AC 2010-2315: ENABLING AND EVALUATING COLLABORATION OF DISTRIBUTED TEAMS WITH HIGH DEFINITION COLLABORATION SYSTEMS

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Randal Abler received the BEE degree from Georgia Institute of Technology in 1986, and worked as a Research Engineer until completing his PhD in Electrical and Computer Engineering in 2000. Dr. Abler's research spans computer networks, embedded systems, sensor networks, and collaborative and educational applications of those technologies. Modern computer networks such as the Internet are a sophisticated combination of computer hardware, network protocols, and user applications. Advances in each of these three components affect the nature of a network in various and sometimes unexpected ways: New computer hardware allows not only higher speed computers but also smaller, lightweight devices such as PDA's and cell phones. New applications bring not only new or better services (voice/video over IP, etc.) but also new challenges as well as malicious applications such as viruses and email spam, which have become commonplace.

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Dr. Julia Melkers teaches and conducts research in the areas of public management, organizational theory, and science and technology policy. Her current funded work addresses collaboration patterns and social networks in science, outcomes of science, and issues around career development and mentoring in STEM fields. Dr. Melkers has conducted performance-related work for the governments of Mexico and Latvia, the American Association for the Advancement of Science, the National Research Council, HUD, the States of Alaska, Georgia, Rhode Island and Maine, the City of Atlanta, and the Atlanta Urban League. Dr. Melkers joined the Public Policy faculty in 2007. She previously was on the faculty of the University of Illinois at Chicago, Georgia State University, and the University of Alaska. She earned her PhD in Public Administration at the Maxwell School at Syracuse University in 1993. She is co-editor of The New Generation of R&D Evaluation Methods: A Cross-National Review of Performance Measurement, to be published by Edward Elgar Publishing in 2007. Her publications may be found in journals such as Public Administration Review, Urban Studies Review, Policy Studies Journal, Public Budgeting and Finance, Journal of Public Administration Research and Theory, Journal of Technology Transfer and Evaluation and Program Planning. Dr. Melkers also serves on the editorial boards of Research Evaluation, Evaluation and Program

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Tamara Clegg is a Ph.D. candidate in the School of Interactive Computing at Georgia Tech in the area of Learning Sciences and Technology. Her research focuses on how we can design technology and learning environments to foster identity development and understanding how this identity development happens. Her research project, entitled Kitchen Science Investigators (KSI) is a hands-on cooking and science program where middle schoolers learn the science behind cooking and scientific reasoning through preparing and cooking food and running science experiments. Throughout their experiences in KSI, learners create explanatoids (short explanations), stories, and annotated recipes in special software that captures their understanding of the science behind their cooking. Tamara's dissertation is focused on understanding how students form identities as scientists, investigators, and chefs, as well as what we can do to foster the development of these characteristics through the program and supporting technology. Kitchen Science Investigators has been featured on CNN and in the New York Times.

Edward Coyle, Georgia Institute of Technology

Edward J. Coyle received his B.S. degree in Electrical Engineering from the University of Delaware in 1978, and master's and Ph.D. degrees in Electrical Engineering and Computer Science from Princeton University in 1980 and 1982. From 1982 through 2007, he was a faculty member at Purdue University, where he served at various times as assistant vice provost for research, co-director of the Center for Wireless Systems and Applications, and co-founder of both the Vertically-Integrated Projects (VIP) program and the Engineering Projects in Community Service (EPICS) program. During the 2006-07 academic year, he was the Kenan Trust Visiting Professor at Princeton University.

Dr. Coyle joined Georgia Tech in 2008 and is currently the Arbutus Chair for the Integration of Research and Education at Georgia Tech, a Georgia Research Alliance Eminent Scholar, and director of the Arbutus Center for the Integration of Research and Education.

Enabling and Evaluating the Collaboration of Distributed VIP Teams with High-Definition Collaboration Systems

Abstract: The Vertically-Integrated Projects (VIP) program creates and supports large-scale, long-term, vertically-integrated teams that pursue design projects embedded in the research efforts of faculty and their graduate students. The undergraduates on these teams earn academic credit for their participation in the projects and benefit from long-term mentorship by the faculty, graduate students, and more experienced undergraduates on their team. In this paper, we report on a unique opportunity for VIP teams at Purdue and Georgia Tech to collaborate on a common VIP project called eStadium. The goal of this project is research, design and deployment of applications related to the real-time delivery of multimedia content over wireless networks to fans' mobile devices in a stadium during football games. To help the teams collaborate to achieve this goal, we have deployed High-Definition Distributed Collaboration (HDDC) systems at Purdue and Georgia Tech. They support two-way, high-definition video links and shared computer applications that together significantly enhance the teams' collaboration on the project.

The VIP Program benefits from a multi-methodological and longitudinal evaluation of progress toward goals and VIP outcomes. The evaluation blends rich interview-based qualitative data with a detailed social network analysis of student-level collaborative interaction and outcomes. The approach draws from studies of scientific collaboration, student learning outcomes, and social network analysis. This paper presents baseline evaluation data on early learning outcomes, student expectations, and the structure and resources of the student VIP networks. The lessons learned from this initial round of assessments will be used to improve both VIP and the collaborative system.

1. Introduction

The Vertically-Integrated Projects (VIP) Program is an engineering education program that operates in a research and development context.[1] Undergraduate students that join VIP teams earn academic credit for their participation in design efforts that assist faculty and graduate students with research and development issues in their areas of technical expertise. The teams are: multidisciplinary – drawing students from across engineering and around campus; 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 three years and each graduate student may participate for the duration of their graduate career. The continuity, technical depth, and disciplinary breadth of these teams are intended to:

- Provide the time and context necessary for students to learn and practice many different professional skills, make substantial technical contributions to the project, and experience many different roles on a large design team.
- Support long-term interaction between the graduate and undergraduate students on the team. The graduate students mentor the undergraduates as they work on the design projects embedded in the graduate students' research
- Enable the completion of large-scale design projects that are of significant benefit to faculty members' research programs.

