upon completing both modules, students earn one extra credit point toward their participation grade.

Additionally, students can earn another extra credit point by completing one of the following activities:

1. Identify three helpful career resources, such as workshops or courses, and post them on the discussion board with an explanation.
2. Meet three interesting companies during the career fair (typically held within the first month of the semester) and share their findings on the discussion board with a brief explanation.
3. Write a 200-word elevator pitch for an upcoming career fair and submit it as a journal entry after completing the elevator pitch module.

3 Assessments and results

The assessment of the developed interventions was designed using a combination of surveys on student perceptions, the university's official teaching evaluation, and summative assessment results. In the Fall of 2024, two sections of the Statics course were offered: Section 1 with 181 students and Section 2 with 174 students. Professionalism and metacognition activities were implemented in both sections at the same time.

Multiple assessment methods were employed to evaluate their effectiveness. First, during the final in-class meeting, students completed a worksheet reflecting on their professional skill development throughout the semester. Second, a separate set of pre- and post-surveys on metacognition skills and self-efficacy was conducted using Qualtrics. Third, students participated in the Student Experience of Teaching (SET) survey administered by the Office of Institutional Research and Equity (OIRE), which gathered general feedback on teaching and learning. Additional open-ended questions were included to gather insights specifically on metacognition and teamwork activities. Finally, student performance from the past four consecutive semesters was analyzed and compared using course grade breakdowns as a measure of summative assessment performance. The following section summarizes the assessment results and provides subjective observations.

3.1 Students' evaluation of teaching results

The university conducts official Students Evaluation of Evaluations (SET) through an anonymous student survey at the end of each semester. To provide a holistic review and assessment of the course and the newly developed activities, open-ended questions were included in the SET to gather detailed student feedback. A total of 123 students (68%) from Section 1 and 119 students (69%) from Section 2 responded to the SET.

To gain the context regarding the differences between the two sections, data on students' academic levels, expected grades, and cumulative GPAs were summarized. In Section 1, the academic level distribution was 2% freshmen, 80% sophomores, 18% juniors, and 1% seniors. In Section 2, the distribution was 0% freshmen, 86% sophomores, 14% juniors, and 1% seniors. This indicates that Section 1 had a slightly less sophomores and more juniors compared to Section 2 (see Figure 5).

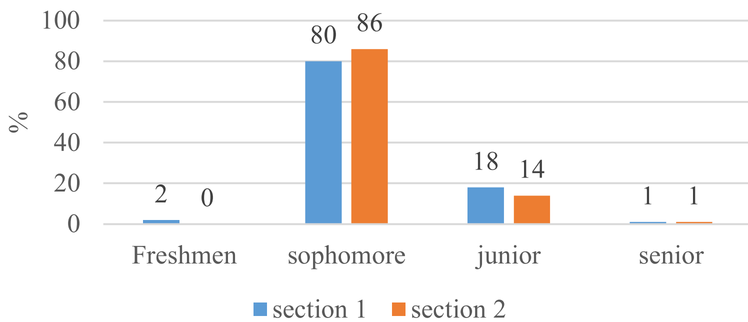


Figure 5 Student composition for each section

Figure 6 shows the expected grades and cumulative GPA for two sections. Section 1 has more students who expect an A than Section 2, and the cumulative GPA of Section 1 was higher than that of Section 2 based on students' responses.

