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VEX College-Level Robotic Competition Senior Capstone Project

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Senior Capstone Project

Abstract

The Accreditation Board for Engineering and Technology (ABET) requires inclusion of a capstone project to baccalaureate engineering technology programs. Capstone project courses integrate technical and non-technical skills from coursework with project management skills. A capstone project requires the solution of open-ended engineering problems with imposed constraints and has clearly defined goals and deliverables. Past practice at the University of New Hampshire at Manchester (UNHM) was to solicit industry sponsored projects from industry partners. Several difficulties arose with industry projects: lack of an adequate number of projects, limited faculty control over project scope, project funding changes, industry personnel changes, and team versus individual student on a project. An alternative method was desired to provide an entire class with a common college sponsored project. The solution chosen was the VEX U college level robotics competition. This paper describes the implementation of the VEX U robotic competition at UNHM as the capstone project.

During the past three years the capstone course has used this competition. An initial investment purchased 10 robot kits and a competition field. This outfits a class size of 25 students working in 5 teams. The first-year implementation cost was approximately $1200 per student and the second and third-year cost under $400 per student. With the outbreak of the COVID pandemic and safety restrictions occurring just prior to the first year of implementation, this choice was timely and allowed the college to provide a capstone project for a full class of students. Faculty had the ability to control and adapt the project as needed. During the second-year, restrictions eased, and faculty again adapted the project. All students were required to participate as a member of a team. Each team planned, designed, built, programmed, and tested two robots to compete in a final end-of-course competition following the established constraints and rules from the published game manual. Faculty had the option to include additional constraint requirements within game rule criteria. The competition at the end of the course can be tailored to be an official VEX event or a stand-alone event for the college course students only. Due to COVID restrictions, stand-alone competitions were held. The first year, small elimination type competitions were held due to student room space restrictions. The second and third year, a single competition event was held which included spectator attendance.

Despite the pandemic and restrictions imposed, a successful capstone project was provided for each student. If the industry project model had been used, it is doubtful that all students in the course would have had successful projects. An important ABET student outcome is the ability for students to work on a team. This is accomplished with the common project model as all students are required to work on a team. Faculty has considerable control over the project which was not possible with the industry project model. While still utilizing the published game manual rules, milestones can be implemented over the course for each semester such as design reviews, robot function demonstration and testing, practice competitions, and team presentations.

Introduction

The Accreditation Board for Engineering and Technology (ABET) – Engineering Technology Accreditation Commission (ETAC) requires baccalaureate engineering technology programs to include a capstone project. Capstone project courses are designed to develop the student's ability to integrate technical and non-technical skills [1]. Technical skills are developed in the normal sequence of required coursework. The non-technical skills such as communication, time management, project management, and interpersonal skills such as teamwork are developed throughout the capstone course. The University of New Hampshire at Manchester (UNHM) uses a two-course, one academic year capstone project (fall and spring terms). The course combines both Mechanical and Electrical Engineering Technology (MET-EET) program students.

An ideal capstone project involves an open-ended engineering problem or project with no one specific solution. There are constraints and limitations which narrow the solution to the problem or project. Major elements of the capstone course should involve the standard phases of the Engineering Design Process listed in Figure 1. Different authors use variations for major and minor phases or steps but most versions cover the same process. For example, Mott et al. uses four phases [2] and Budynas et al. uses six phases [3]. The phases listed in Figure 1 are used in courses taught at UNHM. The Engineering Design Process most often involves iteration between phases, and it is not uncommon to return to earlier phases when necessary.