In this paper, we report on a unique opportunity for VIP teams at different universities to collaborate on a common research project called *eStadium*.[2-6] The goal of this project is research on and design and deployment of systems that enable on-demand delivery of multimedia content to sports fans' wireless devices when they are attending a football game. An overview of the web-based applications that are available to fans in the stadium is available[2,5] as are the mobile web applications themselves.[6] There are additional eStadium projects related to the design of WiFi networks, sensor networks, and software-defined radio for very unique applications in the stadium.[3,7-12] There are sufficient research issues and design projects within this project to challenge eStadium teams at many different universities for many years. VIP teams at Purdue and Georgia Tech have already begun collaborating on this project. Morehouse College and Ohio State are expected to join this effort in the next year.

We have deployed High-Definition Distributed Collaboration (HDDC) systems[13-19] at Purdue and Georgia Tech to facilitate this joint research and design effort. We expect to deploy a third system at Morehouse College next year. These systems enable the teams to conduct virtual meetings with each other so they can work together closely on all aspects of the project. The collaboration currently includes the processes of: project planning, research discussions, and technical presentations. As the project progresses, the processes of project scheduling, system design, development, testing, and deployment coordination will also be supported by the system. Students participating in this multi-university VIP project will thus graduate with the teamwork, communication, technical and leadership skills that they will need to contribute to the geographically distributed teams that are increasingly common in the global workspace.

A thorough baseline evaluation of the VIP program and of this new collaborative aspect in particular are critical to understanding if the program is achieving the goals above and how it can be improved. With the support of a Type 1 CCLI grant from the National Science Foundation, we are conducting the initial formative and summative evaluations of the program this year. The first results from this effort are reported herein.

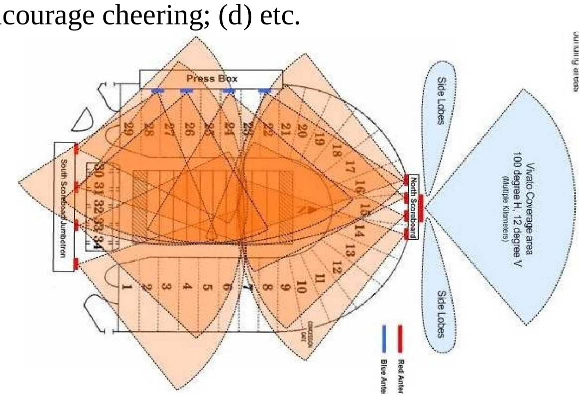
This paper is organized as follows. Section 2 summarizes the eStadium project and describes the many design opportunities embedded in it. Section 3 describes the High-Definition Distributed Collaboration (HDDC) systems that now link Purdue and Georgia Tech. Section 4 describes the progress on the evaluation effort, concentrating on the interviews with students that were conducted this semester and a web-based evaluation focused on the social networks that arise in the student-level collaborations of the eStadium teams. Conclusions are provided in Section 5.

2. The eStadium VIP Team

The eStadium project was launched at Purdue in 2001 by the Center for Wireless Systems and Applications (CWSA), Information Technology at Purdue (ITaP), and Purdue Intercollegiate Athletics. The goal was to create a testbed for both research in wireless networks and development of applications that can be delivered over those networks to fans in Purdue’s Ross Ade stadium. WiFi access points were installed throughout the stadium and multimedia content of interest to fans was captured and made available on Personal Digital Assistants (PDAs) passed out to 65 fans. The content included video-clips of plays during the game, up-to-the-second game stats, player and coach bios, and even a social networking application known as Buddy Finder.

The research issues addressed in this early stage of the project included[1]: (a) characterization and improvement of the Quality-of-Service (QoS) that could be supported by WiFi networks for multimedia applications; (b) study of fan roaming and the hand-offs between APs required to support roaming; and (c) system reliability, cost and effectiveness. The design issues that arose in the creation of the testbed included[1]: (a) the creation and deployment of the on-demand web-based applications used by fans; (b) design of the WiFi network and the video-clip collection and compression system; and (c) integration and reliable operation of the overall system for each home game at Purdue.

The project has advanced significantly since the first video clips were delivered to fans during the Fall 2002 football season. 3G networks have been deployed around the stadium by the cellular companies and the team has designed and deployed a ZigBee-based wireless sensor network in the concourse area of the stadium. Figure 1 shows the WiFi and ZigBee wireless infrastructure deployed in the stadium. A subset of the web pages that were available in a deployment of eStadium at the Cotton Bowl are shown in Figure 2. In addition to these web-based applications, current design efforts have focused on: (a) sensing whether cheering/booing/normal crowd noises are present – in order to label video-clips of plays with their likely popularity to help decide whether they should be delivered by broadcast, multicast, or unicast; (b) acquiring images of lines outside restrooms and in front of concession stands so fans can determine the best time to leave their seats; (c) the creation of games and contests to entertain fans and/or encourage cheering; (d) etc.



(a)

(b)

(c)

Figure 1: (a) WiFi infrastructure designed for the outdoor seating and "tailgating" areas. Verizon, AT&T and Sprint have 3G services in this area, so eStadium applications can be accessed via either network. (b) Sensor network deployment in the stadium: a device enclosure is shown mounted on a beam near a concession stand. It houses a Stargate, a small Linux machine. (c) One of 6 battery-powered MicaZ wireless sensor motes mounted on beams in the stadium's concourse.