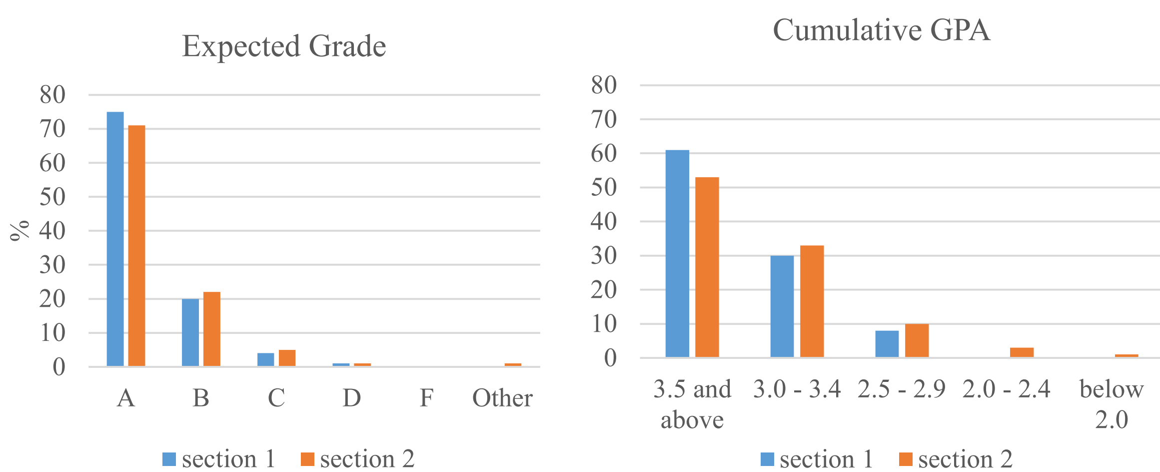


Figure 6 SET Results: (a) expected grade, (b) cumulative GPA

The first open-ended question focused on metacognition skills, asking: "*Do you feel the metacognition activities helped you reflect on your learning and achieve your goals? (e.g., metacognition in-exam questions, self-reflection surveys, exam creation, team goal setting and discussion, and weekly reflections).*" In Section 1, 24 students responded "no," 4 responded "neutral," and 80 responded "yes." In Section 2, the responses were 23 for "no," 2 for "neutral," and 68 for "yes." Figure 7 illustrates the calculated percentage breakdown from these responses.

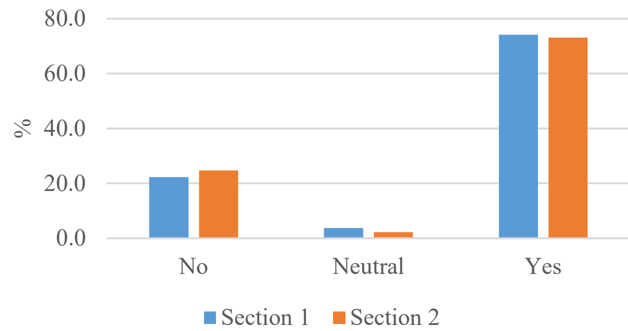


Figure 7 SET Result: Metacognition

The second open-ended question focused on teamwork activities, asking: "*Do you feel the teamwork activities and career modules helped to elevate your career readiness?*" As shown in Figure 8, in Section 1, 18 students responded "no," 8 responded "neutral," and 72 responded "yes." In Section 2, the responses were 25 for "no," 7 for "neutral," and 59 for "yes." Interestingly, some students who disagreed with the statement provided feedback such as: *"I feel those are skills I already had well before this class. However, I would say my critical thinking improved over the semester from this course."*

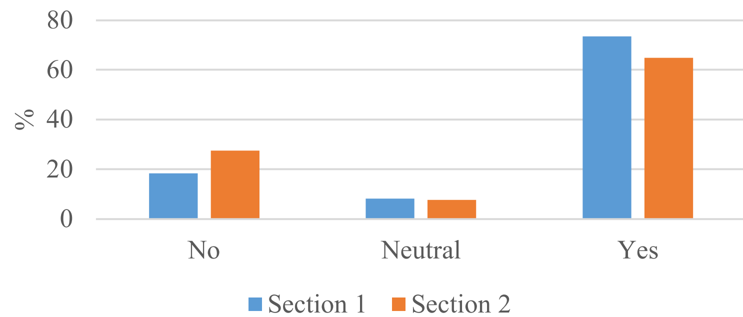


Figure 8 SET Result: Teamwork activity

For those who responded "*yes*," a follow-up question was asked (see Figure 9): "*If so, please share which of the NACE career competencies you have enhanced in this course and how. (NACE competencies: communication, critical thinking, leadership, teamwork, professionalism, technology, equity & inclusion)*." Among the various competencies, teamwork was ranked highest, with 25 responses. This indicates that students who participated in the SET self-reported an improvement in their teamwork competencies through the teamwork activities.

