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BOARD # 177: Contract Grading and Service Learning to Promote Teamwork and Learning in a First-Year Mechanical Engineering Course

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Abstract

A key student outcome for ABET accreditation is the ability to function effectively on a team. Team projects in first-year courses can be powerful in helping first-year students develop community and develop the teamwork skills needed for downstream courses and professional development. The goals of student learning in teamwork can work against typical classroom dynamics where grades are assigned individually. As such, students can feel that team-based assessments are unfair. Students can also feel a lack of motivation towards team projects that seem like merely classroom exercises. In this work, we sought to overcome these dynamics using a combination of service learning and contract grading in a first-year mechanical engineering course in computer programming and instrumentation. In this large course of 111 students, student teams of 5-6 students worked on a service-learning project to support local 4-H education programs. The student teams developed educational materials to teach high school aged youth to build and program robotics systems using the Arduino microcontroller. These projects were made publicly available to youth via a class website. Contract grading was used to allow project teams to set their own goals and assess their achievement of those goals. In this contract grading, teams designed a set of criteria for what a high-quality product would look like. These criteria include goals for the code and construction of the robotics system, the instructional materials developed, and the quality of their teamwork. At the end of the semester, teams were required to assess their performance based on the contract grading rubric they created. A public-facing and externally motivated service project allowed students to see beyond individual goals such as grades. Contract grading allowed groups to take ownership of their projects and assessment in the light of these external goals. Assessment of the results of these rubrics and a voluntary, anonymous survey of students in the class found that students learned to recognize the qualities of shared responsibility, commitment to the team, communication, and respect of teammates as important to teamwork success.

Introduction

A key program educational objective for Accreditation Board for Engineering (ABET) is “an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.” Teamwork skills are valued by future employers as an important skill set. However, teamwork is not always well defined. Perusich et al [1] has defined teamwork as 1.) the ability to be interdependent in tasks, 2.) to share responsibility for outcomes, and 3.) to work together as an intact social entity. Shuman et al [2] defined teamwork skills to include the ability to solicit input from the team, the ability to build consensus and resolve conflicts, and leadership skills. Chowdhury and Murzi [3] defined teamwork by a set of attributes including: shared goals and values, commitment to team success, motivation for the team task, interpersonal skills, open and

effective communication, constructive feedback, diverse team composition, leadership, accountability, interdependence, and adherence to team process and performance.

While teamwork is often assessed as an outcome in capstone courses, first year courses can serve as a cornerstone, developing basic skills in teamwork such as the ability to be interdependent in tasks, the ability to share responsibility for outcomes, and the ability to work together as a single entity with shared goals and values. Team projects in first year courses can also be powerful in helping first-year students develop community and can particularly be powerful for first-generation students that may lack the cultural capital of their continuing generation peers [4], [5]. The goals of student learning in teamwork can work against typical classroom dynamics where grades are assigned individually. As such, students can feel that team-based assessments are unfair. Students can also feel a lack of motivation towards team projects that seem like merely classroom exercises. Frustration can develop when some students are seen as not contributing to a team while receiving the same credit.

Contract grading can facilitate the development of a partnership with students on learning goals [6], [7]. It involves developing joint responsibility for student learning by creating a mutually agreed upon evaluation processes. This can be created through a number of mechanisms but typically involves an agreed upon set of metrics for evaluation. Sometimes, these agreed-upon metrics are assessed by instructors and other times these are assessed by students or in conjunction between students and instructors.

In this paper we will examine the use of service-learning and contract grading in fostering student learning in teamwork in a first-year computer programming course for mechanical engineers.

Course and Project Description

The course is an introductory-level mechanical engineering course. This course teaches programming skills with a focus on programming Arduino microcontrollers in C++ for the first half of the semester and programming in Matlab for the second half of the semester. This course is supported by 1 faculty member and 2 graduate teaching assistants. In Fall 2024, the course had 111 students who completed the course. The course has a 50-minute weekly lecture, a 110-minute weekly lab (two sections), and a 50-minute discussion section (four sections). The course has both individual and team components. Individually, each student was responsible for completing a weekly lab assignment (5 points), a weekly in class activity during the lecture (5 points), and a weekly homework assignment (5 points). There were also three 150-point exams (two on Matlab and one on Arduino). These individual activities constituted 83% of the total course grade.