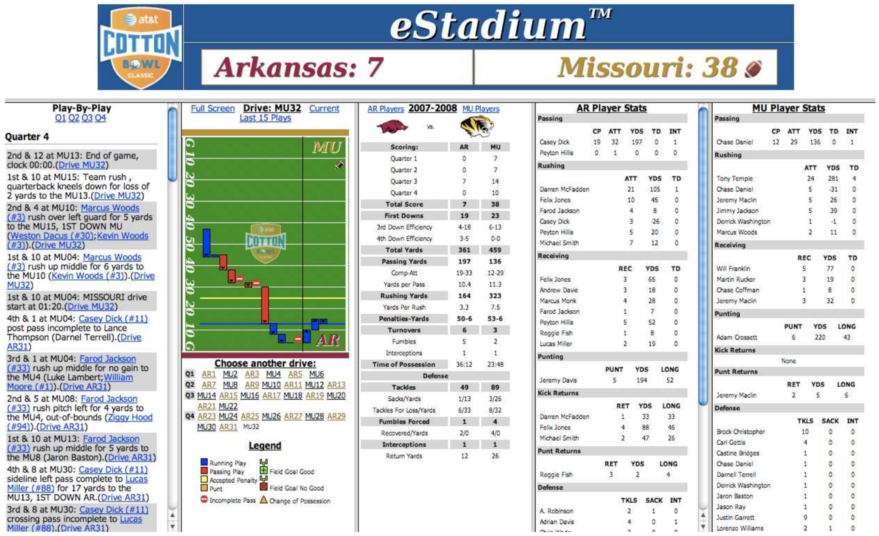


Figure 2: Five eStadium mobile web pages from the Cotton Bowl (shown L to R under banner): NCAA play-by-play; drive vis; game stats; stats for each team. The page of annotated video clips was not available for this game.

The large scale and diverse nature of the research efforts in wireless networks, sensor networks, game design, and social networking requires a similarly large scale and diverse team. For example, the eStadium team at Georgia Tech in the Fall of 2009 consisted of:

- Three faculty advisers, two from ECE and one from CS.
- Three PhD students from ECE and five MS students from CS.
- 20 Undergraduate students from ECE and CS who were a mix of sophomores, juniors and seniors. Approximately half of these students were members of the team the previous semester, which was the first semester the team existed at Tech.

Figure 3 is a photo of the team. The diversity of the team is a testament to the broad appeal of sports to students of many backgrounds. In fact, a number of the students either played football in high school or are self-proclaimed sports fanatics who have attended every football game at Georgia Tech. This is strong evidence that the research/application area of a VIP team can be a critical factor in the participation of a diverse set of students.

Figure 3: Photo showing most of the members of the Georgia Tech eStadium team, Fall 2009.

The flyer used to recruit students for eStadium is attached as an Appendix. It lists the technical issues currently being addressed by the team and the disciplines that will be participating in the project this Spring. One item worth noting is that faculty in Civil Engineering and ECE with interests in wireless systems for structural monitoring of the stadium will join the team this semester.

3. Linking eStadium Teams: High Definition Distributed Collaboration (HDDC) Systems

As with other real-world engineering challenges, the extensive research, design and deployment issues within the multi-university eStadium project requires collaboration at many levels. This situation is now common in industry, with many research and design groups around the world collaborating on large-scale, complex engineering projects. To develop broad collaboration skills and experiences, we have extended the High-Definition Distributed Collaboration (HDDC) system deployed between Georgia Tech's Atlanta and Savannah campuses to include a Purdue site for use in collaborative VIP efforts. The eStadium teams at Purdue and Georgia Tech will be the first to benefit from this capability.

The availability of this system for the collaboration of vertically integrated VIP design teams at different sites – and for studies of collaborations between these teams – has the potential to transform the way that engineering students are prepared for the modern global engineering environment. They will understand, directly from the goals and needs of large-scale projects, how to work in and lead distributed teams, how to use technology to support distributed teams, and how working in distributed teams presents a unique set of challenges.

The HDDC system results from several years of evaluating effective classroom technology.[13-19] The current HDDC system of 3 reconfigurable class/meeting rooms provides a test-bed for developing pedagogically proven and cost effective telepresence technology for education and collaboration. The system utilizes 80" high definition monitors to display a 3840x1080 pixel image of remote rooms, stereo audio and echo-cancelling technology, and gigabit networking, to provide high resolution video and high quality audio that enable a virtual presence with fidelity dramatically exceeding that of current classroom systems. The difference in video quality is demonstrated in Figures 4 and 5. The stereo audio enables a person’s voice to move with their image, creating a more natural experience than the disembodied voices of present systems.

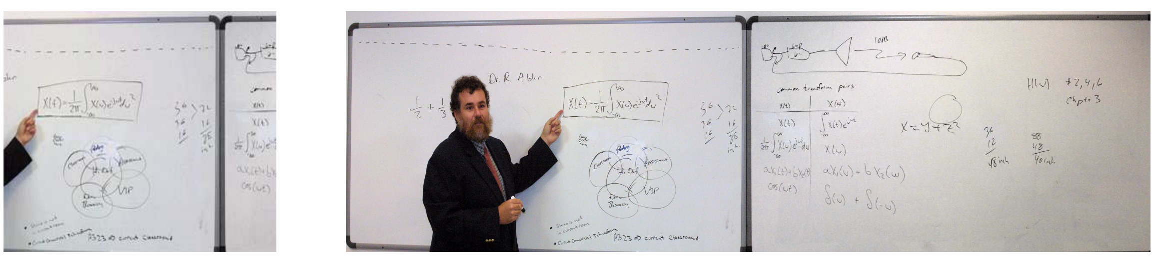


Figure 4: Comparison of commercial (left) and HDDC (right) systems' fields of view.

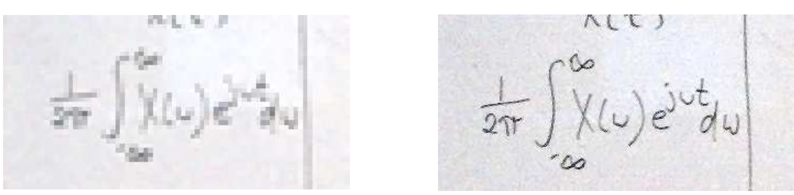


Figure 5: Comparison of commercial (left) and HDDC (right) clarity.

While the use of high-definition video and stereo audio technology provides significant impact, a major purpose of the HDDC testbed is to evaluate best-practices across a wide range of courses, teaching and presentation styles, and student-student as well as student-instructor interaction, for the educational application of such technology.