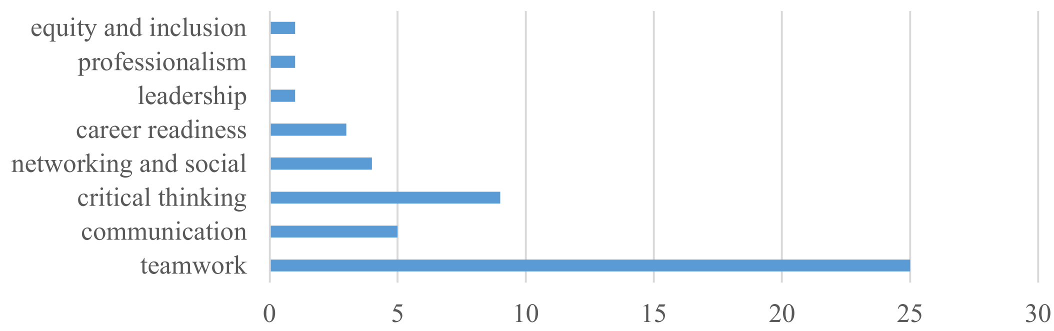


Figure 9 SET Result: Growth in NACE competencies

3.2 In-class semester reflections

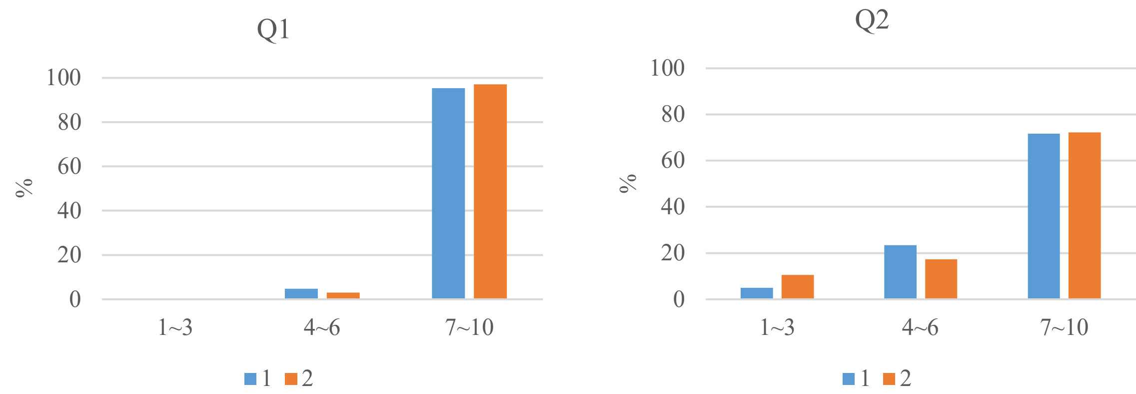
To encourage active participation, an in-class semester reflection was conducted during the final Thursday meeting. Students were asked to complete the back of the worksheet by answering three questions listed in Table 7, along with providing open-ended feedback on how to improve the activity. A 10-point Likert scale was used for their responses, with 1 indicating *strongly disagree* and 10 indicating *strongly agree*.

Table 7. Semester reflection questions

Category	Questions
Self-reflection	▪ Q1: Do you feel you are a good team player? ▪ Q2: Do you feel your teamwork skills were improved compared to before taking this course? ▪ Q3: Did you acquire any teamwork skills through this activity?

For the first question (Q1), which asked students to self-assess their abilities as good team players, 172 students from Section 001 and 133 students from Section 002 participated. The responses are shown in Figure 10 (a). There were no responses in the Likert scale range of 1 to 3 (*disagree*), 4.7% and 3% of responses fell in the range of 4 to 6 (*neutral*), and 95.3% and 97% of responses were in the range of 7 to 10 (*agree*) for Sections 001 and 002, respectively. This indicates that most students perceive themselves as good team players.

For the second question (Q2), which asked whether their teamwork skills improved because of the course, 162 students from Section 001 and 133 students from Section 002 participated. The responses are shown in Figure 10 (b). In this case, 4.9% and 10.5% of responses were in the Likert scale range of 1 to 3 (*disagree*), 23.5% and 17.3% fell in the range of 4 to 6 (*neutral*), and 71.6% and 72.2% were in the range of 7 to 10 (*agree*) for Sections 001 and 002, respectively. More than 70% of students believed that their teamwork skills improved after taking this course.



(a) (b)

Figure 10 Semester reflection results: (a) Q1: Do you feel you are a good team player? and (b) Q2: Do you feel your teamwork skills were improved compared to before taking this course?

For the third question (Q3), which asked about the types of teamwork skills students acquired through the activity, the responses were categorized into several broad themes, as it was an open-ended question. Overall, three key competencies were identified: communication, teamwork, and professionalism. Responses related to communication skills included aspects such as effective communication, active listening, and respecting others' opinions. Teamwork skills included teamwork, collaboration, leveraging individual strengths, and building comfort within teams. Professionalism skills were described in terms of accountability, efficiency, compromise, and effectively utilizing available resources. The number of responses for each of these three skill categories is shown in Figure 11, highlighting that student self-reported communication and teamwork skills as the primary competencies acquired through this course.

