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A Multidisciplinary Joint Senior Design Project in Engineering and Computer Science

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This paper presents an interdisciplinary, cross-team, year-long senior capstone project involving eleven students from Electrical Engineering (EE), Mechanical Engineering (ME), Computer Engineering (CPE), and Computer Science (CS) at our university. The project, H-Mobile, is a semi-autonomous robotic device with forklift-like features. H-Mobile provides remote control and self-driving assistance, navigating to target heavy objects, lifting them, and then carrying and depositing them where the user wills. This project aims to assist individuals who are movement-impaired when attempting to retrieve objects at home. Over the course of three quarters, a group of engineering students identified the problem and developed a broad solution, beginning with pitching ideas to CS students and forming their joint team in the fall, followed by designing and prototyping in the winter, and final integration in the spring. A team contract and deliverable list were outlined along with the joint team formation. This addresses common challenges faced in interdisciplinary collaboration by emphasizing clear roles, shared goals, and continuous communication. A weekly joint-team meeting with a faculty member, rotating among the EE, ME, and CS disciplines, and a quarterly presentation to the advisory board serve to further facilitate this process. The paper discusses project structure, collaboration strategies, and lessons learned from implementing a multidisciplinary and cross-team capstone experience, contributing valuable insights into engineering education and team-based project management.

Keywords: Multidisciplinary, cross-team, and Capstone senior design project

1. Introduction

As the complexity of engineering problems has increased in industry, senior capstone design courses have increasingly emphasized joint and cross-team work experiences that mirror real-world, collaborative engineering environments. Previous studies have presented various models of team-based capstone projects, including the integration of capstone courses with student competition design teams [1], the use of nested or hierarchical team structures within a single discipline [2], and collaborative senior design projects conducted across geographically separated institutions [3]. Collectively, these efforts demonstrate the pedagogical value of teamwork, coordination, and communication in capstone education. While these studies highlight important aspects of team-based learning, many focus on collaboration within a single discipline, within a single course structure, or between similar institutional contexts. Few provide insight into the deep, sustained, multidisciplinary collaboration between engineering and computer science students operating as a unified, joint design team.

Our university has been offering an engineering senior design project course for more than 35 years. Since 2010, it has been framed as a year-long senior design project for all engineering majors, including electrical engineering, computer engineering, general engineering, and mechanical engineering. This aims to significantly enhance students' communication and project management skills through interdisciplinary and complex design projects, aligning with ABET student outcomes related to effective communication, collaborative engineering practice, and the ability to apply engineering design in complex, real-world contexts [4].

In the past, the Computer Science program at our university offered a quarter-long capstone design project course. In 2022, the Computer Science program changed its capstone design course from a quarter to a year to synchronize the course sequence with the engineering design project. The change was made with the goal of encouraging collaboration between CS and Engineering students, fostering cross-team environments, and preparing students for the multidisciplinary and cross-functional nature of today's workforce. No joint team was formed due to students' concerns about the complexity of cross-team interdisciplinary projects and the communication difficulties between teams, blurring lines of responsibility. Students were concerned that their success would heavily rely on the other team.

In the fall of 2024, an engineering team interested in developing an autonomous robotic device was paired with a computer science team willing to develop a remote-control phone application with a monitoring function. This project is designed to assist individuals with movement impairments in retrieving heavy objects at home. The project team consisted of two mechanical engineering students, one electrical engineering student, two students double-majoring in electrical and computer engineering, and six computer science students. Three faculty members, one from Electrical Engineering, one from Mechanical Engineering, and one from Computer Science, were assigned to facilitate this project. The student teamwork self-assessment survey and course grades were applied to assess the teamwork and evaluate the quality of the project.

This cross-team, interdisciplinary project aligns with ABET outcomes by enabling students to identify and solve complex problems through the integration of hardware and software systems, and to apply engineering design to create a safe device that supports individuals with disabilities. Communication and teamwork improved for both teams throughout the entire year of collaboration. Ethical and societal considerations were also addressed through a focus on accessibility, safety, and user-centered design.