The implementation of the HDCC systems in the VIP labs at Purdue and Georgia Tech are shown in Figures 6 and 7. The system at Purdue was purchased with funds from the Type I CCLI grant from NSF that is supporting the creation and evaluation of these distributed VIP teams. The systems were first used in December for: several meetings between advisors at the different sites; for remote participation in the end-of-semester progress presentation of the eStadium sensor net at Purdue; and for project planning meetings. This coming semester, the sensor networking subteams of eStadium at both sites will meet with each other on at least a bi-weekly basis. This will require coordination of meeting times across two campuses – which often necessitates meetings at 4:30pm or later to ensure everyone can participate. The tools for evaluating the effectiveness of this collaboration are currently under development.

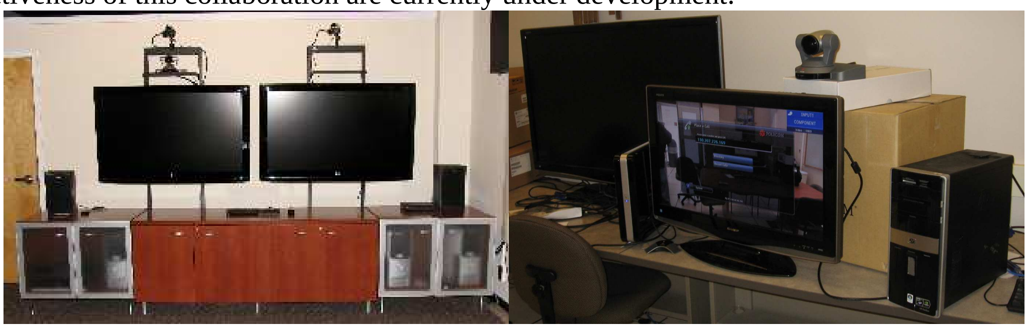


Figure 6: HDDC Systems in the VIP Labs at Georgia Tech (L) and Purdue (R). The dual high definition monitors at each location allow simultaneous viewing of meeting participants and computer applications from the remote site.

4. Course Evaluation Results and Social Network Characteristics

The VIP Program is an innovative approach to developing multi-institutional, vertically-integrated engineering design/research projects. Through the use of vertically-integrated teams, students interact with various ranks of students and faculty, with the intention of gaining technical expertise and a wide range of skills related to the research group environment.

VIP faculty are able to directly observe changes in student learning and then adapt their mentoring and teaching approaches accordingly. However, faculty tend only to be familiar with teams whom they interact with frequently, and may not be able to address the question of "What is the VIP Program accomplishing overall?" In order for the VIP Program to be most effective, a solid understanding of overall student learning gains, interests, and team interaction skills is needed. Thus, to gain a more accurate and overall view of the outcomes of the VIP endeavor, a parallel external evaluation process has been created to address impacts on students and issues regarding progress in integration.

Evaluating the outcomes of research investments can provide useful data that indicate outcomes or "returns".[21,22] In evaluation terminology, this approach is a *summative* one that captures programmatic outcomes, benefits and effects.[26,27] Yet, evaluations can also be important in providing *formative* input that will improve programmatic operations, particularly with new programs or organizations.[27] Given this, an important aspect of the VIP program is the integration of an external evaluation that addresses both formative issues that may help in improving the VIP effort in real time, as well as a summative approach that provides evidence of VIP outcomes. The evaluation, designed and conducted by social scientists at one of the VIP institutions, will occur along the two years of the VIP Program grant, and includes both qualitative and quantitative data collection that are collected in each of the four semesters during the grant period. This allows for some longitudinal tracking of student experiences, reported outcomes, and learning over this time.

The value of an external evaluation for the VIP Program is that it can provide data on VIP processes and outcomes specific to certain teams, but also across all teams. The VIP evaluation has therefore been designed to address the "bigger" questions that will enhance VIP program building, and provide meaningful evidence of the nature of student learning and other outcomes of the VIP process. In particular, issues of student learning and socialization in the research environment, mentoring, knowledge-based interactions and collaboration, and use of technology, have been identified that guide the development of interview and survey instrumentation (as detailed in Table 1.) An implicit goal of the inclusion of students in research processes is to enhance their scientific and technical human capital, and therefore their overall research capacity.[20,23,25] These evaluation issues were therefore developed to address the core purposes and goals of the VIP program, including the development of student learning regarding technical issues, engineering design, but also the social aspects of the research process, such as working on teams and with external stakeholders or users.

Table 1: VIP Core Guiding Evaluation Questions

Student Learning and Socialization: How is the student experience (at all levels) and knowledge of engineering design processes changed as a result of VIP involvement? What other skills and knowledge have they gained (technical skills, working within a team, communication, attitudes and interest in engineering, etc.) that may be attributed to the VIP experience? How do these coincide with faculty expectations of the student experience? If there are differences, what might explain them and how can the VIP program be improved?

Student Mentoring Experiences: What expectations do students have regarding faculty and peer mentoring in the VIP environment? What types of mentoring exchange are considered to be most valuable with the VIP design team environment? What knowledge and skills are gained from faculty mentors? What knowledge and skills are gained from peer (student) mentors?

Developing Knowledge and Learning Exchange Networks in the VIP Environment: What communication and interaction patterns develop in the VIP environment over time? What knowledge regarding design skills, team functions, and other engineering-relevant experience are provided across these networks? How do they cross rank, discipline and institution? What are the benefits, or detriments, to the integration of multiple levels of students in the VIP projects? Do some levels of students benefit more than others? Are experiences different for women or underrepresented minorities in the VIP project environment? What are the key barriers and facilitators to skill building and knowledge exchange in the VIP environment: across disciplines, across rank, and across institutions?

Technology Impact on Student Learning and Team Building: What communication technologies are most important in developing ties across VIP teams and institutions? How is the HDDC perceived and used in the communication process by faculty and also by students? Do students access different knowledge across institutions that impacts their learning? What issues do students and faculty face in the acceptance, use, and related outcomes of the HDDC?

