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VERTICALLY INTEGRATED PROJECTS: IMPROVING THE OVERALL UNIVERSITY COMPETITION EXPERIENCE

Gregory D. Chipman
Graduate Student
Georgia Institute of Technology
Atlanta, Georgia, USA

Thomas F. Fuller
Professor
Georgia Institute of Technology
Atlanta, Georgia, USA

ABSTRACT

Beginning in 2009, Vertically Integrated Projects (VIP) courses have been implemented at Georgia Tech. These VIP classes allow undergraduate students to receive academic credit for participating on teams that further faculty research efforts. The teams are multidisciplinary, vertically-integrated, and long-term. Participation on these teams has been shown to help students develop an understanding of project timelines, and effective project communication, while gaining other applicable real-world experience.

EcoCAR 3 is the latest in a series of Advanced Vehicle Technology Competitions (AVTCs) sponsored by the Department of Energy since 1988. At Georgia Tech, the EcoCAR 3 team has been structured using the VIP program to improve the all-around experience of faculty members and the graduate and undergraduate students. Based on Georgia Tech's previous experience in EcoCAR 1, the team leadership hoped to increase participation of undergraduate students, improve collaboration between students and faculty members, and raise retention levels. The team has shown improvements in each of these categories through implementation of the VIP program. Some of the primary challenges that the team experienced during the first year of competition are also presented here, along with plans for further improvement in future years of the competition.

INTRODUCTION

Vertically Integrated Projects (VIP) [1] is a program at Georgia Tech that allows undergraduate students to receive academic course credit for participating on teams that contribute to faculty research. VIP is now instituted at fifteen universities (thirteen in the U.S. and two internationally). VIP is the only program that runs long-term, large-scale teams that are embedded in the research activities of faculty and their graduate students. These VIP teams are multidisciplinary—drawing students from around the university, vertically-integrated—maintaining a mix of sophomores through PhD students each semester, and long-term—each undergraduate student may participate in a project for up to seven semesters. The structure of these VIPs is illustrated in Figure 1. Undergraduate students are integrated with graduate students and faculty members working on long-term research projects. The longevity, up to seven semesters, is a benefit to undergraduate students as it gives them the opportunity to learn and grow over time, in contrast with conventional classes and typical undergraduate research experiences. The continuity of VIP courses also offers the student the necessary time to meaningfully contribute to a significant endeavor in their respective technical area. The VIP course offers students the opportunity to have a unique experience that cannot be obtained in conventional classroom

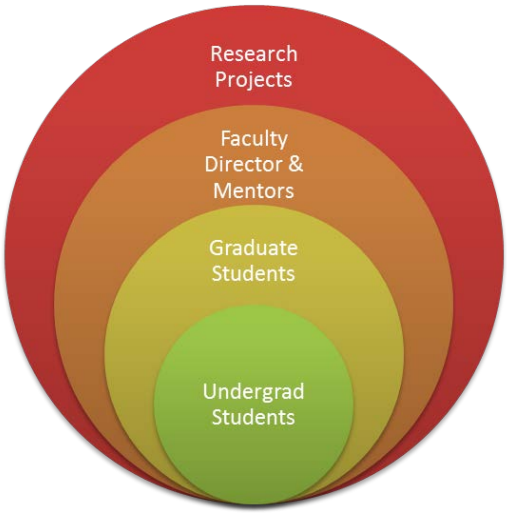

Figure 1. STRUCTURE GOALS OF VIP PROGRAM

settings. These experiences prepare students to better integrate themselves into future industrial projects as they join the workforce.

The VIP course originated as a program called Engineering Projects in Community Service, EPICS [2]. The EPICS program used the same undergraduate student structure as VIP but rarely included the participation of graduate students. This omission of graduate students was principally because the teams focused on projects for local community service organizations and did not have the funding for graduate students. The EPICS program was a service learning program as opposed to VIP, which is an undergraduate research experience. VIP was developed from EPICS with the objective of providing projects of greater technical depth and breadth. As shown in Table 1 (reproduced with data from reference [3]), the percentage of students that responded with a grade of A or B on the impact that EPICS had on their technical skills was lower than their evaluation of other key skills. This fact was the main driving force for shifting from the service oriented structure of the EPICS program to the more research oriented VIP program. This shift provided students with projects that were of a greater technical depth and served to improve their technical skills more than the projects that had been typical in the EPICS program.

Table 1. EVALUATION OF EPICS PROGRAM

Attribute	Average for Spring 1996-Spring 2003
Technical skills	71%
Understanding of the design process	80%
Communication skills	83%
Ability to work on a team	88%
Resourcefulness	79%
Organizational skills	77%
Awareness of the community	73%
Awareness of the customer in an engineering project	81%
Awareness of ethical issues	68%
OVERALL EVALUATION	84%

Undergraduate research is viewed as a critical component of the undergraduate educational experience [4]. In the School of Chemical & Biomolecular Engineering at Georgia Tech., the rate of participation of undergraduate students in research is about forty percent and growing. However, VIP provides an additional dimension compared to conventional research experiences, namely a large team structure that is associated with the projects. VIP also differs because it is by design multi-disciplinary, allowing students to interact with students and faculty members outside of their own major. This type of experience more closely mimics the project environment present in industry. VIP provides another opportunity for students to gain experience that will benefit them as they prepare to enter industry.