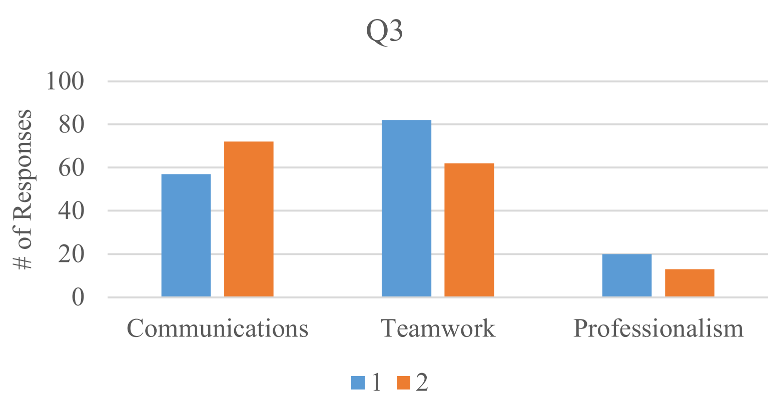


Figure 11 Semester reflection result: Q3: Did you acquire any teamwork skills through this activity?

3.3 Qualtrics survey on metacognition and self-efficacy

To ensure a more systematic assessment, pre-surveys and post-surveys were conducted to measure students' metacognition and self-efficacy. This study was approved by the Institutional Review Board (Protocol # H22-0133, PI: Shinae Jang) of the University of Connecticut, and students were invited to participate in both surveys with the incentive of earning extra credit toward their course scores.

To facilitate participation, a QR code linking to the Qualtrics surveys was provided to students. The pre-survey was conducted during the first two weeks of the class, while the post-survey took place during the final two weeks of the Fall 2024 semester. The scores from both sections were combined, and all data were de-identified before being shared with the instructor for analysis.

A total of 112 students from both sections participated in both the pre- and post- Qualtrics surveys. The survey utilized a 7-point Likert scale, with responses ranging from *strongly disagree* (1) to *strongly agree* (7), including intermediate options such as *disagree* (2), *somewhat disagree* (3), *neither agree nor disagree* (4), *somewhat agree* (5), and *agree* (6).

The survey included a series of questions from the Metacognition Awareness Inventory, which contains questions assessing students' knowledge and self-regulation of their learning [30]. Since the activity was designed to enhance professionalism and self-regulation, the survey focused primarily on evaluating the *regulation of cognition*. Within this domain, the survey included 11 items, assessing various metacognitive skills, including planning, monitoring, information management strategies, debugging strategies, and evaluation [31]. Among the metacognition questions related to the regulation of cognition, responses from three representative questions (see Table 8) were analyzed to identify potential areas for designing future metacognition activities.

Table 8 Metacognition Questions from MAI [30].

Code	Question	Category	M_{pre}	M_{post}	t
M1	I read instructions carefully before I begin a task.	Planning	5.25 (1.20)	5.35 (1.19)	-0.71
M2	I ask others for help when I don't understand something.	Debugging Strategies	5.44 (1.41)	5.43 (1.30)	0.06
M3	I ask myself how well I accomplish my goals once I'm finished.	Evaluation	4.80 (1.52)	5.19 (1.37)	-2.29*

Note. $N = 110$; M = mean; Standard deviation in parentheses, * $p < .05$

For all three questions, the majority of responses indicated *agreement* (scales 5–7), suggesting that students' self-perception of their metacognition skills was generally positive (see Figure 12). Some changes were observed between the pre-survey and post-survey responses. For M1, the number of agreement responses (scales 5–7) showed a slight increase. For M2, the number of disagreement responses (scales 1–3) decreased slightly. For M3, there was an increase in agreement responses and a decrease in disagreement responses, showing the most significant changes among the three questions. Although it is challenging to draw definitive conclusions about improvements in metacognition skills for planning and debugging strategies, it is encouraging that students' perception of their self-evaluation abilities improved after completing the course.