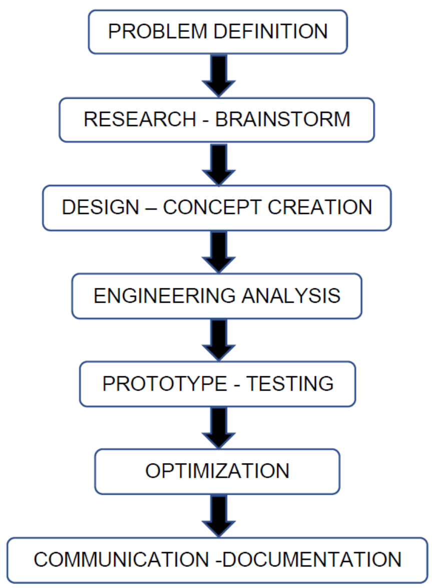

Figure 1. Phases of the Engineering Design Process

Project management and team management skills are developed during the capstone course. Teams are encouraged to schedule and manage their own weekly team meetings outside of class time. Students learn to break down the overall problem into manageable major and minor tasks, then create timelines and schedules. Students must estimate and construct a budget. Each team member performs tasks as assigned, planned, and managed by the team. Successful end-results (deliverables), as well as oral and written presentations communicating the student's solution to the problem are expected. Course faculty act as the engineering manager over the teams and help to facilitate the project and guide student/team progress.

The traditional model at UNHM had been to find industry sponsored projects for capstone projects. These projects typically contain all the phases of the engineering design process stated above for a capstone experience and have routinely been utilized when readily available. Although it may seem a simple and ideal solution to use the industry sponsored project model, there are some major disadvantages. Faculty have had difficulty finding adequate numbers of projects for given class sizes. Attempts to line up projects ahead of the fall semester have not been entirely successful. Industry is controlled by the market and economic considerations. Projects can change drastically or be cancelled, company personnel (project managers) may change, or budgets are modified or cut. Since the project is controlled by the company with an assigned engineering manager who is not faculty, the scope of work can be variable, teamwork may not be integrated, and assessment equity is an issue. One of the ABET student outcomes is for students to effectively function as a member of a technical team [1]. This may not be possible with all industry projects due to the scope of work.

At UNHM, the usual route was to find capstone course projects by soliciting industry sponsored projects from industry partners. With the COVID pandemic restrictions imposed during the spring of 2020, this approach was untenable. The faculty instead shifted to the use of a “common project” for all students in the course which could be managed on campus and by program faculty. The choice was to use a college level national robotics competition.

There are various national and international robotic competitions available for student participation. Many are designed and limited to primary and secondary school age groups. However, there are some competitions specifically geared for college students. College level competitions usually required fully or partially autonomous robot functionality. The three main categories for robot application include ground-based vehicles/systems, underwater vehicles, and aircraft or aerial drones. Robotic application competitions are designed to present real-world design problems and encourage students to find solutions integrating various aspects of technology. An example of undergraduate students participating in an autonomous underwater vehicle (AUV) international competition is discussed in Yusof et al. [4]. A second example of an underwater robotic competition is the Robosub competition discussed in Gilbeault et al. [5]. A manufacturing themed competition is the Agile Robotics for Industrial Automation Competition (ARIAC) which is discussed in Downs et al. [6]. An unmanned aircraft systems (UAS) competition is used as a student project in Walker [7]. A popular television program called Battlebots showcases a combat-style robot competition where robots must disable their opponents using various weaponized actuators. The Battlebot competition is open to private (non-student) and college sponsored teams. An example of a college Battlebot team is presented in Mullins & Peterson [8]. Another approach as presented by Fox [9] is to create an independent, college course-specific, robotic competition. Since the author had previous experience working with the local VEX robotics competition community, the VEX U robotics competition was chosen by faculty for use as the capstone course project for the academic year 2020-2021.

Using a defined group project such as the VEX U robotics competition has several major advantages. This robotics competition offers the same engineering problem to be solved for all student teams. Each student team designs, builds, programs, and tests two robots which compete together within the competition rules and constraints. The team must determine a strategy for their robots to perform the various tasks prescribed by the current game to score a maximum number of points. A published game manual sets rules, limitations, and constraints. The VEX U college level competition is based upon the same game used by the VEX high school level competition. The high school level limits available components which are legal for use on robots; robot construction is limited basically to non-modified VEX robot components. The VEX U college level competition allows the use of additional construction materials and non-VEX components which can be fabricated or manufactured. This modification allows more design options for students thus allowing a more open-ended solution and no one robot design solution. Within this additional material and component allowance, faculty have the option to create additional constraints such as fabricated components to be included as part of the course. For example: UNHM has a machine shop and a 3D printing lab, so faculty require that each robot include a minimum of three machined/fabricated parts and three 3D printed parts.