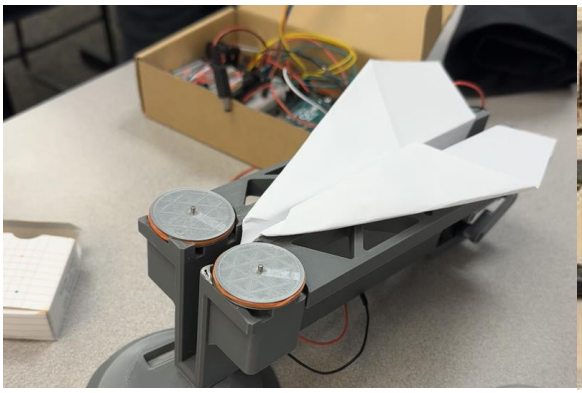
The remaining 17.5% of the total course grade was a semester long team-based project with teams of 4-6 students (Table 1, Figure 1). The project was to create a robotic system using the Arduino microcontroller that fits within the rules for the 4-H county fair and then to create instructional materials such that a 10-18 year old youth participating in 4-H could recreate the

project. For the project there were many deliverables. The first were weekly deliverables (5 points each) that were due during the discussion section. During a typical discussion section, each team presented their deliverable to the instructor or a graduate teaching assistant. Each team member must be present (or obtain an excused absence) to receive deliverable points and twice during the semester each team member must be the primary presenter (for an additional 10 points). Towards the end of the semester, the team presented their final product in a poster and physical demonstration to representatives from the community partner (20 points). Finally, the team submitted their final deliverable that includes the code for the project, the instructions for the project, and a video demonstration of the project. At the same time, each team member submitted an individual final report which is an assessment of their team's project based on a rubric created by the team earlier in the semester. Finally, 30 points were assigned at the end of the term based on full participation in the project as determined by two team peer reviews and instructor observation.

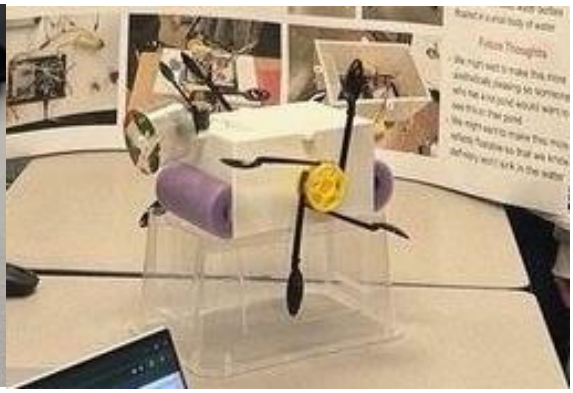
Table 1 Point Structure for the Project

	Number	Points	Total	% of Project Score	% of Course Total
Present Deliverables	2	5	10	5.7%	1.0%
Weekly Deliverables	13	5	65	37.1%	6.5%
Project Presentation	1	20	20	11.4%	2.0%
Final Report	1	35	35	20.0%	3.5%
Individual Assessment	1	15	15	8.6%	1.5%
Participation	1	30	30	17.1%	3.0%

The weekly deliverables had both individual and group work such that 41% of the total project grade was based on individual activities and 59% of the total project grade was based on the performance of the team. A significant proportion of the grade was based on individual activities to encourage all students to be accountable to the team. It was also important to have a strong proportion of the grade be based on success of the team to promote interdependence of the team.