Georgia Tech was selected this past year to participate in EcoCAR 3; a four year advanced vehicle technological competition (AVTC) sponsored by the Department of Energy and General Motors (GM). As part of this competition, a team comprised of undergraduate and graduate students at Georgia Tech will be given a stock Chevrolet Camaro to modify into a hybrid-electric vehicle. In addition to improving the fuel efficiency and reducing emissions of criteria pollutants, the design must maintain the performance of this iconic American muscle car. In addition to GT there are fifteen other university teams from North America competing in EcoCAR 3.

As part of the competition, teams are asked to follow a similar design process as that used at GM. This vehicle development process and the nature of the student competition have been described for previous versions of AVTCs [5]. The process is detailed and over the years has become more comprehensive in scope. As a result, the size of the teams are large, and a broad range of skills needed. The competition aspect of the GT EcoCAR 3 team also creates a stark contrast with other VIP programs because of the additional presence of external sponsors that stipulate deadlines and other rules and regulations on the GT EcoCAR 3 team. Other VIP teams often have the liberty to follow their own academic schedule and are largely regulated by the faculty adviser without outside stipulations. This contrast has exposed some challenges with working within the VIP program as part of this competition that will be detailed later on.

Georgia Tech participated in earlier AVTC competitions: Future Truck (1999-2004), and EcoCAR 1 (2008-2011). Based on the team's previous experience in AVTCs, the GT EcoCAR 3 team elected to structure the competition team using the VIP program. The leadership on the team believed that the VIP program would help us to improve in several key areas that had been seen as challenges based on previous AVTCs. The areas that needed improvement included 1) increasing and more evenly distributing the participation of students, 2) improving communication within the team, 3) and raising retention of team members. These challenges were partially addressed with the team structure, and therefore a comparison between the structure used in the EcoCAR 3 competition as compared with that used in previous AVTCs at Georgia Tech is explained. In the next section, the results of these changes will be detailed, highlighting some of the potential reasons for these improvements with implementation of the VIP program. Some new challenges that the GT team has faced in this first year as a result of the team's implementation of the VIP program are also discussed. Finally, the team's plans to improve further the competition team in future years are presented.

VIP SENIOR DESIGN COMPARISON

Among the sixteen EcoCAR 3 teams there are a variety of structures that have been adopted. Many other EcoCAR 3 competition teams are organized around a senior design or capstone design course. The senior design process is well

documented [6]. Comparing and contrasting this common structure with the VIP course structure serves as a good starting place for understanding some of the basic benefits and challenges of the VIP program. The VIP program has a spread of students from first year college students to graduate students. In contrast, a senior design course is composed entirely of college seniors, and for the most part the students are from a single discipline. The VIP course is taken for 1-2 credits by undergraduate students whereas the senior design course is typically four credits or more per semester for the final year of college. Lastly, the VIP course is long term with students participating on the team for multiple years while the senior design course is for one year resulting in a high turnover rate.

The VIP course has a fairly even spread between sophomores to seniors, while in the team's experience being slightly skewed towards less experienced students. The fact that many students are early on in their college experience can create difficulties because they have not developed many of the necessary skills to contribute meaningfully to the competition team. Alternatively, senior design and capstone courses have students who are nearly ready to enter the workforce and who have developed a broad set of fundamental skills as part of their education. Thus with the VIP structure, it has been important to establish training techniques to help underclassmen quickly develop the necessary skills so that they can have a positive experience on the competition team. This positive experience will encourage them to come back in future years when they can contribute more meaningfully and continue to develop their skills on the GT EcoCAR 3 team.

In the VIP program at GT, students typically take 1-2 credit hours per semester—three credit hours are allowed in some cases when combined with a senior design project. In contrast to many of the more typical VIP projects, EcoCAR is externally sponsored and has a rigid set of project milestones. Thus, the workload can be high, and the deliverable's deadlines do not necessarily align with the academic schedule at GT. This situation has created a gap between the amount of work expected for a one or two credit class and the effort needed to make a meaningful contribution to the team. Many students are tempted to give the minimum effort to get the grade they need in the class to balance their demanding schedules. However, if students do not proverbially go the extra mile and put in some extra time beyond the minimum required, they will not be able to make the contributions necessary for the competition team to be successful. The students will also not gain the desired experience from their participation on the GT EcoCAR 3 team.

This situation is in contrast with a senior design course where the workload expected by the students and that required by the competition are comparable. Additionally, the fact that a senior design course is often associated with a final product aligns well with many of the deliverables for the competition. However, both VIP and senior design projects are built to be aligned with the academic calendar, so they both share the difficulty with an external sponsor where deliverables may fall a week, or two, or more before or after the end of the semester. Because there are multiple universities participating in the EcoCAR 3 competition, each with their own academic calendar, there is little flexibility for the competition to match academic calendars.

To further assess a team's ability to complete competition deliverables, the work required by different structures to complete a task will be analyzed. Each task takes a number of student hours to complete. The number of total hours required for the tasks varies with the number of students working on the task. This is because the more students working on the project the more time that is required for collaboration between the students to synthesize their work together. The n^{th} student assigned to a task adds n more communication links [7]. Thus, additional time is required to make sure that each student assigned to the task is on the same page. As more students are assigned to a task, inefficiencies grow. It has also been found that assigning more people to a task follows the law of diminishing returns where each person added decreases the effort exerted by each individual on the task. As you assign more people to a task you will eventually reach what is called the crashpoint of the task, the point at which adding more people actually increases the time required to accomplish a task [7].