2. Interdisciplinary Collaboration cross Teams

In the fall quarter of 2024, students from both teams collaborated on drafting their team contract (Appendix A) to outline clear communication rules and expectations. They then signed a deliverable list that defined the appropriate scope of work for both sides (Table 1). The engineering team began their risk reduction prototyping for the remainder of the fall quarter and provided a test bench for the computer science team by the end of the quarter. The winter quarter served as the primary prototyping stage for both teams; the weekly check-in meetings provided them with a platform for sharing questions and problems with one another. Faculty members would step in when communication problems and conflicts arose and coached students to help each other with respect and humility.

Table 1. Project deliverable lists from both teams

The deliverables list from the Engineering team.

- Grabbers extend, grasp, and retract
- Drag the load onto the platform
- Platform lifts load up
- Grabbers push out the load at any height
- Device drives with the platform in a lower position
- Warning labels and instruction manual

The deliverables list from the CS team.

- Level 1: Movement from mobile controller, Camera/sensor data as input. Replay undo/redo and reverse. Working mobile Recalibration Emergency Logging features
- Level 2: Voice activation (Optional) Quick turn/quick movement options (Turn 90 degrees, etc.)
- Level 3: Camera identification, Pathing and navigation, Go to the charger

In the spring quarter, students collaborated closely to integrate the projects. Every quarter, engineering students underwent two individual design reviews within the engineering senior design course and one joint presentation with the CS team to the advisory board. Students also sought extra funds to support their project from the advisory board.

To facilitate collaboration across disciplines and teams, multiple communication channels were established: (1) the Joint Teams used Zoom for online weekly meetings and (2) GitHub for document sharing and version control. In addition, (3) in-person weekly meetings were held within each team's capstone course. Communication was conducted through Microsoft Teams, Emails, GitHub, and in-person conversations. Weekly joint meetings hosted by one of the instructors served as the core of collaboration, where students shared progress updates, addressed integration issues, and aligned upcoming tasks. The meeting notes and action items document is a simple yet beneficial tool for both students and faculty members to track team issues and project progress.

3. Student Learning Outcomes

Students developed technical design and analysis skills, as well as project management and teamwork skills, through their capstone design courses. The previous paper examined how our university's engineering senior design course learning outcomes align with ABET Outcomes [4].

Besides the general learning outcomes, in this joint senior design project, the ME students developed skills such as CAD modeling, Kinematics, and actuator integration. They were able to manufacture most of their parts in the on-campus mechanical shop. The EE student designed a power management PCB circuit for their system and learned how to wire the entire power and control systems. The two double-major students took motor control, sensor integration, PID control, and embedded system design. All the students in the engineering team gain more hands-on experience through manufacturing and rapid prototyping.

As requested by ABET, we intend to expose students to industry standards, safety, and compliance. IP rating of the electrical housing and safety labeling standards was integrated into their final deliverables. The entire CS team successfully developed a mobile app, including Bluetooth communication protocols, sensor data processing, state management, a logging system, and error handling. It is worth noting that both teams developed cross-team integration skills, including system integration, version control, integration testing, and field testing, which give them a deeper understanding of the project design process in the complex joint project.

Students' interaction within the team, cross the team, and with faculty members are the three important venues for students to develop their communication skills. Students from EE, ME, CPE, and CS brought diverse technical perspectives, vocabulary, design approaches, and expectations. Weekly joint-team meetings with faculty advisors rotating among the participating disciplines were effective in addressing both technical challenges and team management issues. Our student feedback consistently indicated that this close and continuous faculty mentoring helped clarify roles, align expectations, and resolve misunderstandings early, thereby reducing friction among team members commonly observed in interdisciplinary settings. A project management software is recommended for implementation in the future joint project.