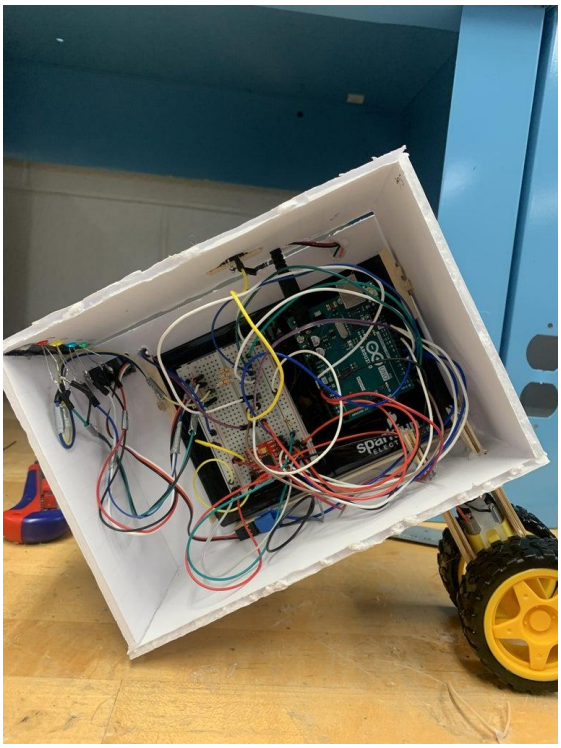


a. Automatic Paper Plane Launcher



b. Fish Feeding Rowboat

c. Coin Dispenser



d. Light Sensing Robotic Car

Figure 1 Teams created a range of robotic systems such as those illustrated here. These systems were expected to meet the requirements for the 4-H Robotics requirements for the Kansas state fair. The teams were then required to create instruction for youth to create the project. These instructions were made freely available through the website instructables.com.

Service Learning and Community Partnership

To better engage students in teamwork, it was important that students value the team's task. In an earlier paper, we introduced the use of service learning in our team projects [8]. A goal of

this effort was to motivate teamwork by adding external value to team projects. The service-learning project consisted of developing instructional materials for the building of Arduino-based robotics for use by youth participating in 4-H robotics competitions at county and state fairs. Our community partner is the Kansas 4-H Program. 4-H is a network of youth organizations supported by federal funding to support learning in youth aged 5 to 18. Youth participating in 4-H have the opportunity to compete in county and state fairs in many categories including computer science and robotics. Youth competing in the robotics competition are required to create a free-standing robot no larger than 2 feet wide, 2 feet high, and 2 feet deep with some kind of automated articulated structure. Teams within the course were asked to create a robotic system using an Arduino microcontroller that could successfully be entered into the county fair. They were then asked to create a clear set of instructions to construct the project, including computer code and an instructional video. These instructions were shared using the website instructables.com. Links to these instructions were then made available to the local 4-H program through a university website [9].

Promoting Teamwork in Deliverables

To promote teamwork, several elements were included in the weekly deliverables including a team contract, weekly reflections on teamwork, and two mid-semester peer evaluations. During the third week, the team was asked to create a team contract that included:

1. defining performance expectations for team members (such as showing up to team meetings of completing work by group identified deadlines),
2. defining roles for each team member (such as meeting planner, code manager, etc.), and
3. defining a meeting schedule.

During week four, the team was asked to research project instructions available on the internet (including those created in previous semesters). From those instructions, the team was asked to develop a list of qualities that define an exemplary set of instructions for a robotics project. In week six, after completing brainstorming and selecting a project idea, the teams were asked to create an assessment rubric for their final project that included the following categories:

1. Physical Construction and Operation of System
2. Code Complexity and Quality
3. Originality and Functionality
4. Instructions and Video Quality
5. Final Poster and Device Presentation
6. Team Characteristics and Functioning

For this rubric, the teams were asked to define levels of performance (expert, proficient, apprentice, and novice) for 3-4 qualities with each category. The teams were given a template to create their rubric and one quality under physical construction as a guide. For this sample quality “Project Requirements and Appropriateness for 4H”, expert level was “Project meets all requirements for 4H robotics. Project is well formed for a high school student and would be fun

and exciting to create.", proficient level was "Project meets all requirements for 4H robotics. It is doable for a high school student.", apprentice level was "Project doesn't meet all requirements for 4H robotics. It is missing elements to make it doable for a high school student.", and novice level was "Project is missing on several requirements. It is not likely to be doable by a high school student as presented."

During weeks seven and thirteen, each individual was asked to complete peer and team evaluations using ITP Metrics team assessment tool [10]. This tool returns reports to both the instructor and team members with ratings on a scale of 1-5 on commitment, communication, capabilities (knowledge and skills), focus (keeping the team on track), and maintain high standards. In addition, each week, each individual was asked to reflect on the team's collaboration for that week. They were asked to discuss how well their team communicated, how well work was documented so others could understand it, whether everyone contributed as promised, and whether everyone felt they were respected by their team members. These reflections were presented during the discussion section but the presenter for that week.

Contract Grading

During the final week of the semester, the teams were asked to submit their final product (Arduino code, project instructions, and a video). In addition, each team member was asked to use their team's rubric to examine their final product and grade their performance based on the qualities they selected and levels they created. Most students rated their team between apprentice and expert in the qualities they had selected. Average team scores across the 6 categories ranged from 2.35 (apprentice) to 4.0 (expert) (Table 2).

Table 2 Range and average of team scoring across the six categories (1-novice, 2-apprentice, 3-proficient, and 4- expert) for 20 teams.