For the GT EcoCAR 3 team, critical tasks that required a significant amount of time to complete were split up between too many students, two or three times more students than in a typical senior design course. This division has led to difficulties with coordinating critical tasks, ones that are probably better performed by smaller groups devoting approximately 20 hours per week than the typical 5 hours per week of a VIP student. What's more, it has at times left students feeling isolated and without a strong sense of ownership of the project tasks, leading to diminished returns from each individual's efforts. Given the rule of thumb of three hours outside of the classroom for each credit hour, current students are not obligated to allot the needed time for successfully completing the assigned task. This amount of time dedication is much more typical in a senior design course than in VIP courses as currently constituted.

In order to be successful in future years, the GT team must institute a cultural cross between the one credit course and an extracurricular activity. Students should be aware that the course credit is a benefit for their participation on the GT team, but that for the team to be successful and, ultimately, for them to gain the full benefits of their experience on the team more time will be required of them. Finding students who are willing to participate on the GT team by registering for the course and also have the enthusiasm to dedicate more time than necessarily dictated by the credit hour associated with the course will be key to the team's success in future years of the EcoCAR project.

One major benefit of the VIP program is its longevity. Starting as sophomores, students will be able to participate in the project for up to three years. This prolonged engagement means that the skills they develop will continue to grow and, over time, their experience will increase in value. The longevity of students participation on the GT team also helps with

knowledge transfer as it provides more continuity in the team structure. Therefore, leadership positions can be filled by students with previous team experience. For senior design teams the complete replacement of the team each semester is the largest challenge of their competition team. Each year their whole team structure is reset as they begin with new members participating. Thus, the VIP program will help with the continuity and overall growth of students by allowing them to participate on the competition team for a longer period of time. The model works only if retention is high. For this reason, it is critical that students have positive experiences early on in their participation on the GT competition team. In order to reap the benefits of a more experienced team in later years, team leadership must help the students to want to come back by helping them to have positive experiences early on in their participation on the GT competition team.

ECOCAR 3 LEADERSHIP STRUCTURE

The EcoCAR 3 leadership at Georgia Tech, shown in Figure 2, is overseen by three faculty advisors. The team leadership also includes four students who fill leadership positions that oversee various aspects of the competition team. The four positions are the Engineering Manager, Electrical Manager, Project Manager, and Communications Manager. The leadership oversees nine sub-teams, which include five engineering sub-teams: mechanical, modeling and simulation, innovation, electrical, and controls, and four non-engineering sub-teams: project management, development, facilities, and communications. The sub-teams are each led by an undergraduate student who serves as an intermediary between their respective sub-teams and the upper level leadership. There are approximately 25 undergraduate students that participate on the competition team from semester to semester. Each undergraduate student is assigned to one engineering and to one non-engineering sub-team. The dual assignment was intended to allow them to develop both technical and non-technical skills that will benefit them in their future careers. One additional benefit of the VIP program is that it allows other graduate students to receive elective research credit. This past semester for example, the team had two additional graduate students who were contributing to the competition team by taking the course for elective research credit. They have been especially beneficial in reducing the load on the four managers and in assisting the undergraduate students in better developing the capabilities they need to meaningfully contribute.

The leadership structure splits responsibilities in overseeing the GT EcoCAR 3 team. The Engineering Manager oversees the technical aspects of the project, and assures that the undergraduate students are given manageable tasks to contribute to the technical development of the vehicle. He is also responsible for validating the work of the undergraduate students as they synthesize all their work together into the final product. The Electrical Manager assists the Engineering Manager by overseeing subsets of the technical aspects of the project that are more specific to the electrical and controls

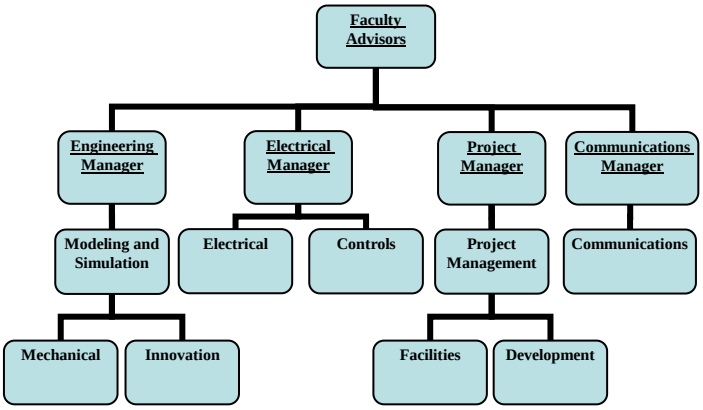

Figure 2. GEORGIA TECH ECOCAR 3 TEAM STRUCTURE

applications necessary for the technical deliverables. The Engineering Manager generally oversees the mechanical, modeling and simulation, and innovation sub-teams while the Electrical Manager oversees the electrical and controls sub-teams. The Electrical Manager collaborates with the Engineering Manager on verifying the final technical products produced by the undergraduate students on the competition team.