From a project management perspective, students learned valuable lessons about coordinating. The use of a shared team contract, clearly defined deliverables, and regular progress reviews encouraged accountability and transparency. Faculty guidance during weekly meetings helped students balance subsystem-level optimization with overall system integration, a challenge frequently encountered in real-world engineering projects. As a result, students developed a stronger appreciation for systems thinking and cross-functional communication.

4. Assessment of Teamwork and Quality of Projects

The student teamwork self-assessment survey covers the areas of commitment, communication, problem-solving, conflict handling, and meeting conduct. The survey form is included in Appendix B as a reference. Students are requested to individually rate their overall team based on the team's ability to see tasks through to completion, team's performance in being open to new approaches and listening to new ideas, team's performance in avoiding placing blame, and instead discussing the process improvements, team's performance in ensuring everyone participates, team's performance in getting input from entire team before a decision is made, team's performance on choosing an appropriate time and place to discuss and explore the conflict, and team's performance on coming to meetings prepared. Each item is listed as 1-5 points from lowest to highest; 5 points represents the most satisfying outcome.

The average satisfaction scores for the three quarters are presented in Figure 1. The other two engineering-only senior design teams (Team 1 and Team 2) are utilized as a control experiment.

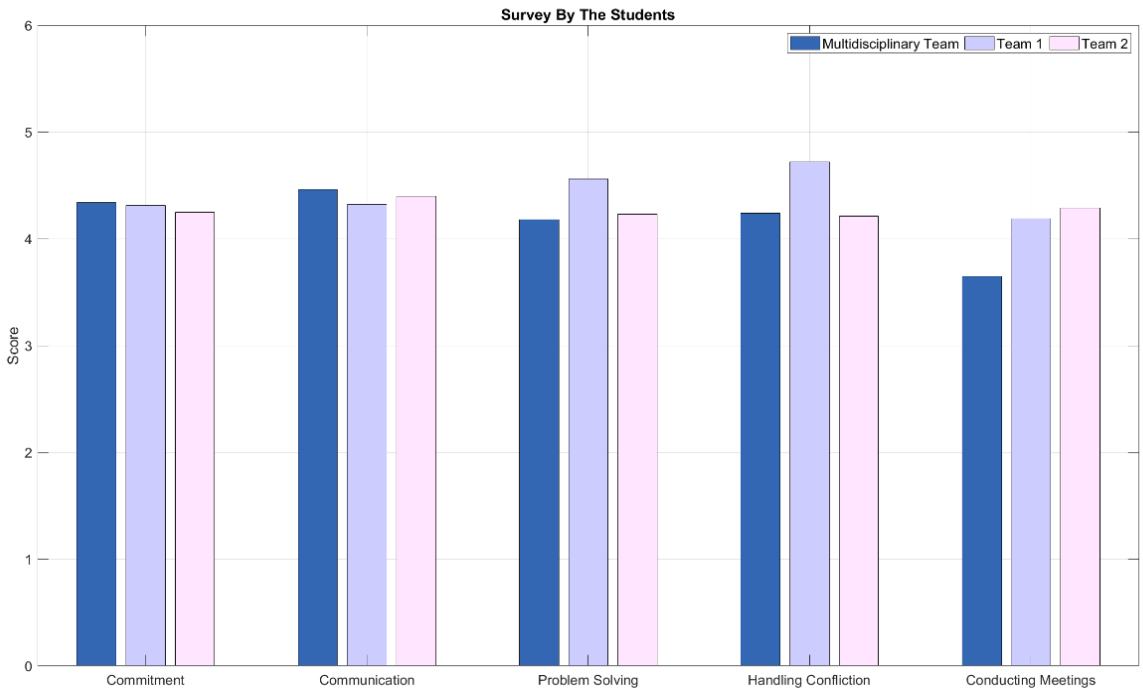

Fig. 1 Student Teamwork Self-Assessment Survey Results

In the student teamwork self-assessment, the joint team excelled in the categories of commitment and communication, as the students initiated the collaboration and demonstrated stronger ownership of their project. In addition, instructors provided extra attention to coaching cross-team communication and made extra efforts to host weekly check-in meetings led by the instructors, which helped the joint team achieve better communication than the other two teams. However, the joint team struggled in the categories of problem-solving and conducting meetings. Due to the nature of the joint project, students were faced with more problems to solve in a complex working environment. “Conducting meetings” is used to assess the team's performance in coming to meetings prepared. After analyzing the conducting meetings score quarter by quarter to identify the reasons, it was found that the joint team was comparable to the other two teams in the first two quarters and then dropped dramatically in the final quarter of integration.

Here are some key takeaways from this experience. First, Integration is the most challenging period of collaboration, and it requires more attention from instructors to assist students in navigating this stage. In reverse, instructors mentored them in the other direction, as we wished they had already acquired the soft skills in the final stage and could run autonomously. Second, it would be important if the joint capstone design project were structured identically and followed the same timeline, so that students are evaluated using the same rubrics. This was our first trial, and the CS and Engineering teams were following different CS and Engineering Capstone course curricula, which created some discrepancies that frustrated students, particularly in the final integration stage.