	Minimum Team Average Rating	Maximum Team Average Rating	Average Team Rating
Physical Construction and Operation of System	2.3	3.9	3.4
Code Complexity and Quality	2.7	4.0	3.7
Originality and Functionality	2.9	4.0	3.5
Instructions and Video Quality	2.9	4.0	3.6
Final Poster and Device Presentation	2.0	4.0	3.6
Team characteristics and functioning	2.4	4.0	3.6

While most students gave a range of scores reflecting their confidence in the quality of their final product, it should be noted that some students did give their team an "expert" (4) rating in all qualities, even when that score was likely not deserved. A few students also misunderstood the process of rubric scoring and submitted materials that were not usable for these ratings. As such,

the qualities defined by the students were used by the instructors for the final product grading, but we didn't end up using the students' scoring as part of the final assigned grade. In this first semester of using contract grading, a comparison of instructor assessed scores and student assessed scores found a very weak correlation ($R^2 = 0.04$) between after student assessed total score and instructor assessed total score. In a second semester (Spring 2025), we improved the process of contract grading self-assessments by providing additional instructions on how to create and submit a scored rubric and by offering students a chance to revise rubrics after beginning construction of the projects. Future work will examine if these efforts improve the quality and accuracy of student self-assessment relative to instructor expectations.

While there were limitations in the utility of the final submitted scores, the process of creating a rubric and self-assessment was very valuable. A voluntary exit survey (Table 3) demonstrated that students were able to recognize the importance of shared responsibility, commitment to team success, and open and effective communication in team activities. Similarly, the qualities selected by teams for the teamwork category of their rubrics reflected these qualities with 66% of teams having a quality that reflected shared responsibility (such as "everyone contributes and is knowledgeable", "each member does their share", "doing fair share with equal contributions", "all team members contribute to the group's success"), 78% of teams having a quality that reflects commitment to the team, 72% having a quality that reflects communication, 55% having a quality that reflects treating teammates respectfully, and 22% having a quality that reflects flexibility (2 teams did not create qualities under the categories and were excluded from these percentages).

Survey

At the end of the semester, a voluntary and anonymous survey was conducted to assess the course with the approval of the University of Kansas Human Subjects Committee. Twenty-four (24) of the 111 students participated in the survey. In this survey, several questions were asked about student learning and activities around teamwork. Of those that responded, 65% reported interacting with the project teammates outside of the project activities including supporting each other doing homework and studying for exam. Of those that responded, 26% of the students reported interacting with teammates outside of the class activities suggesting that these projects were important in building community amongst these first-year students. Using a Likert scale, students were asked to assess the importance of qualities to teamwork (Table 3). Students reported shared responsibility for outcomes, open and effective communication, and commitment to team success as the most important qualities for future team projects. They reported that they were largely successful as team members in these qualities although closer to somewhat successful as a team in these qualities.

Table 3 In a survey, students were asked to assess how important the listed qualities are for teamwork in future team projects on a Likert scale with 0 being not important and 100 being very important. Students were also asked to rate their success as a team member as well as their team's overall success (0 being not successful and 100 being successful).

	Important For Future Team Projects	Most Successful at as a Team Member	Team Most Successful With
Shared Responsibility for Outcomes	85.3	81.0	77.8
Commitment to Team Success	83.2	89.2	80.3
Open and Effective Communication	84.3	86.8	81.7
Constructive Feedback	66.3	70.0	70.4
Leadership	76.0	77.7	73.2
Interdependence	68.3	77.1	76.3
Soliciting Input from Teammates	73.9	76.6	72.0
Consensus Building and Conflict Resolution	76.2	80.6	80.0

Conclusion

In this work, the combination of service learning and contract grading was used to instill in students important characteristics of successful teamwork including shared responsibility, commitment to team success, and communication. The rubrics created by the students reflected these qualities and students' self-assessment on these rubrics and survey responses reflected student learning on the values of these characteristics. In future work, we will examine how self-assessments can be made clearer to students, a few of whom had difficulty understanding the use of rubrics. We also plan to examine the potential for using the student's self-assessment more directly in grading for the course. In this course, teamwork represented only a small proportion of the total course grade (17.5%). However, the methods described here could be used in courses such as capstone design where teamwork is a larger portion of the total grade. Contract grading methods allow for assessment to be tailored to projects that might be variable in presentation by allowing teams to designate the important qualities of a project and then work to achieve those qualities.

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