Early Evaluation of the VIP Program

At the time of this writing, the VIP Program is early in its grant period. The initial evaluation data collection has therefore been primarily formative in nature and focused on student expectations and early experiences. It also serves as baseline data, useful for later comparisons. In particular, early data collection has involved a both qualitative (focus groups and interviews with students) and quantitative (on-line survey of VIP students.) Together, the results of these data collection efforts provide a rich understanding of student expectations, as well as some early indications of student interaction, knowledge exchange, and learning that will be tracked over the subsequent eighteen months of the grant period.

First, a series of focus groups and individual interviews were held with 48 Georgia Tech students, or 75% of Georgia Tech VIP students[1] in the Fall Semester of 2009, organized by VIP team. Interviews were conducted by the external evaluator and an advanced graduate student. Individual interviews were also held with students who were unable to attend the focus group sessions. The focus groups and interviews employed a semi-structured interview process[24] that was organized around key evaluation themes. First, students were asked to indicate how they first learned about the VIP Program and what sparked their interest. This is important contextual information that can provide feedback regarding program advertising to VIP leadership, but also give the evaluation team a fuller understanding of students' backgrounds and interests. Second, students were asked to describe their team work processes and interaction. As noted earlier in this paper, the composition and organizational structure of the teams vary considerably. It is important for the evaluation team to account for these differences in survey instrumentation and analysis of findings. Third, students were asked about their expectations for what they might gain through the VIP experience. Here, students were probed to address both technical as well as non-technical knowledge and experiences. Fourth, while most students have only been engaged in the VIP Program for one term, it is important for the evaluation to capture any early learning or other outcomes. Students were asked to assess their learning thus far, and what they have gained early on in their VIP experience. Finally, a key aspect of the evaluation is to provide formative input to VIP leadership. Thus, students were also asked for suggestions on how to improve the organization and processes of the VIP Program.

Second, an important data collection component over the two years of the grant involves a survey of students. This survey includes a series of questions about student expectations and interests, self assessment of learning in a range of categories, education and career aspirations, feedback on their VIP experience. An important aspect of this survey is that it includes a series of detailed social network questions that allow for the quantification of relationships among VIP students. The survey uses a global network design to explore the student relationships with others formally affiliated with the VIP program.[28] Through the use of detailed survey questions respondents indicate specific relationships, and the nature of exchange with their VIP colleagues. This approach provides a robust and rich set of data that addresses the important social aspects of the VIP experience. In 2009-10, the on-line survey of students was conducted shortly after the conclusion of the focus groups. The survey will be repeated at the end of each semester, allowing for longitudinal analysis of network structure and interaction, as well as changes in other items included in the survey. Students were invited to the online survey and provided with a unique userid and password. An important feature of an evaluation such as this is that students are

[1] No interviews or surveys were implemented at this point with Purdue University students due to the unusually small number enrolled in e-Stadium during the Fall 2009 semester. As the HDCC system is implemented and enrollment continues to increase, the interaction of the e-Stadium team across campuses will be of particular interest to the evaluation team.

provided confidentiality in their responses in order to enhance the quality and rate of response. In the VIP program, the external evaluator is faculty at one of the institutions, but in a separate social science department and not engaged with the VIP students on a regular basis outside of evaluative interactions. Overall, 62 students were surveyed, and 39 responded for a 62% response rate. Responses were distributed across VIP teams, as well as across student rank (70% undergraduate respondents).

<u>Evaluation Results</u>

The early qualitative data reveals details on student expectations, but also importantly, early outcomes and benefits of VIP participation. Overall, our early findings may be categorized in the following groups: *student backgrounds and interests, team nuances, individuals' expectations, early outcomes, and areas of improvement.*

First, to understand the *student interests and background*, it was useful to understand how students learned about VIP and what attracted them to enroll. From the interviews, our data show that the majority of students had learned about the VIP program primarily through email notifications/advertisements and faculty class presentations. A smaller group of students learned about VIP as they actively sought research opportunities (i.e., attending seminars on undergraduate research opportunities, talking to professors) or through friends that were already in the VIP Program. Interestingly, several students reported learning about the program through course registration listings when they were perusing possible courses in which to enroll.

As students learned more about what VIP entails, we asked students what compelled them to enroll. When asked about what interested them about VIP, students expressed a number of issues, as shown in Table 2. For example, they noted that they were initially interested in the program and their particular team because of its relevance to the real world (i.e., creating a system for real users), their interest in the specific engineering or design issue, their desire to enhance their technical skills, and/or their desire to get involved in doing research.

Table 2: Student Interest and Motivation in Joining the VIP Program

Overall Category	**Themes**	**Illustrative Student Quote**
Impact	• Relevance to specific users • High possibility of stakeholder use of VIP product • Importance of project • Working on something novel	"I joined [VIP team name], b/c it seemed like the broadest relevance, had a wider goal than just a technical project. The project description mentioned the [non-profit center this team worked with] instead of designing with the hope of someone interested in using it. That meant we would be designing to specifications or needs of users."
Interest in Topic	• Fills a lack in student's program (curriculum of field at university) • Team closest aligned with field • Fits skills • Team's relevance to a different discipline • Football Interest (e-	"[VIP project] … combined stuff on engineering with things I like to do outside of engineering."

	stadium)	
Building Technical Expertise	• To get a better feel for hardware • Learning about technologies – (e.g., PHP, MySQL) • To learn to apply what they are learning in course work	"Importance of this project is that it's not just some hypothetical research in a class. Here, you're learning to do, as compared to just learning in classes, so that's one of the things also that I like about it"
Research and Long Term Project Work	• Interested in faculty advisors' work • Seeking research opportunities • Wanted to get experience on a long term project • Teams aren't competing – putting together the parts of one whole • Interacting with a team • Good exposure to the real world	"Adding on to the whole long term project thing, you also have to work with a ... technical project where teams aren't competing as they are in the classroom, they're more, all of the people with the same goals, and all of us are working towards an objective. So you have all these different teams coming together through different things that are related"

Addressing student satisfaction in general is complex. In a research experience such as the VIP, if *student expectations* do not match with their experience, they may become frustrated and less satisfied. For VIP leadership, understanding early expectations assists in team management and also in the information dissemination process. In our initial focus groups, we asked students "What are the key skills that you hope to develop by working on the VIP team?" In discussion, we also encouraged them to distinguish between technical skills, and other skills specific to working on an applied group project. From the focus groups and interview, several themes emerged, as shown in Table 3.