VEX U Robotics Competition

The Robotics Education and Competition (REC) Foundation sponsors various competition levels for different age groups. The competitions use a game style format. The game style format more easily engages student interest and tends to make learning an enjoyable activity. The game changes yearly, introducing new challenges. The college level competition, VEX U, is a variation on the high school level game with advanced requirements: longer autonomous functionality and inclusion of advanced components for a more open-ended robotic solution. In general, the game uses geometric shaped game objects, includes course obstacles, has goal targets with varying point values, and usually includes a bonus challenge. The objective of the game is to use a two-robot team to manipulate the game objects through the course obstacles and score points within the goal targets. There are timed autonomous and driver control periods. Teams must develop a game strategy and decide if their robots will be either single or multifunctional in scoring options. There is a published game manual with game rules and robot construction and material constraints which is updated periodically.

There are two major types of competitions within each VEX level competition event. Teams must compete with their two robots. The first is a head-to-head match competition where each team of two robots compete against other teams. There are defense and offense strategies. Teams play qualifying match rounds to earn team ranking. Highest ranked teams then play elimination matches leading to a tournament champion. The second type of competition is the Robot Skills Challenge where robot teams compete on the field against the clock with no opposing teams. There are two separate timed rounds for autonomous and driver control. The goal in the Robot Skills Challenge is to score the most points in the timed periods. The scores from both the autonomous and driver control rounds are combined as a total Robot Skills score.

The competition event culminates with two major judged awards, the Design Award and the Excellence Award. The Design Award is for the team which has the best overall robot design including a well documented engineering notebook which describes chronologically the entire design process over the duration of the project. The Excellence Award is the highest award, and includes performance rankings in both qualifying matches, skills challenges, and other judged awards. Judges are recruited from industry partners and non-course faculty.

First Year of Implementation: 2020-2021

The first year of implementation used the VEX game called “Change Up” and involved teams of robots placing balls into vertical goal posts to score points. There was a red team and a blue team with corresponding-colored balls. Each goal could contain a maximum of three balls. Each ball scored in a goal earned points while the top ball gained control of the goal post. Goal posts were oriented in a tic-tac-toe pattern and rows could be scored by teams controlling the goal posts for added bonus points. Robots could “de-score” balls and alter the control of goal posts for a dynamic game.

The first year using the VEX U project was a new experience and the project requirements and milestones were modified from the old industry sponsored project model. Table 1 shows the project milestone requirements by semester and percent semester grade. As the fall semester progressed some necessary changes became evident. The grading of the engineering notebook was changed from three times per semester to a weekly requirement for the spring term. This change allowed faculty to monitor team progress on a weekly basis, which would allow more timely intervention when needed. Since the project spans two semesters, culminating with a competition at the end of the spring semester, the oral and written assignments for the fall semester report on the team’s proposed design solution and game strategy. The oral and written assignments for the spring semester report on the final design solution and competition results for the overall project.

Table 1. 2020-2021 Course Milestones (Gradable Assessment Assignments)

Fall 2020 Assignments	Percent of course grade
Attendance	10
Resume Workshop	10
Literature search exercise	10
Engineering Notebook (3 entries)	15
Oral Presentation (with PowerPoint)	20
Written Proposal Paper (draft and final)	35
Spring 2021 Assignments	-----
Attendance	10
Winter Break activity report (oral)	10
Engineering Notebook (weekly entries)	20
Major Oral Presentation (*URC)	20
Sponsor Evaluation - Competition Day	10
Written Final Paper (draft & final)	30

*URC - Undergraduate Research Conference held yearly at UNHM in April.