Course grades were used to evaluate the quality of the senior design projects. 60 % of students’ final grades were determined by project execution. Instructors also considered advisory board feedback while grading. The joint team has the highest grades across all three quarters in all the engineering senior

design projects. The average joint team grade exceeds expectations, demonstrating that the joint team meets learning outcomes. In the future, a project quality survey for both instructors and advisory board members could be included to assess the joint project's quality, using a more quantitative approach.

5. Pedagogical and Technical Challenges Through the Collaboration

Students in different majors have various backgrounds and working styles. Diversity brings both opportunities and challenges in collaboration.

Technical hurdles often arise due to the differences. To address their knowledge gap, instructors offered additional technical lectures, seminars, and Q&A sessions during weekly meetings and after class. Lectures on mobile system modeling, control system design methods, and PID controller tuning are beneficial for both CS and Engineering students, helping them close the gap in their knowledge of both hardware and software.

In addition, instructors mentored students in design iteration and taught them to use effective tools and strategies to handle team conflicts. As presented earlier, students faced more conflicts in a joint working environment. For instance, the engineering team was inclined to plan proactively due to the lengthy cycle of hardware manufacturing and design reiteration, and they requested that the software team assess their capacity for software implementation in this manner in advance. It created difficulties for the software team, as their design process was disrupted by these requests. Instructors advised the software team to triage these requests based on project requirements, technical constraints, and the shared deliverable list. Additionally, all major decisions and resolutions were required to be documented, along with a point of contact, in the weekly joint meeting notes. This approach helped the joint team function effectively as a cohesive unit, engage in constructive conflict resolution, and apply engineering principles to make informed decisions consistent with ABET student outcomes.

To mitigate the challenge of different working styles, engineering students were required to create a common testing platform, known as a test bench, to share the actual development environment with CS team members. The engineering team set up the ROS middleware on GitHub and shared it with the CS students. The engineering students also developed and shared a test bench with the installed middleware, allowing CS students to solve problems through hands-on practice. Attempting to solve these problems purely through theory would have wasted time and offered little practical learning. By encouraging the Engineering team to lead the setup and enabling collaboration, the CS students were able to use the continuously updated test bench for their app development. This approach promoted practical learning and effective interdisciplinary collaboration.

6. Recommendations for Future Projects

Based on the lessons learned from the joint capstone design project, the following recommendations are offered for future joint projects.

1. Collaborative design reviews are recommended for a joint capstone design project. Unified grading rubrics and shared expectations from instructors are essential for the project's success.