The Communications Manger orchestrates the outreach efforts of the competition team as the GT team strives to share the message of electrified transportation. Each competition team is required to maintain an official team website, Facebook, and other online and social media sites. The competition also requires blogs and outreach events to spread certain key messages (*i.e.*, hybrid vehicles and sustainability) to the general public. The Project Manager, a new position on the GT EcoCAR 3 team, oversees the scope, schedule, and budget of the competition. Previously these tasks were also assigned to the Engineering Manager, but this tended to cause these important parts of the project to be neglected as it stretched the abilities of the Engineering Manager. The goal of this newly established position was to assign a team leader who could primarily focus on the non-technical aspects of the competition. A successful project requires a well maintained schedule, a balanced budget, and a visible, well-defined scope to enable collaboration amongst all participants.

The power balance between the Engineering Manager and the Project Manager has been important to establish throughout this first year of competition to enable team success. To evaluate this power balance, a matrix-structure is commonly used. When using the matrix-structure to assess the balance between the Engineering Manager and the Project Manager on the competition team it can either be described as strong, balanced, or weak. “The strength of the matrix is based upon who has more influence over the daily performance of the workers: project managers or line managers. If the project manager has more influence over the worker, then the matrix structure functions as a strong matrix as seen through the eyes of the project manager. If the line manager has more influence

than does the project manager, then the organization functions as a weak matrix as seen by the project manager" [8]. While a balanced matrix-structure is the goal, it can be difficult to find the correct healthy tension between the Engineering Manager and the Project Manager. It is important for there to be constant communication between the Engineering Manager and the Project Manager to ensure that the directives they give to the team are not contradictory. A high level of collaboration is also necessary to guarantee that the team is always on the best path. Another insight that has been gained in this first year of the competition is that the balance is dependent upon the individual strengths of the team's Engineering and Project Managers. The balance between key leadership positions and individual team members is an important aspect of the competition team that could be analyzed in a future work.

IMPROVEMENTS SEEN USING VIP

The goals associated with structuring the Georgia Tech EcoCAR 3 team with the VIP class were detailed as follows:

1.) Increasing participation among undergraduate students.

2.) Establishing better communication among the faculty, the graduate and the undergraduate students.

3.) Improving retention of team members throughout the competition.

In Georgia Tech's experience in EcoCAR 1 it was seen that although the team was a similar size; *i.e.*, approximately 30 members, only a few of those participants contributed in a major way to meeting the deliverables of the team. This imbalance is believed to have been in part due to the inability to integrate new team members with proper training and collaboration. The motivation of individual students also varied, leading to mixed results among the participants on the competition team. The GT team has seen more equal participation among team members in the EcoCAR 3 competition team thus far. Leadership believes this is because of the increased accountability associated with the course class credit associated with the VIP program as well as processes for managing VIP projects. Every team member is expected to attend class on a weekly basis and report on assignments that they have been given by team leadership. Each team member is also expected to keep a design notebook detailing their activities each semester to contribute to the project. These notebooks are reviewed two times each semester by faculty members to provide feedback on each team member's contributions. While these notebooks have sometimes been seen as busy work for the undergraduate students, it has served the purpose of providing a media to show their accomplishments each semester to the faculty. The increased communication with and accountability of each individual has led to more equal participation among the GT EcoCAR 3 team. An additional feature that is part of the VIP process is peer evaluations. Students are required to provide confidential evaluations of other students with whom they worked closely during the semester. These evaluations are available to the faculty to help assess the performance of the team. Even though the comments are not accessible by other students, they have a positive effect on the team dynamics.

While improvement has been seen by using the VIP program structure, further improvements are needed to account for the unique aspects of the EcoCAR 3 competition. These improvements can be accomplished by initiating a few additional practices in future years. Team leadership plans to assign more experienced team members as mentors for new team members, which should allow them to acclimate to the competition team more quickly and provide them with someone who they can feel comfortable asking questions. Mentoring will also help the experienced student as they learn leadership skills through teaching and guiding the newer students. Additional training has also been found to be necessary because of the relative youth of the competition team. Many students enter the VIP program not yet having the necessary skills to independently contribute to the team. In future years, leadership plans to improve the team's training procedures on the pertinent programs by utilizing more experienced team members from this past year to help teach the new team members.

Leadership also plans to begin a more extensive use of Gantt charts to keep track of team assignments and the overall team schedule. Gantt charts are used extensively in industrial project management and cannot in themselves be thought of as an innovation. However, the degree to which these and other project management tools are needed to successfully run an EcoCAR 3 team have been one of the key lessons learned during the first year of competition. Using a Gantt chart structure to assign tasks to team members with clear deadlines increases team members' accountability. The Gantt chart also allows for the assigned student to update their progress on their assigned task on a weekly basis. The expectation for the student to update their progress adds another level of accountability and an increased vision of team member's individual progress for the team leadership.

As discussed earlier, it will also be important to help undergraduate participants become aware early on that full participation on the competition team through the VIP program will require more time than a typical 1-2 credit course that they take in school. Team leadership needs to find students who have the interest level required and who are willing to dedicate this additional amount of time. Lastly, the team plans on moving into the team's garage space at the end of this year. Moving into this garage space will increase team member's participation because the team will all be working in one central location. During this first year of competition, the team has often been working from different locations, which has sometimes led to poor coordination of assigned tasks, along with an inability to receive immediate feedback to questions associated with the assigned tasks. The addition of a central location for the

competition team to work together will improve equal participation by allowing better communication between all of the team participants.