Students are randomly assigned to teams by faculty while attempting to equalize membership of both MET and EET students. There were five teams of four students. With the COVID restrictions for students working on campus and the number of students allowed in various lab spaces at a given time, students were allowed to work on or off campus on their robots. Due to these restrictions, coupled with remote access for class time, students were granted leniency with deadlines and hard milestones were relaxed. This resulted in less than adequate work performed by some teams during the fall term. An attempt to have a practice competition requirement set for the early spring semester saw dismal results as teams were not ready with their robots. This put more pressure on the teams to do most of the robot building and testing during the spring semester.

The original plan was to hold a single competition event in late spring where all teams could attend and compete in both the head-to-head matches and skills challenges. Continued COVID restrictions made this impossible. Instead, due to the restriction on the number of students allowed in the lab with the playing field, two mini-competition qualifier events were held with selected teams. Teams competed in both match style and skills challenges during the two qualifier events. A Zoom feed was available for teams not present. Match results were tallied from each mini-event and the three highest ranking teams advanced to compete in a final match style competition held on a third day.

Lessons Learned First Year

The old project model milestones listed in Table 1 were not ideal due to the change to a "common project" plan. Stricter adherence to project milestone dates was needed but with the COVID restrictions and the hardships students were facing, milestone dates were relaxed so that each team could make progress. The fall semester was more difficult for most students. Unfortunately, weak enforcement of deadlines in the fall semester resulted in two teams having limited competitive robot performance and only achieving minimum passing grades for the course. Three teams did very well by building very competitive robots. Another major issue was determining team members' individual performance versus group performance. There was the classic issue of not all team members contributing equally. Separate assessments of individual effort as well as team group performance measures were needed.

Overall, despite the COVID restrictions, all students were able to complete a senior capstone project course. If, instead of the robotic project, students had worked on industry sponsored projects, it is doubtful that all would have had a successful project. The VEX U project saved the capstone course for this particular year.

Second Year: 2021-2022

The second year using VEX U as the capstone project focused on a new game called "Tipping Point." This game consisted of seven movable goals with posts, some with multiple branch posts at differing heights. Two goals were red, two blue, and three yellow (neutral). Game pieces were small curved rings which could be scored in the base of a goal or on goal branch posts. Different goals and branch posts had differing point values. Each team played either as the red team or blue team. Red and blue goals had to be moved to a team's home zone to earn points. Yellow goals were neutral and could be scored by either team in their home zone. This year's game included an "end game" component using a tilting balance platform similar to a see-saw. At the end of the game if a team's correct color goals or neutral goals were elevated onto their balanced platform (platform parallel to the floor) major bonus points were possible. Additional bonus points were also gained for a team's robots balanced on their platform. The strategy for winning this year's game was to get as many goals and/or robots on their team's platform. The rings were low scoring items and ended up being obstacles, getting entangled in the robot's drive wheels.

The milestones were modified from the previous year and geared more toward the common project approach versus the industry project method. Table 2 lists the semester milestones. The engineering notebook weekly entry was retained. Team progress reporting on a weekly basis allowed faculty to follow each team and, if necessary, to offer guidance. A teamwork grade component was added in the fall, which was largely based upon a single self-evaluation assessment. This method was not ideal, as some students graded their contribution level inaccurately as was indicated by other team member input. For the spring term, instead of a single teamwork grade component, an additional requirement for each weekly notebook entry was to record each team member's weekly contribution effort. Two grades were then entered for each notebook assignment, a team or group grade, and an individual grade for each member's contribution. This change allowed faculty to intervene early to adjust team dynamics.

The winter break activity report, which was better suited to the previous industry project model, was replaced with graded scrimmage practice sessions requirements for both match and skills challenge competitions. Students were informed of these requirements and dates during the fall semester. The plan was to encourage work to continue over the semester break and have the robots ready for the event in the early spring semester. This event proved important. After the first practice session with their robots competing on the playing field, students began to become more engaged with the project.