Using these findings, we then constructed a series of questions in the online survey of students. Here we asked them about a range of technical as well as other research and team skills. First, we asked them to provide a self assessment of their own skill set in regard to a specific set of technical and other skills. In a later question, we then asked them to indicate their interest in building these skills through the VIP experience. Combining these results, the findings show that students have strong interests in not only technical skills, but also in the social and managerial aspects of working on design teams. As shown in Table 4, the majority of students emphasize project planning, communication, and managerial skills. Although not shown here, overall skills levels were not surprisingly higher among the graduate student respondents. However, their interests and what they hope to gain from their VIP experience differ considerably. As a caveat, these are baseline data and involve relatively small numbers of students. These results, however, can be especially useful to VIP faculty as they engage with students and plan and tailor activities. For graduate students, this also provides insight and a reminder that undergraduate students may hold different skills sets as well as goals. Overall, the majority of undergraduate emphasize contextual and managerial sets of knowledge more often than do graduate students. The data also point to the importance of differentiating by student levels in both program content and in evaluating results. Later surveys will ask them to assess the extent to which they have learned these skills and knowledge through their VIP experience.

Table 3: Student Identified Learning Expectations		
Overall Category	**Themes**	**Illustrative Student Quote**
Preparation for - **Job Search** - **Job** - **Future Courses**	*Job Search* • Looks great on resume • Real world CS experience – can use for job search process • Recommendation for grad school or job *Job* • Working on something that will be used – good for job *Future Courses* • Preparation for Senior Design • Ability to relate VIP work to courses taken in the future	*Job Search* "I'm looking for a recommendation letter for grad school, hopefully, or for a job. I'm planning to work on it [VIP project] until I graduate, so I want to work closely with [faculty advisor]." *Job* "It's not limited to just being a class. So being a part of something like this that's actually going to develop something useful, you can point to this for potential employers and actual work experience, it's not just school." *Future Courses* "[I expect to gain] interpersonal skills and apply technical knowledge while working on a project. It seems like a great preparation for senior design."
Work on Interesting Topic	• Working on real world applications • Working on something of interest	"I was expecting to work on something that will be used by a lot of people or a real world application. And I think I was able to experience that and get that out of the project."
Technical Skills	• Wireless networks • PHP, MySQL • Problem solving - putting theory to practice • LAN Networks – was surprised that he also learned 3G and 4G • Surprised at how much I learned on my own • Thought it would be easy (b/c he had taken relevant courses) – but was wrong	"… teamwork and problem solving…(is) why I joined the team. I initially had some knowledge about the theory, and I wanted to have some practical work done, so practical use of theory. I'm preparing for that and learning a lot. I took a class and the first lectures from (VIP LEAD) prepared us - gave a background of what was going on. It's important for me to know and put it into practice." "I knew I would learn a lot about LAN networks but didn't think I would pick up 3G or 4G. I know more than I thought and more than I even need. It's a great thing to have going into interviews."
Teamwork Skills	• Interacting with a team – jobs like that • Interacting with different teams	"… interacting with different teams, personally, since I'm doing the back end recognition part, I'll be working on that with [graduate advisor], so I'm on my own team, but when it comes to integrating the entire thing, I'll be working with everyone, so I really like it."

Table 4: Student Expectations: Technical and Other Skills: Baseline Survey Results				
		What skills do you hope to develop as a result of your participation in the VIP Project? *(% indicating "yes")*		
	How knowledgeable would you say you were in each of the following skill areas before participating on the VIP team? Mean Results *(1=no knowledge; 2= low knowledge or skills,; 3= working level of knowledge or skills; 4=highly advanced knowledge or skills)*	**VIP Students Overall** *(n=39)*	**% Under graduate Students** *(n=27)*	**% Graduate Students** *(n=12)*
understand communication hardware and systems	2.44	58%	88%	58%
identify and solve practical or applied problems	3.03	69%	83%	42%
plan a long term project	2.70	67%	78%	45%
understand how technical solutions are used in an applied context	2.75	64%	75%	42%
communicate technical concepts and designs to others	3.00	67%	74%	55%
manage a project team	2.62	67%	74%	55%
collaborate on project team solutions	2.91	65%	74%	45%
design systems, components, or processes to meet practical or applied needs	2.59	61%	67%	50%
understand computer hardware and systems	2.69	53%	67%	25%
work on a multi-disciplinary team	2.74	65%	65%	64%
computer programming	2.89	64%	63%	67%
use the techniques and tools necessary for engineering practice	2.53	47%	63%	17%
work on a project team within my discipline	3.06	47%	58%	25%
make professional presentations	2.94	53%	57%	45%
write professionally	3.03	50%	52%	45%
resolve team conflicts or disagreements	2.82	44%	48%	36%
design/conduct experiments	2.89	50%	46%	58%
designing computing algorithms	2.63	42%	46%	33%
analyze or interpret data	3.00	44%	42%	50%

Early Outcomes

The value of an early evaluation data collection process is that useful formative data may be gathered that will inform project management. Yet, while students are only completing their first term in the VIP Program, some early outcomes and benefits may be observed. This in particular is important to track longitudinally due to issues of memory. As students advance, they may not recall some of the early learning or advances that occurred, that seemed significant at the time.