Georgia Tech's EcoCAR 1 team also had insufficient communication between different levels of the team. VIP fosters a greater level of communication between faculty members, and the graduate and undergraduate students. A weekly class time provides a minimum level of interaction for everyone to be in one location to hear general team announcements and see every participant on the team. Each sub-team member also has at least weekly interaction with their sub-team lead who supervises their progress on assigned tasks. The course structure of the VIP program also allows for an emailing system to send emails to the whole competition team, along with the ability to post announcements to the course website. Other commonly used resources, such as the competition rules, have also been posted up on the course website to increase ease of access. The VIP course has improved communication by providing a central, more formalized platform on which the competition team can be structured rather than using a normal extracurricular setting.

Communication, while improved, has still been the most common complaint across all levels of team participants. The team has created a central Google drive location to try to help increase collaboration between team members and improve the visibility of the project status for each team member. Sub-team meetings have also taken more of a central focal point in increasing the level of communication and productivity of each sub-team. Sub-team meetings have been shown as the essential meeting for establishing the sub-team status on a weekly basis, assigning tasks to individual team members for the following week, and addressing any questions and concerns that have come up in the past week.

Georgia Tech's EcoCAR 1 team often had many team members coming and going in short periods of time. These disruptions made it difficult to establish continuity on the project team. A key benefit of continuity is that an individual's productivity increases as the length of time that the student is on a competition team grows. The EcoCAR 1 team did not realize this advantage. As such, it was important for the GT EcoCAR 3 team to increase retention over the duration of the competition. One condition that affected the retention of students in EcoCAR 1 was that participants often did not feel involved, which led to them not having positive experiences with the competition team. There also was no additional motivation for staying with the competition team. The VIP program, as seen above, has helped to ensure that each team member is assigned significant tasks that they can contribute to the project and help them to have positive experiences with the competition team. The VIP class also rewards students with academic credit for their participation on the EcoCAR 3 team, which provides additional motivation for many students to continue to participate on the competition team. The amount of credit that they receive also increases over time as they can register for more credits each year that they participate on the competition team. This all culminates in the ability to use the VIP course as their senior capstone course for some engineering students.

Improved retention of the best students has been seen during this first year of competition. Because of the large number of students who participate in internships and co-ops as well as those enrolled in study-abroad programs, it is common for students to skip a semester. Therefore team leadership defines retention in terms of the percentage of students that have previously participated on the team. The level of retention throughout the team's first three semesters of the competition is shown in Figure 3. Of course, the first semester there were no returning students. However, this metric has grown, and now the figure stands at 50%. The team's long-term goal is to have this number close to 70%. Neither numerical data nor systematic studies are available for EcoCAR 1, but anecdotally retention is vastly improved with the VIP program.

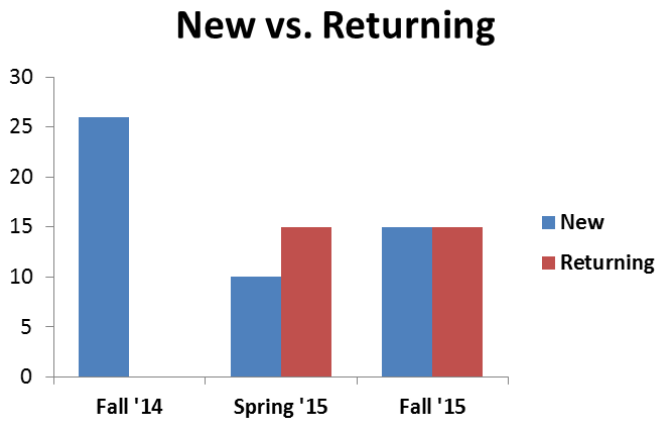

Figure 3 – RETENTION DURING YEAR ONE

To reach the team goal for increased retention, team leadership plans on making expectations clearer from the outset of the VIP course each semester. Even though students are only registered for 1-2 credits each semester, team leadership has found that the required workload is often more than what would be anticipated by an average two credit class and additionally that the work level expectation is fairly uniform regardless of how many credit hours the student has registered. For team members to be effective it has been found that ten hours is expected on a week to week basis. It is important that undergraduate students understand these expectations as they make the commitment to participate on the GT competition team.

Team leadership also plans on improving retention further by the use of mentors. These mentors will provide a friend on the team that will help newer team members to feel more integrated and get to know different team members better. As the team becomes closer knit over time it will help to increase the retention of each team member as they come to enjoy their experience on the competition team more and more. Increased retention will lead to increased productivity as team members are more acclimated to the team competition

environment and have gained more of the necessary skills to contribute meaningfully to the competition deliverables.

The VIP program has been effective in remedying many of the challenges that the GT team faced in the EcoCAR 1 competition. Namely, the team has seen an increased amount of participation that is more evenly distributed amongst the undergraduate students, the communication across different levels of the program has improved, and the team has seen a higher level of retention of the best students on the competition team. While improvement has been seen in all areas, team leadership has detailed some further improvements that are needed. These are currently being implemented and there are plans to adopt further changes to improve the team's ability in each of the above challenge areas for the GT competition team. Because of the break between EcoCAR 1 and EcoCAR 3, GT is in many ways like a new team to the program. The GT team's inexperience has led to their being a lot of areas which could be improved on as the team progresses in the competition. A later paper will report on the outcomes of these further implementations as the GT team continues to learn and gain experience in the competition and in improving the educational value of this project for all of the team's undergraduate participants.