Table 2. 2021-2022 Course Milestones (Gradable Assessment Assignments)

Fall 2021 Assignments	Percent of course grade
Attendance (selected sessions)	10
Resume Workshop	10
Literature search exercise	10
Engineering Notebook (weekly entries)	15
Oral Presentation (with PowerPoint)	15
Written Proposal Report (draft and final)	30
Teamwork Evaluation	10
Spring 2022 Assignments	-----
Attendance	10
Scrimmage and Skills Practice Sessions	15
Engineering Notebook (weekly entries)	15
Major Oral Presentation (URC)	15
Competition Event Day	15
Sponsor Evaluation (faculty)	10
Written Final Paper (draft & final)	20

There were five teams (four teams of four and one team of five students). COVID restrictions started to ease in the fall and more restrictions were removed in the spring term. This helped teams get more work done. Teams were still allowed to work on or off campus. Most teams chose to work on campus. The fall term got off to a good start, but there was still an issue with the level of significant progress with respect to robot building and testing. Student engagement was lacking during the fall semester.

With lesser spring term Covid restrictions, the planned early spring practice competitions dates set were stressed as significant deadlines. All five teams were ready for the first scrimmage match competition unlike the previous year when no teams were ready. At these practice matches, students became engaged once they started to compete against one another. This was a significant turning point where students began to become more interested in the project and had a higher energy level.

UNHM held their first VEX U Robotics Competition in April 2022. The competition was limited to the UNHM capstone course teams. All five teams competed in both the match competition and the skills challenges. One team earned the Design Award for having an innovative mechanism for scoring rings onto the high goal branch posts. The team which emerged as the Tournament Champion (matches) and the Robot Skills Challenge Champion also earned the Excellence Award. Spectators were allowed and teams invited friends and family.

Lessons Learned Second Year

During the second year using the VEX U robotic project, students did not show much interest and enthusiasm for the project during the fall semester. The spring scrimmage practice sessions signified a turning point. Adding milestone events which foster student engagement are needed for the fall semester. Several early design reviews are needed to get students to design their robots sooner. Proposed for next year was a mandatory robot drivetrain practice competition event in late fall. This will ensure that robots are being constructed and some preliminary programming is accomplished before the end of the fall term. Most major team assignments (notebook entries, oral presentation participation, written reports) included individual contribution grades as well as a team group grade. There were still some issues with some team members not contributing equally. This still needs to be addressed by stressing that low team contribution may result in low grades and possible failure of the course.

Project management practices need to be emphasized such as planning time for the testing and troubleshooting phases into their working schedule. Some teams realized this late in the semester when adequate time was not allocated for testing. This affected their outcome at the competition.

Cost of Implementation

Depending upon the number of students and teams, the cost is variable. In the first year using the VEX U platform, the cost was approximately $1200 per student (20 students = $24K). The majority of robot component parts are reusable. The playing field and perimeter remain the same, with the addition of a new set of game elements. Miscellaneous new components include replacement motors, hardware items, and sensors. Prices have risen over the past two years and approximate current prices are reflected in Table 3.

Table 3. Current Initial Cost – (Class of 20 students - 5 teams)

Quantity	Description	Unit Cost	Cost
10	Basic Robot Kits (reusable)	$1900	$19,000
1	Game Field (reusable)	$1300	$1300
1	Game Element Kit (yearly)	$600	$600
----	Miscellaneous components	$3000	$3000
	TOTAL	----	$23,900

Second year costs were much lower. Additional items needed were the new game element kit, replacement motors, additional batteries, hardware items, and consumables. The cost per student for the second year was approximately $400 (see Table 4). This cost is estimated to be the same for subsequent years (plus price increases) unless additional equipment is desired. One such item purchased for our third year was pneumatic component kits at $250 each. For ten robots this would be an additional $2500.