From our interviews, students reported a number of early outcomes as a result of VIP involvement (Table 5). Overall, students reported learning about working on teams, learning technical skills, learning interdisciplinary skills and issues, learning how to write research reports, and learning how to integrate work between multiple teams. Importantly, these early outcomes underscore the important learning that occurs regarding the social aspects of team-based research. This is particularly important for the VIP program and is a core goal of the grant overall.

Table 5: Early VIP Reported Outcomes and Benefits

Overall Category	**Themes**	**Illustrative Student Quote**
Technical Skills	• Embedded Hardware systems • Servers and websites • Taking (throughput) measurements • Making practical solutions, improving on systems • New languages and their best uses • *More General Technical Skills Reported* - Databases - Networking - Operating Systems - Information Security	"Something I learned is, at first, I was just expecting html, PHP, and MYSQL. Those are the languages I would be using to do the project, but when I needed to do onclick or something, I had to use Javascript. And I've had to learn a lot of different languages just to do this one project using a lot of different toolkits that I've never used before. So, those are all the new challenges I wasn't expecting. "
Research Reports	• Writing research reports/papers Presentations of work Giving "real world" presentations	"… we've improved our ability to write papers… It definitely improves our skills in communication as well as making presentations…..I think doing that [presentations] more often is going to help us in how we'll be presenting our technical work to other people."

Table 5: Early VIP Reported Outcomes and Benefits (continued)		
Interdisciplinary Skills (one VIP team)	• Understanding political issues • Learned how technology affects society • Learning about technology in other countries • Developed interest in other non engineering courses as supplements	"I aspired to (and succeeded) at learning how technology affects society and the interaction between technology and community. I also learned how to collaborate with different groups of specialties (fields). You find everyone's strength and you try to help them. You try to build your project around what people could do."
Working on a Team	• Working in groups • Team communication • Team member responsibility and accountability • Interpersonal interactions	"Apart from technical skills, a lot of interpersonal interaction has come up in this project that we wouldn't experience as much in a classroom environment. For example, meeting outside of class to finish a project that you know you'll be presenting for an advisor, isn't something that you would really do in any other class except with seniors. And to experience that early on in college is a really good asset especially to your resume. That's a really good aspect is that you actually learn how to work on teams, and learn how to work with others, and just keep the lines of communication open, when you needed help you knew how to ask for it, rather than try to figure it out on your own like we usually do in classrooms."
Integration	• Integration of project parts and tasks and knowledge.	"[VIP] is also different from the classroom and from..internship(s). We probably all work on projects and they're not integrated with one another, but the VIP program, the VIA team, each has done a small part of the entire project itself. And it's sort of like a model of a real business, of the programming department and how they try to modularize the pieces and then later on try and work with each other and integrate each of the little pieces into the huge end result we're all hoping to reach or obtain in the near future. I think that's one of the things I learned about was how, to work with each other and integrate all the tiny things from code here, databases there. It's what you don't get from projects in class where you just code it and complete it and everyone has the same copy. But here is a project, everyone has little pieces and we're working together to combine the things to one huge thing, that's a pretty impressive feat in my opinion."

The qualitative data are important in identifying themes and also the evaluation to explore certain issues in rich detail. The related survey data that will be gathered over the course of the grant period will then allow for the longitudinal tracking of student attitudes, experiences, and reported learning from their VIP interactions and experience. In this baseline survey, we asked students to indicate the extent to which they had learned certain concepts and skills. As shown in Figure 7, the early results support the baseline qualitative results. Both graduate and undergraduate students report overall positive outcomes of their VIP Team experience, with some minor differences between undergraduate and graduate student outcomes. Tracking these over time will then provide useful feedback to VIP faculty leadership.

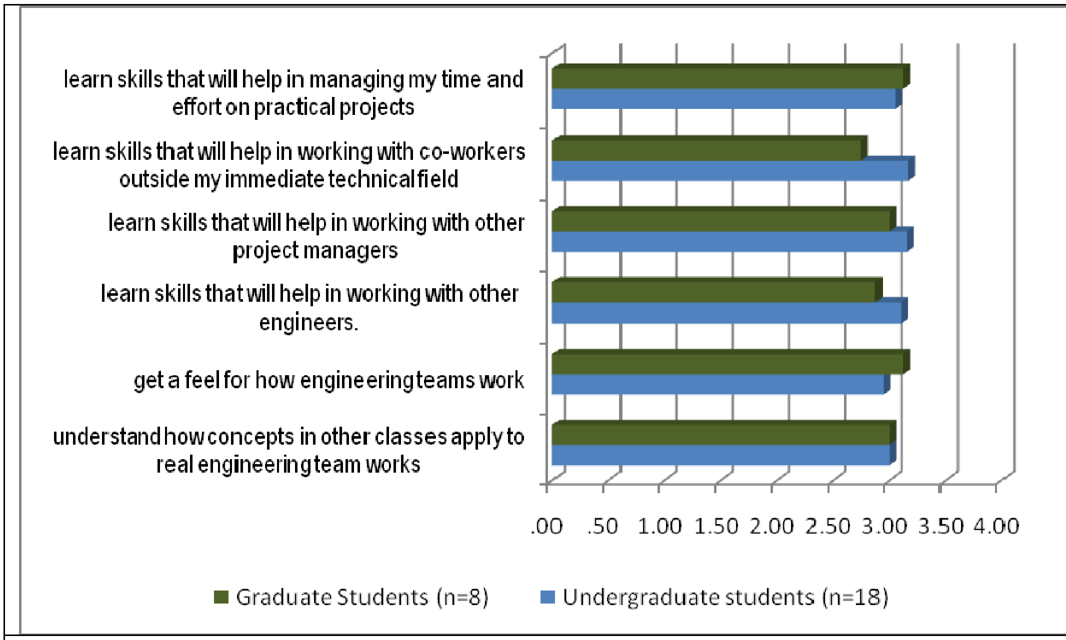


Figure 7: Student Self Assessment of VIP Team Skill Sets
"Participating on my VIP Project team helped me to:…"
(1= strongly disagree, 2=disagree, 3=agree, 4=strongly agree)

Early Outcomes and VIP Student Networks

These early learning reports by students are important in distilling details about early learning. The VIP Program actively acknowledges the social aspects of research design teams by integrating students in a variety of ways. From both an evaluative and a project management perspective, the question arises of how the dynamics of the VIP program and teams facilitates learning, and how that can build over time.