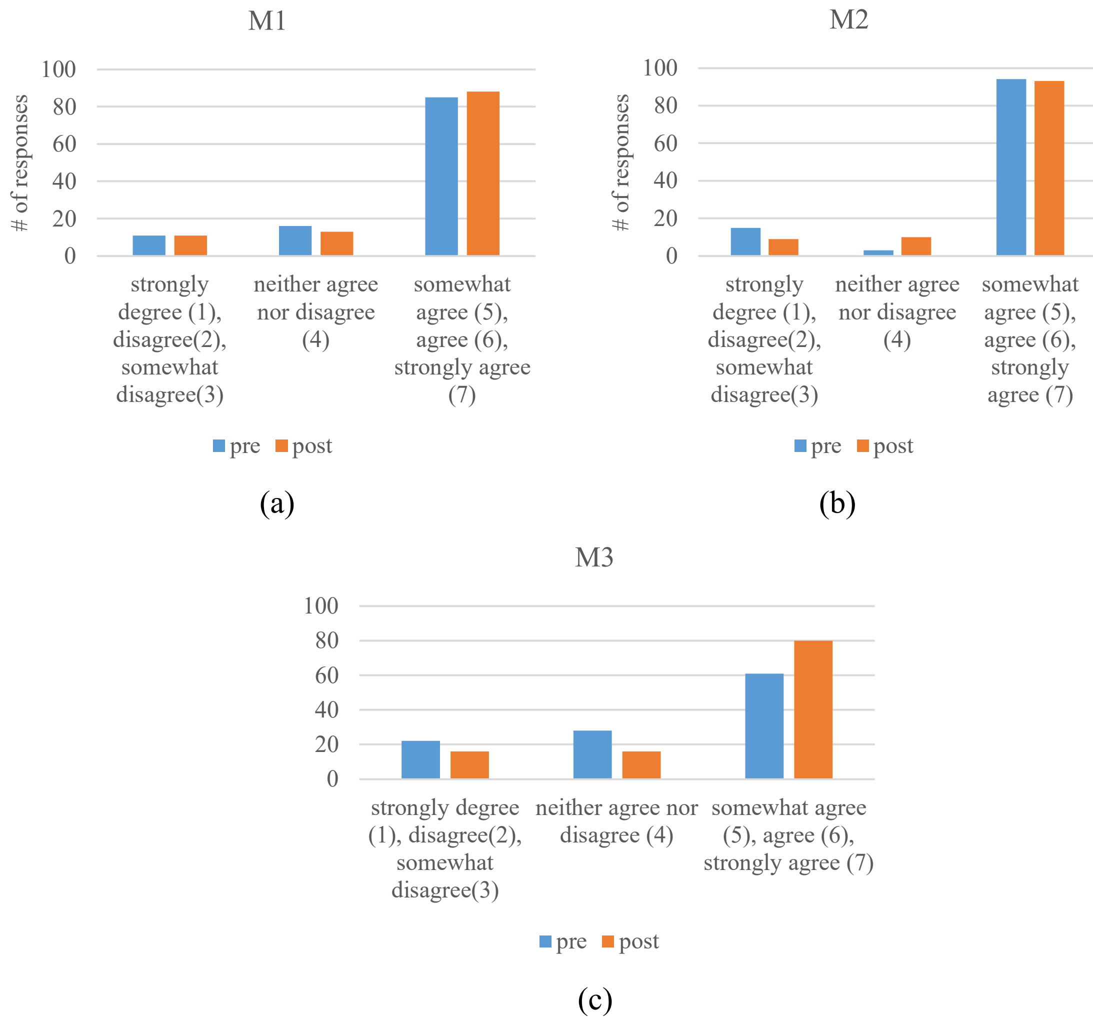


Figure 12 Pre- and Post-Survey: Metacognition Questions (a) M1: I read instructions carefully before I begin a task, (b) M2: I ask others for help when I don't understand something, (c) M3: I ask myself how well I accomplish my goals once I'm finished.

The pre-survey and post-survey on students' self-efficacy were conducted using six modified questions from the self-efficacy subscale of the Motivated Strategies for Learning Questionnaire [32] (see Table 9). Again, students from both sections were invited to participate, and their responses were combined. A total of 111 students completed both the pre-survey and the post-survey. Paired-sample *t*-tests were used to examine if the differences between pre-and post-survey responses were statistically significant at the item-level (Table 9).

Table 9 Self-efficacy Questions

#	Questions	M_{pre}	M_{post}	t
SE1	Compared with other students in this class I expect to do well.	5.20 (1.20)	5.68 (1.23)	-3.72**
SE2	I expect to do very well in this class.	5.48 (1.10)	5.73 (0.98)	-2.08*
SE3	I think I will receive a good grade in this class.	5.31 (1.25)	5.79 (1.34)	-3.25**

SE4	My study skills are excellent compared with others in this class.	4.45 (1.04)	5.61 (1.21)	-1.66
SE5	Compared with other students in this class I think I know a great deal about the subject.	5.37 (1.13)	5.42 (1.35)	-0.31
SE6	I know that I will be able to learn the material for this class.	5.54 (1.13)	6.05 (1.24)	-3.87**

Note. $N = 110$; M = mean; Standard deviation in parentheses, * $p < .05$, ** $p < .01$

Overall, the responding students generally agreed with the questions, indicating high self-reported self-efficacy. For SE1 and SE3, the number of students who agreed with the statements increased slightly in the post-survey compared to the pre-survey as shown in Figure 13. For SE2, both the number of students who agreed and those who disagreed increased, as some responses shifted from neutral. For SE4, SE5, and SE6, the number of students who agreed increased, while the number who disagreed decreased, indicating positive improvement. The responses to SE4 through SE6 suggest that students' self-efficacy regarding their skills, knowledge, and abilities was self-reported to have increased in the post-survey compared to the pre-survey.