FIRST YEAR CHALLENGES

While improvements have been seen in the EcoCAR 3 team at Georgia Tech, there are still many challenges that team leadership has observed during this first year of competition. These challenges include:

1.) Equal motivation between technical and non-technical aspects of the project.

2.) Communication between faculty and students and between different sub-teams.

3.) Meeting deadlines set by project partners with students whose schedules are relatively inflexible.

4.) Finding ways to help students succeed in a highly self-motivated environment.

What follows will detail these challenges, some successful techniques that team leadership has implemented, and future plans team leadership has to further improve the Georgia Tech EcoCAR 3 Team.

Georgia Tech is one of the premier engineering institutions in the country and, as such, is primarily composed of engineering students. This has led to the challenge of having a fairly 1-dimensional competition team composed entirely of engineering students. A majority of students join the EcoCAR 3 VIP team because of the excitement they have at the prospect of designing a hybrid vehicle. They see it as an opportunity to explore more deeply a topic in which they see themselves potentially working in the future. Many students are not as excited, even unaware, about the scheduling, fundraising, outreach events, or other non-technical aspects of the project that are essential to the project's success. The benefit of gaining these skills is also not as readily apparent to undergraduate students. This lack of enthusiasm has led to the need to place more emphasis on the non-technical requirements of the project to ensure that these necessary tasks are given equal weight with the technical aspects of the project by the students.

This additional emphasis has required the Communications and Project Mangers to work more closely with the undergraduate participants on each of their sub-teams to help them understand what is required. Some of the problem is inherent because of the low awareness and low interest of typical engineering students in outreach and project management activities, but there is also the uneasiness associated with doing unfamiliar tasks that many have never been exposed to previously. Usually, this discomfort level with unfamiliar tasks is overcome by the motivation of the student to learn skills that will benefit them in their future careers. Unfortunately, because many do not see the relevance in many of the non-technical aspects of the project, successful achievement of these tasks requires the tasks to be broken down into more clearly defined, doable sub-tasks to promote team member's success on these non-technical assignments.

Another key to improving participation on non-technical assignments is to get to know individual team members and assign them tasks that more closely align with their interests and strengths. This will help each team member to successfully make unique contributions to the team as they utilize their individual interests and strengths to accomplish assigned tasks. As team members gain experience and familiarity with these tasks it will help them to understand the importance and relevance of the non-engineering tasks in their future careers and to feel a greater motivation for accomplishing the non-engineering aspects of the project.

As the Communications and Project Managers have become more comfortable in their respective roles it has also improved the participation of the undergraduate students on their respective sub-teams. Further improvements that are planned include making goals at the beginning of each semester for the sub-team. For instance, the development sub-team is tasked with reaching out to companies who could potentially help the GT team financially or otherwise to team up as partners or sponsors. The first semester was largely unsuccessful with unclear goals being set. There was improvement seen in the second semester as goals for a number of companies for each student to contact was established. This provided a benchmark for each student to measure themselves against to see if they were meeting the requirements for the non-engineering sub-team. Goals across the different sub-teams with a detailed plan of how to accomplish those goals would be helpful in improving the productivity of each sub-team as undergraduate students are often motivated, but unsure of what is expected from them as a member of the competition team.

Communication between faculty and students, while improved by the VIP program, has still been seen as one of the primary challenges this first year of the competition. Many college students are uncomfortable communicating with professors and consider talking with them as a last ditch effort. Team leadership hopes that continued interaction through the VIP program will help students to realize that the faculty is here to help the team to succeed and that there is no reason to be ashamed or too afraid to ask questions as they experience difficulties with assigned tasks. Team leadership also imagines that with time the comfort level of students will increase and the number of team members approaching faculty for help on the project will correspondingly increase, thus enabling greater vertical integration than currently experienced. In common classroom experiences students often feel uncomfortable asking faculty questions. Team leadership hopes to promote a feeling of collaboration between the students and faculty so that the team's overall performance will improve. As students are more willing to seek feedback from not only the faculty members and graduate students but their fellow peers there will be a marked improvement in the performance of the team.

Additionally, communication within individual sub-teams has improved, but communication between sub-teams has been challenging. Many sub-teams get absorbed in the work that they must complete and neglect the important aspect of ensuring communication between sub-teams to verify that all of the sub-teams are working toward the same goal. Weekly leadership meetings between the faculty and upper level student leadership have been established to improve coordination between different sub-teams. These meetings have shown improvement in assigning different tasks to specific people to distribute to the sub-teams which they supervise. Weekly meetings of sub-team leads with upper level leadership have also been established in an effort to improve collaboration between sub-teams. These meetings allow for a time for sub-team leads to discuss intersecting aspects of the project where close coordination of the sub-teams is important for the overall success in the detailed task. The meeting allows for clearer separation of duties on each task that requires collaboration from two different sub-teams. These meetings have improved the team's ability to cope with this challenge that has been faced during the first year of competition. Although additional meetings can be cumbersome, team leadership has found that they have been necessary to improve the level of communication between the different levels of the competition team and to enable better collaboration between the different sub-teams.