2. Emphasize integration from Day one, strategies such as schedule integration in different phases, not just a final integration, identify at least one integration risk discussed in every weekly meeting, and require an integration failure analysis report in the final deliverables can be considered.
3. Design a joint capstone project design process with iteration and recovery opportunities, and normalize the early setbacks as part of the process.
4. Include project management software in the process.
5. Mentor students with effective tools to handle team conflicts.

7. Summary

The project had a positive impact on students' readiness for professional engineering practice. The joint team's work environment, which required students to collaborate with peers from other majors, closely mirrored industry settings where engineers must work cross teams and specialties. Frequent interactions with students from other disciplines and participation in joint presentations further reinforced this experience, helping students develop confidence in explaining their design decisions to non-specialist audiences. This exposure served as an important stepping stone toward careers in industries where inter-team collaboration is the norm.

The inclusion of joint-team presentations and question-and-answer sessions during advisory board meetings provided a more industry-like and practice-oriented learning experience. Students were required to articulate system-level trade-offs, respond to critical feedback, and defend their design choices in a professional setting.

Overall, this multidisciplinary, cross-team capstone project functioned as an experiential learning activity. The combination of close faculty mentoring, structured collaboration, and industry-aligned evaluation created a learning environment that not only supported successful project outcomes but also significantly enriched students' preparation for real-world engineering practice.

8. Acknowledgement

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Appendix A: Team Contract

Team Contract:

We agree to:

- Meet at the agreed time.
- Not have our tasks to influence other team.
- All functionalities will be independent between teams.
- Grading rubric and responsibility attribution will be completely separate for both teams.
- Team representatives will come to the meetings prepared.
- Share issues with other team at the beginning of every meeting.
- Clearly assign and carry out progress and updates (i.e. progress %, scheduling, weekly reports, etc.)
- Ensure everyone participates.
- **INTEGRATION GRADING FOR BOTH TEAM WILL BE WEIGHTED AND ATTRIBUTED EQUALLY.**
- Listen openly to other team's viewpoints.
- Address any blocking issues that come up quickly and with high levels of communication

Meeting Times: We agree to meet at least once per week during at least one of these times. Ideally a majority of team members from each sub-team (Software/Engineering) will be present.

Mondays 5pm-6pm

Wednesdays 11am-12pm

Appendix B: Questions in Student Team Self-Assessment Survey

Commitment

1. **Rate your team's ability to see tasks through to completion.**
   Examples -
   5 stars: We had an ongoing action item list, we reviewed and updated the action items every week, and finished all tasks on time or early.
   4 stars: We had an ongoing action item list, we reviewed and updated the action items every week, and finished all tasks... sometimes we were late on tasks though.
   3 stars: We had an ongoing action item list, but struggled to keep it updated and sometimes we were late on tasks.
   2 stars: We had a vague idea of what tasks we needed to do every week, and everyone kind of did what they were supposed to do.
   1 star: We didn't organize tasks and didn't complete tasks on time.
2. **Comments: Where did our team excel? Where can our team improve? Please provide *specific* examples of successes and struggles and how they were supported or addressed.**

3. **How can our team be *even better*? Specific actions that could improve team performance in this area**

Communication

1. **Rate your team's performance in being open to new approaches and listening to new ideas.**
   Examples -

   5 stars: We were receptive to ALL team members' ideas or approaches, even if it they were weird or unreasonable. We took these ideas seriously and considered ways in which their idea or approach could have merit. We asked constructive questions to get to the heart of what they were communicating.
   4 stars: We were receptive to MOST team members' ideas or approaches as long as they were reasonable. We asked constructive questions to get to the heart of what they were communicating.
   3 stars: We discounted several unreasonable or weird ideas.
   2 stars: We discounted MOST unreasonable or weird ideas.
   1 star: We did not listen to any new ideas or approaches within our team.
2. **Rate your team's performance in avoiding placing blame, and instead discussing the process improvements.**
   Examples-
   5 stars: When faced with problems outside our team's control, we ALWAYS found ways to get the work done. Our team NEVER blamed each other or other circumstances during meetings or project updates.
   4 stars: When faced with problems outside our team's control, we MOSTLY found ways to get the work done. Our team RARELY blamed each other or other circumstances during meetings or project updates.
   3 stars: Our team had SOME circumstances outside our control, which caused us to struggle. In at

least one of our project updates or during meetings, we blamed our status on the problem.
2 stars: Our team had MANY circumstances outside our control, which caused us to struggle. In our project updates or during meetings, we blamed our status on the problems.
1 star: Our team frequently found circumstances outside of our control, and we indicated who or what the problem was instead of finding ways to do the work.