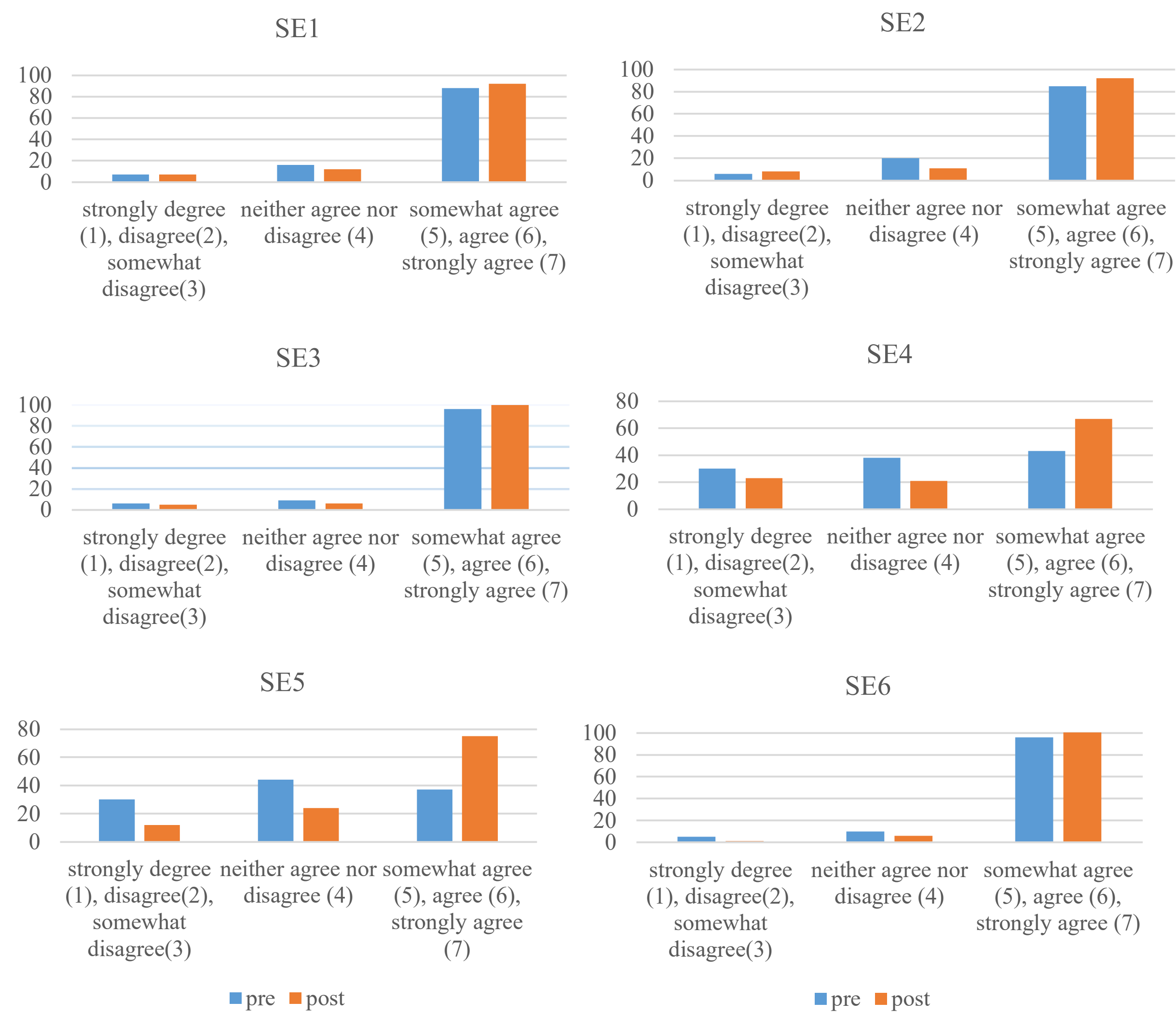


Figure 13 Qualtrics Survey: Self Efficacy

3.4 Academic performance

To evaluate students' overall achievement compared to previous semesters, the average total scores from four consecutive semesters were analyzed. In recent years, average scores have improved, reflecting better student performance. This trend continued in 2024, with the average score reaching 90.7 as the highest (see Figure 14). Student scores are influenced by many factors, including preparedness, intellectual aptitude, the instructor, and teaching methods. While we cannot control students' preparedness and qualifications, the high scores suggest that the used teaching methods did not negatively impact student performance.