One additional plan that team leadership is implementing next year includes receiving a one slide update from each sub-team lead each week. The slide will detail what progress has been made the past week, what is planned for the next week, and any difficulties or questions they have for the faculty, graduate students, or other sub-teams. These slides will each be reviewed during the weekly leadership meeting. This brief report, while simple, will enable greater visibility between different sub-teams and across different levels of the competition team. The report addresses many of the key areas in which the team has struggled. Namely, the reports ensure that sub-teams are on schedule and are able to receive answers to the challenges that they are experiencing from week to week. These weekly reports should improve the overall performance and communication of the GT competition team.

Scheduling and meeting deadlines of the team's project partner has been challenging because of students' inexperience with the proper way of working towards scheduled deadlines. Many students make their way through school putting out one fire after another, working long hours when necessary but often procrastinating working on assignments until they are closer to the deadline. However, in work environments it is important to plan ahead in order to ensure a higher quality final product by allowing time for collaboration of all team members on the deliverable. Work on the required deliverables needs to be more evenly distributed over the full period of time that is available to allow for higher quality deliverables. Setting internal deadlines has been important to ensure that the team keeps on schedule and to provide enough time before the deadline to receive the necessary feedback from faculty advisors, graduate students, and other team members. The schedule is also challenging because of the inflexibility associated with the schedules of the undergraduate participants. Weeks like finals weeks, spring break, and school project deadlines can be challenging because many students are often unavailable to work during these weeks on the competition project. It has been necessary to think ahead when these weeks approach to ensure that leadership takes into account the fact that undergraduate students will have extremely limited availability during these weeks. Working earlier on deliverables, thinking ahead on the schedule, and establishing internal deadlines have been key in improving the GT team's ability to meet deadlines and produce higher quality deliverables.

Team leadership also plans to implement more extensive use of Gantt charts to help improve the visibility of the schedule for team members, along with a more detailed listing of the team's plan to accomplish the project deliverables. The Gantt chart allows tasks to be assigned to individual students and for the students to update their progress on the Gantt chart so that the sub-team leads can know how everyone is doing on their assigned tasks. The ability to assign individual tasks also makes it easier to see the responsibilities of each individual team member along with the established deadlines for them to accomplish their assigned tasks. Team leadership hopes that the Gantt chart will help to improve the team's ability to meet the competition deadlines as the team works earlier on deadlines and has an increased sense of responsibility and knowledge of the team schedule among each of the individual team members. This will also guarantee that the team puts more effort into the proper scheduling of all the required tasks to be accomplished by the competition team from semester to semester by requiring a more formal presentation of the team's competition schedule for each semester.

The competition team often requires a high level of self-motivation to overcome the ambiguity and difficulty of assigned tasks. Because there is often no "right answer" and no all-knowing supervision, students are often assigned a different type of tasks than those encountered in conventional classroom settings where systems are highly defined. This leads to students often not accomplishing a desired amount of productivity as they struggle to know how to begin. One way to help students overcome these initial barriers are to break down the overwhelming tasks into smaller more digestible subtasks. This breaking down of tasks allows the students to develop confidence in their abilities as they see the progress that they make towards their overall goals. This, along with positive feedback from leadership and internally set deadlines, helps participants to be more successful in achieving the desired level of productivity. This is especially important early on in team members' experience as they are adapting to the different work environment than the one they have encountered in their typical classroom settings throughout the rest of their education.

One reason that this is so difficult is detailed in another paper that discusses challenges faced during another VIP project at Georgia Tech. The paper states that, "the project leaders expect to see autonomy, initiative, intellectual maturity and a certain level of proactiveness while students expect detailed guidance and constant feedback on their progress" [9]. The competition team managers' abilities to bridge the gap between student's and faculty's expectations have been vital in helping undergraduate students to be more productive and successful. Rather than being frustrated by the undergraduate's lack of progress and blaming it on a lack of motivation, it has been important for managers to be willing to invest a significant amount of time early on in the process to help undergraduate students gain their footing. That being said, there still is a significant amount of variability between the productivity of individual undergraduate students that is centered on their motivation level. Undergraduate students need to come with a certain amount of determination to succeed and do their best at assigned tasks or no level of increased supervision will help them to succeed in accomplishing their individual assigned tasks. As with most bridges, both sides need to make additional effort and ultimately meet on middle ground in order for ultimate success to occur. Thus leadership has exerted a greater effort to assign students clearer tasks with internal deadlines that are manageable for the student, but also have made increased efforts to ensure that the team finds students who are willing to put in the required effort because otherwise the team leadership is just wasting their, and the student's, time in a futile effort to be successful.

A certain amount of "hand-holding" has led undergraduate students to grow in confidence as they gain their own footing on the competition team. As leaders assign tasks to the team members it is also important for them to give consistent feedback to each team member to ensure that they are on the proper track for successfully completing the assigned task and avoid further frustration when the assigned task comes due. Internal deadlines set before the final deadline are important for assessing if the students are on track to successfully complete the assigned task, or if a course correction is needed. This is especially important early on in the adjustment period for new team members who may not be fully cognizant of how to best schedule their time in successfully accomplishing assigned tasks. Team leadership believes that establishing a mentor system will also help students to accomplish the assigned task as they are given a key resource to help them finish their assigned task and answer any questions they have regarding how to best proceed in finding ways to address the necessary task that do not always have one, or any, correct answer. This increased level of supervision allows for each team member to have an increased level of productivity as they acclimate to the real world environment present on the competition team.