3. **Comments: Where did our team excel? Where can our team improve? Please provide *specific* examples of successes and struggles and how they were supported or addressed.**
4. **How can our team be *even better*? Specific actions that could improve team performance in this area**

Problem Solving

1. **Rate your team's performance in ensuring everyone participates.**
   Examples -
   5 stars: All team members attend ALL team meetings. During the meetings, we ALWAYS make sure everyone's voice is heard and feels valued. We create a positive work environment for all team members.
   4 stars: All team members attend MOST team meetings. During the meetings, we make sure everyone's voice is heard and feels valued.
   3 stars: Some team members struggle to attend meetings. We are SOMETIMES in a hurry and struggle to make time to ensure all team members have a chance to speak.
   2 stars: Some team member struggle to attend meetings. We are USUALLY in a hurry and haven't been intentional to ensure every voice is heard.
   1 star: Whoever can come will come to our meetings and we don't make time for discussions or keeping everyone included.
2. **Rate your team's performance in getting input from the entire team before a decision is made.**
   Example -

   5 stars: We always make time and discuss with every team member before we finalize a decision.
   4 stars: We usually make time and discuss with every team member before we finalize a decision.
   3 stars: We sometimes make time and discuss with most team members before we finalize a decision.
   2 stars: We only get input from team members who we think are affected by the decision.
   1 star: We have one person who makes all our decisions
3. **Comments: Where did our team excel? Where can our team improve? Please provide *specific* examples of successes and struggles and how they were supported or addressed.**
4. **How can our team be *even better*? Specific actions that could improve team performance in this area**

Handling Conflict

1. **Rate your team's performance on choosing an appropriate time and place to discuss and explore the conflict.**
   Example -

5 stars: When a team member has a concern with someone on their team, they bring it up with the person in private. If that doesn't work, they bring it up with the team. If that doesn't work, they bring it up with the professors.
4 stars: When a team member has a concern with someone on their team, they bring it up with the person in private. If that doesn't work, they bring it up with the team. If that doesn't work, they try to ignore it.
3 stars: When a team member has a concern with someone on their team, they bring it up with the person in private. If that doesn't work, they tell the whole class.
2 stars: When a team member has a concern with someone on their team, they don't talk about it at all.
1 star: When a team member has a concern with someone on their team, they tell the whole class first and make snarky remarks about the person.

2. **Comments: Where did our team excel? Where can our team improve? Please provide *specific* examples of successes and struggles and how they were supported or addressed.**
3. **How can our team be *even better*? Specific actions that could improve team performance in this area**

Conducting meetings

1. **Rate your team's performance on coming to meetings prepared.**
   Example -

   5 stars: All team members ALWAYS came with status updates on their tasks, and completed their assignments ahead of time.
   4 stars: All team members USUALLY came with status updates on their tasks, and completed their assignments ahead of time.
   3 stars: Team members frequently came unprepared, but meetings still followed the agenda and the assignments were mostly completed ahead of time.
   2 stars: Team members frequently arrived unprepared, and meetings occasionally were for completing assignments together.
   1 star: Team members never came to meetings prepared, and meetings were usually just completing assignments together.
2. **Comments: Where did our team excel? Where can our team improve? Please provide *specific* examples of successes and struggles and how they were supported or addressed.**
3. **How can our team be *even better*? Specific actions that could improve team performance in this area**