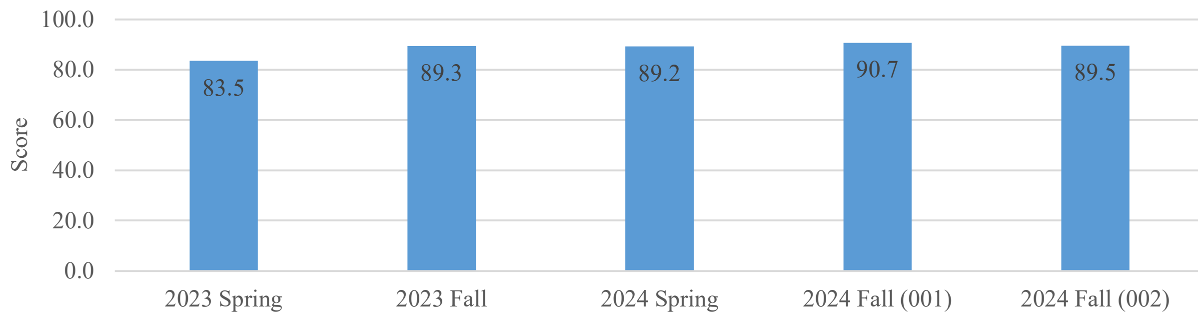


Figure 14 Average course total scores: recent trend (out of 100)

Furthermore, improving retention rates is critical to ensuring that aspiring engineers remain in the program and successfully complete their studies. To evaluate the impact of recent course changes, the grade distribution for the Statics course was recorded and compared across several semesters in Figure 15. The percentage of students earning grades of A and A- has shown a steady increase over the years, reaching over 80% for Fall 2024, Section 1. This trend suggests that more students are achieving high levels of understanding and mastery of the course material. Notably, the percentage of students receiving grades D and F dropped significantly following the introduction of teamwork activities in Spring 2024. This decline in low grades may indicate that the collaborative and interactive components of the course might have enhanced student understanding, engagement, and overall success. These results suggest the potential of teamwork-based learning strategies to improve both individual and collective outcomes in engineering education.

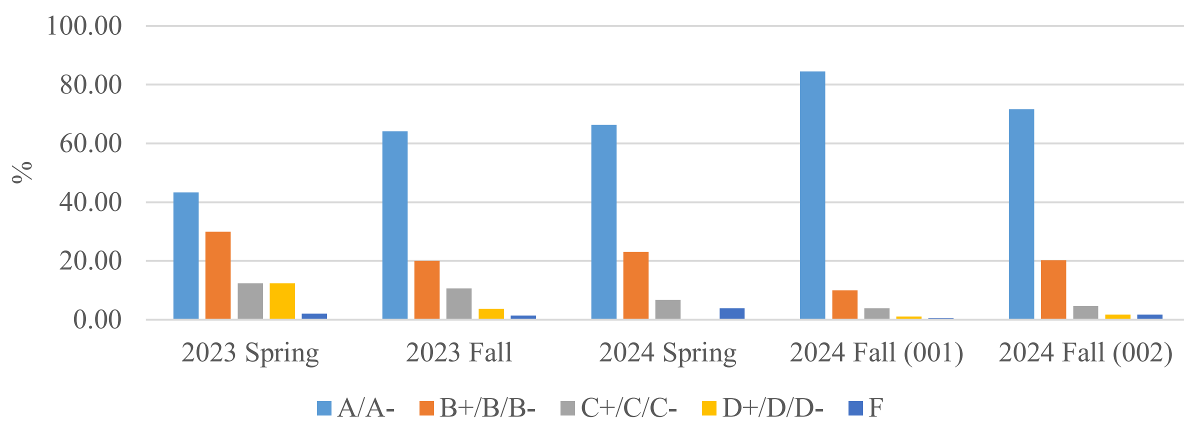


Figure 15 Course Grade Breakdown: recent trend

4 Lesson learned and discussions

Professionalism skill acquirement: Based on the in-class semester reflection, over 70% of students reported noticeable improvement in their teamwork skills after completing this course, compared to their proficiency before enrollment. This suggests that the course design successfully fosters growth in teamwork. Students consistently noted that the course helped them develop critical skills, including communication, teamwork, and professionalism.

Additionally, insights from the Student Evaluation of Teaching (SET) reinforced these findings, with a predominant percentage of respondents reporting enhanced teamwork and communication abilities. For many students, engaging in collaborative projects provided them with practical opportunities to navigate group dynamics, resolve conflicts, and communicate effectively.