CONCLUSION

In conclusion, in some areas the VIP program has helped to implement a more successful AVTC project team at Georgia Tech during this first year of competition. There have also been a number of weaknesses identified for the VIP structure when used for the EcoCAR 3 project. On the positive side, the team has seen an increased amount of participation among all team members, and somewhat improved communication between faculty, graduate students, and undergraduate students. Also, in spite of some of the team's challenges, the rate of retention was found to better than in EcoCAR 1, and the leadership's long-term goal of 70 percent is within reach.

Even though team leadership has seen the desired improvement in key areas, the paper detailed some of the initial challenges that the GT project team has experienced during this first year of competition. While there has been better participation by all undergraduate students, there is a definite learning curve associated with the culture of how to best succeed on a project team. Team leadership has found that the best way to help students overcome this learning curve is to give them smaller, more manageable tasks with clear deadlines. Communication has been a commonly identified frustration among team members before and during this first year of competition. Additional meetings to coordinate between differing levels of leadership has been important to enable better collaboration between the varying levels of the competition team, as well as between the different sub-teams. A central location for information has also been key for increasing visibility of required information. Team leadership hopes that weekly reports of key accomplishments along with an increased use of Gantt charts will also help improve communication.

The biggest challenge team leadership has found in this past year has been balancing project deadlines set by the team's sponsors with the fact that VIP students are taking the class for 1 to 2 credit hours a semester and have inflexible schedules. Team leadership plans to better manage the team's schedule by working earlier on deadlines to offer more leeway

with students when the deadline approaches and establishing clearer internal deadlines. This is also important because once the team has fallen behind schedule; team leadership has found it more difficult to involve the undergraduate students as the team seems to constantly be in a race against time. More pervasive use of the Gantt chart system will also serve to increase the sense of accountability and visibility of the team schedule for each team member. Team leadership also plans on using team mentors in later years to help new team members acclimate to the team environment and integrate themselves as a full team member more quickly and easily. The VIP program has been very beneficial to the GT EcoCAR 3 team in this first year and team leadership plans to continue using and improving upon it in the years to come.

Georgia Tech's EcoCAR 3 Team's mission statement is as follows: "To develop a cutting edge hybrid vehicle that exceeds all technical requirements provided by our sponsors via ingenuity and pragmatism while cultivating the potential future leaders of the automotive industry." The education of undergraduate students is one of the primary goals of the GT team's participation in this AVTC and team leadership believes that VIP has helped the GT team in improving the educational benefit for each undergraduate participant on the competition team and team leadership will continue to strive to enable each undergraduate participant to have the most positive and beneficial experience that they can have when they choose to participate on the GT competition team. This positive experience will enable them to prepare themselves to become meaningful contributors in the automotive industry of the future. The VIP program, along with the AVTC, provide experiences that are not conventionally available in typical university education, but that provide students with skills that will enable them to more quickly assimilate in industry.

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REFERENCES

[1] Coyle, E. J., Allebach, J. P., and Garton-Krueger, J., 2006. "The Vertically-Integrated Projects (VIP) Program in ECE at Purdue: Fully Integrating Undergraduate Education and Graduate Research," *Proceedings of the 2006 ASEE Annual Conference and Exposition*, Washington, D.C.

[2] Coyle, E. J., Jamieson, L. H., and Oakes, W. C., 2006, "Integrating Engineering Education and Community Service: Themes for the Future of Engineering Education," Journal of Engineering Education, **95**(1), pp. 7-12.

[3] Coyle, E. J., Jamieson, L. H. and Oakes, W. C., 2005 "EPICS: Engineering Projects in Community Service," International Journal of Engineering Education, **21**(1) pp. 139-150.

[4] A. L. Zydney, J. S. Bennet, A. Shahid, and K. W. Bauer, 2002, "Faculty Perspectives Regarding Undergraduate Research Experience in Science and Engineering," Journal of Engineering Education, **91**(3) pp. 291-297.

[5] Regev, I. D., Snyder, K., Ku, J, Harish, R. Lor, L, and Liu, X., 2012, "Parallel-through-the-road Plug-in Hybrid Vehicle Development Process," SAE Technical Paper 2012-01-1772, doi: 10. 4271/2012-01-1772.

[6] Dutson, A. J., Todd, R. H., Magleby, S. P., Sorensen, C. D., (1997) "A Review of Literature on Teaching Engineering Design Through Project-Oriented Capstone Courses", **86**(1) Journal of Engineering Education, pp. 17-28.

[7] Wysocki, R. K., 2011, *Effective Project Management: Traditional, Agile, Extreme*, John Wiley & Sons, Indianapolis, IN, Chap. 5.

[8] Kerzner, H. R., 2013, *Project Management: A Systems Approach to Planning, Scheduling, and Controlling*, John Wiley & Sons, Hoboken, NJ, Chap. 3.

[9] Viljoen, N. M., 2012, "Managing for the Triple Bottom Line in Project-Based Learning," *42nd International Conference on Computers and Industrial Engineering*, C. S. L. Schutte eds. Curran Associates, Red Hook, NY, 1, pp. 211-222.