Table 4. Cost second year (20 students - 5 teams)

Quantity	Description	Unit Cost	Cost
----	Miscellaneous expendables	----	$7500
1	Game Element Kit (yearly)	$600	$600
		TOTAL =	$8100

Third Year 2022-2023

The third year uses the new game called “Spin Up.” In this year’s game the game pieces are small semi-foam disks. The object is to score disks by launching or shooting them into a high goal. This is similar to frisbee golf on a smaller scale. Disks which land on the floor under a team’s high goal are scored for the opponent. In addition to the disks there are bi-colored rollers mounted on the field periphery which can be rotated so that they are owned by a team for bonus points. The end-game involves horizontal expansion where a robot tries to cover as many field tiles as possible for additional bonus points. The field floor is made up of thirty-six 2’ x 2’ interlocking foam tiles.

The course milestones have been reformulated to account for changes mentioned earlier in lessons learned from the first two years of implementation. These are listed in Table 5.

At the time of this writing, the spring semester was 85% complete. UNHM held its second VEX U competition in late April. There with five teams (four teams of four and one team of five students) competing. The fall and spring milestones listed in Table 5 worked well for both semesters. These milestones appear to be adequate moving forward into the next year. All five teams were better prepared on competition day than the previous year’s teams. A single team emerged as the Tournament Champion (matches) and Robot Skills Challenge Champion as well as earning the Excellence Award. A second team won the Design Award for their innovative design solutions for disk intake and shooting mechanisms.

Table 5. 2022-2023 Course Milestones (Gradable Assessment Assignments)

Fall 2022 Assignments	Percent of course grade
Attendance (selected sessions)	10
Resume Workshop	10
Literature search exercise	10
Engineering Notebook (weekly entries)	10
Three Design Reviews (oral presentations)	20
Robots Test Event	10
Written Proposal Paper (draft & final)	20
Teamwork Evaluation	10
Spring 2023 Assignments	-----
Attendance (selected sessions)	10
Scrimmage and Skills Practice Sessions	15
Engineering Notebook (weekly entries)	15
Major Oral Presentation (URC)	15
Competition Event Day	15
Written Final Paper (draft & final)	20
Teamwork Evaluation	10

Assessment

The latest set of course milestones (gradable assessments) listed in Table 5 at present are working well for the course. The students are more engaged as evidenced by most team members contributing equally and excitement levels shown at competitive events (robot testing, scrimmage matches, and skills challenge practice sessions). The project moved forward toward the April competition with successful design review presentations which involved the entire class and invited guests (working engineers) critique and questioning. During the fall semester, the resume writing and literature search assignments have been retained from the original version of the course which used the industry sponsored projects model. The resume workshop is useful for students preparing to enter the work force or for working students preparing for new employment opportunities. The literature search assignment is conducted jointly with the UNHM library staff to educate students on finding and citing reputable source material to conduct research.

Assessing teamwork is an ongoing process. Individual team member contribution levels are assessed using student self-assessment evaluation forms along with summary information from the team’s weekly notebook entry information. Each team member is required to fill out a Team Member Individual Contribution Course Project Evaluation form twice each semester. This team evaluation form targets the overall team member contribution related to the overall course project and is tied to the Teamwork Evaluation line item in the course milestones (see Table 5). Table 6 shows the Team Member Individual Contribution Course Project Evaluation form. Each team member rates all team members (including self-rating). Another method used to evaluate team participation uses specific milestone group assignments. The URC Oral Presentation and Final Written Report has both a team or group grade and an individual team member contribution grade component. A similar team member evaluation form is used for each assignment with specific ratings related to the particular assignment (see Table 7).