However, some contrasting perspectives emerged, particularly among students in Section 2. A subset of these students expressed that they were already proficient in professional skills, leading them to perceive the class activities as less beneficial.

Despite these differences, the overall positive feedback indicates that the course successfully equips most students with the tools to excel in collaborative and professional environments. Future iterations of the course might consider differentiated approaches to better address the varying skill levels among students, such as offering advanced activities for those who demonstrate proficiency early on. This could ensure that all participants, regardless of their starting point, find the course both challenging and rewarding.

Metacognition skill acquirement: A substantial percentage of students reported that they had already acquired metacognition skills, particularly in areas related to planning and debugging strategies, as observed in the Qualtrics pre- and post-surveys. In terms of self-evaluation of metacognition skills, more students expressed agreement in the post-survey compared to the pre-survey, indicating some improvement in this trait over the semester. The continuous self-assessment and evaluation processes integrated throughout the course may have contributed to this improvement, reinforcing the importance of these practices in developing metacognitive abilities. Feedback from the Student Evaluation of Teaching (SET) further supports these findings, with over 70% of students indicating that metacognition activities helped them reflect on their learning and achieve their goals. Two student quotes illustrate the positive impact of these activities:

- *"Be more conscious of the amount of time that I'm putting into studying and getting ready for exams and how that reflects within the results of my exams. It also helps because I know then how to better prepare myself for the next exam and what study methods work best for me. It keeps me more aware of what I need to actively do to do better on exams."*
- *"Yes, the metacognition activities helped reflect on your learning and achieve your goals because they tested whether you were paying attention during the lesson. This also created engagement with the lesson."*

However, not all students found the activities equally beneficial. Some felt they already possessed metacognition skills and therefore found the activities less helpful, though they acknowledged the value these practices could have for peers without such skills. Additionally, some students viewed metacognition exercises as extra work, expressing a preference for using that time to focus on problem-solving tasks instead.

These insights suggest that while metacognition activities were broadly effective for most students, future iterations of the course could consider balancing these activities with problem-solving opportunities or tailoring them to accommodate varying skill levels.

Self-efficacy: Data from the Qualtrics surveys showed that most respondents reported higher levels of self-efficacy regarding their overall performance by the end of the course. This suggests that the course activities, particularly those focused on metacognition, contributed to students' confidence in their abilities. Metacognition activities are instrumental in helping students assess their performance more realistically by encouraging reflection on their learning processes and outcomes. This realistic self-assessment allows students to identify areas for improvement, leading to better academic performance and increased confidence.

The surveys also suggested a significant improvement in students' perceptions of their knowledge acquisition. A larger percentage of students agreed with statements about their acquired knowledge in the post-survey (SE5) compared to the pre-survey. This indicates that, after completing the course, students not only felt they had gained more knowledge but also perceived themselves as more knowledgeable than their peers. Such a shift in self-perception reflects an increase in confidence and self-efficacy, which are critical components of professionalism. By understanding their strengths and weaknesses, students can more effectively navigate professional challenges and engage in lifelong learning.

Moreover, the link between improved academic performance and self-efficacy is worth noting [33]. As students observe tangible improvements in their outcomes, such as better grades or enhanced understanding of course material, their belief in their capabilities grows. This increase in self-efficacy can create a positive feedback loop, where students are more motivated to set and achieve higher goals, further strengthening their professional skills.

To build on these findings, future iterations of the course might consider expanding metacognition activities that emphasize actionable feedback and personalized goal setting. Such strategies could help students translate their increased confidence into practical, professional outcomes, fostering not only academic success but also long-term career readiness.

5 Conclusions

The implementation of teamwork and metacognition activities in the large Statics course demonstrated a positive impact on students' professionalism and academic performance. Teamwork activities enhanced students' communication and teamwork skills while supporting the course's learning objectives in problem-solving and critical thinking, as supported by high academic performance and assessments. Students also reported improvements in self-efficacy related to self-evaluation, highlighting the value of metacognition activities in fostering self-awareness and reflective practices. The usage of the new active learning classroom played a crucial role in enabling these outcomes by facilitating team activities and providing opportunities for moderation by the teaching team. Moreover, metacognition activities contributed to the cost-effectiveness of teamwork by training students to be effective self-evaluators, enabling peer and self-feedback mechanisms. These efforts showed a strong potential to advance the dual goals of academic excellence and professional development of a large course such as Statics.

Acknowledgments

This material is based upon work supported by the National Science Foundation under IUSE/PFE:RED Grant No. 1920761. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation. The support is gratefully acknowledged.

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