Table 6. Team Member Individual Contribution Course Project Evaluation

Team Member Name	Percent contribution: overall team project (%)	Attendance: scheduled meetings and work sessions (0-10)	Communication with other team members (0-10)	Completion of assigned tasks within the expected time. (0-10)
1				
2				
3				
4				
5				
	Total = 100%	----	----	----

Notes: Percent contribution: 4-person team ideally each contributes 25%, 5-person 20%.
Attendance, communication, and completion of tasks: 0-10 scale (10 being highest)

Table 7. URC Presentation Team Member Individual Contribution Evaluation

Team Member Name	Percent contribution to overall PPT Presentation Efforts (%)	Number of PowerPoint slides member contributed	Communication level with other team members for assignment (0 -10)	Completion of assigned tasks for this assignment (0 -10)
1				
2				
3				
4				
5				

Notes: Percent contribution: 4-person team ideally each contributes 25%, 5-person 20%.
Communication, and completion of tasks: 0-10 scale (10 being highest)

Student Feedback

Student feedback has been mixed. During the first year of implementation some students were opposed to the common project plan and wanted to pursue the old model using an industry project. Other students who had experienced difficulties working on a team or with team member participation issues wished that they had done their project alone. However, many students did enjoy the project. A couple of notable examples included two EET students pursuing MET project related tasks on their robot designs. Another student who had limited programming experience decided to take up the challenge to pursue more programming related tasks. Many students realized once the project was underway that time management and project management skills were vital components. The practice scrimmage competitions, practice skills challenge sessions, and the final competition generated student enthusiasm and excitement. Many students were proud to highlight their robot designs and performance at the competition event.

College VEX U Competition Options

The REC foundation has developed an easy system for hosting a competition at a college. An official competition field along with the current game element kit can be purchased at a reasonable cost. The competition field is reusable each year. The REC provides the software needed to conduct the competition. Competitions can be sanctioned as an official competition event which can be listed on the REC Robot Event webpage and linked to all other official events (possibly function as a qualifier for the World Competition). If linked to the Robot Event webpage it can be open to other college level teams. Each region has an event partner network of high schools and/or colleges which host monthly events leading to the World Championship Competition. An alternate option is to conduct and hold an unofficial competition which does not link to the REC webpage and only the capstone college teams participate. At UNHM, competitions so far have been conducted as unofficial college team events for simplicity and timing. If desired to make the event a qualifier event, it would become necessary to hold the competition much earlier in the spring semester.

Conclusion

Implementation of the "common project" approach with the VEX U Robotics Competition has been a successful project for the past three years. The burden of finding and securing outside industry sponsored projects for the capstone course has been eliminated. The issue of students working on a team on the capstone project is ensured. The first year of implementation was difficult with the COVID restrictions and students attempting to cope with the associated issues both on and off campus. The second year was more manageable, and the spring term saw student engagement increase. The modifications made in Table 5 for the third year have prepared students well for the this year's competition.

Faculty were in full control of the project. By having the project completely in-house versus tied to industry, faculty could adapt as needed especially with the COVID restrictions. The course faculty member acts as the engineering manager directing student project teams over the two-semester course. Deadlines and milestones are set by faculty. Extra constraints as related to curriculum and lab availability within the rules of the game manual were included (e.g., fabricated machined and 3D printed part requirements).

The VEX U competition can be adaptable to fit college budget constraints. A college can choose to host official or unofficial competitions. If it is an official competition, then each year the college must update to a new game. If it were an unofficial competition, the college could reuse previous game setups if desired to help reduce cost. At present, the three years of VEX U Competition at UNHM were unofficial and limited to UNHM course students, the first due to strict COVID restrictions and the second and third because it was simpler. Future competitions may be open and allow other colleges to participate. At present the author is aware of only two other colleges in the New Hampshire, Massachusetts, and Vermont region that have VEX U teams.

The UNHM VEX U Robotics Competition capstone project provided all students with the opportunity to integrate their technical skills gained in previous coursework and their application to a major project. The project involved all the phases of the engineering design process, displayed in Figure 1, which is common to an industry project. Project management skills are gained directly from their involvement with project planning, scheduling, and deliverables. Team dynamics helped to develop team management and interpersonal skills which are important and needed in the industry setting.

Individual contribution assessment is still an ongoing challenge to effectively identify students who are not participating equally. Student self-assessment is not 100% accurate as some students under- or over-rate themselves and/or their teammates.

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