One mechanism for understanding how VIP can structure itself to facilitate student learning, is to address the social structure of the VIP student group. Individuals are linked through "social network ties" that reveal not only dynamics of the group itself, but also the resources exchanged across those ties.[28] For example, as students develop collegial relationships within VIP, we would expect increased flows of interaction and assistance. If students don't know one another, there is little opportunity for informal exchange and discussion. This is important because a foundational element of VIP is the development of groups that interact over time, exchange knowledge, and learn engineering design and team process issues together. Given this, an important component of the evaluation involves social network analysis to track the development of student interaction, knowledge and assistance exchange, and eventually, learning outcomes. The survey was constructed in a form typical for social network analysis in order to assess ties, linkages, and the strength of those linkages within an organizational environment. [28,29] Using standard social network survey design, students were provided with lists of VIP students, and then asked a series of questions about their relationships with those individuals. In this baseline survey, we asked questions about 1) how students know one another; 2) how frequently they personally interact; and 3) the individuals that are most important to them in providing specific types of advice and discussion related to VIP activities. While the overall response rate for the survey was 62 %, the roster method also allows us to capture relationships of individuals who did not respond to the survey through the identification of relationships by other survey respondents. Therefore, all 62 students are represented in each of the network graphics. We treat the ties as existing if at least one individual identifies the tie.

To illustrate, we provide baseline results to demonstrate the social dynamics of the VIP group, as well as resource exchange among VIP students. These baseline data provide initial insight into the social structure and dynamics of the group. Over time, observation of changes in the networks will not only guide VIP faculty in project planning, but will also provide detailed data on the ways in which VIP students collaborate, interact and exchange information.

While network graphics can be visually interesting and informative, certain statistics allow for a meaningful comparison of network dynamics. In the networks displayed in Figures 8, 9 and 10, we provide statistics for five standard network-level metrics: density, centralization, average degree centrality, external-internal index for campus, and external-internal index for discipline.[28,30] Together these five measures provide a useful descriptive characterization of the nature of the network, and the relationships within that network. Over time, changes in these statistics may be observed and used to develop a better understanding of the ways in which individuals are linked within the VIP Program. Importantly, their meaning must be then interpreted in light of organizational goals and objectives. For example, in some cases, organizations may benefit from highly connected, or "dense" networks. In other cases, decentralized networks may be more beneficial. More specifically, we provide statistics on:

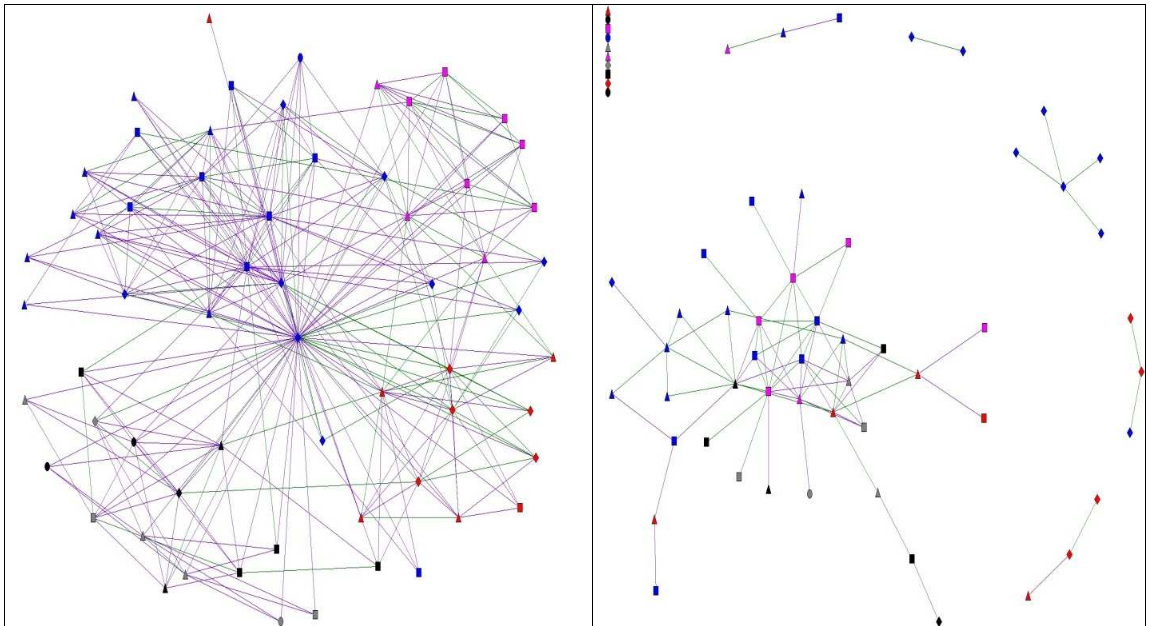
- *Network Density*, which measures the percentage of ties that exist compared to the number of possible ties. If networks are not very dense, that may reflect opportunities to build additional linkages within the network. (Potential value 0-100%)
- *Network Centralization* measures the degree to which a network is "centralized" around one or more individuals. In VIP, these individuals may be key graduate students who provide resources and link undergraduate teams together. (Potential value 0-100%)
- *Average Degree Centrality* measures the average number of immediate connections that each individual has in the network. Depending on the specific network, it may reveal how individuals integrate with one another. In VIP, if individuals have relatively few ties, then this would suggest that they are only benefiting from the knowledge and interaction from a few student colleagues, rather than drawing from the broader team.
- *External Ties*, E-I Index measures the extent to which a particular network is made up of individuals outside as compared to inside a particular defined group. For VIP, this is an important statistic for assessing the degree to which relationships are across undergraduate and graduate student groups generally, across student rank (sophomore, junior, senior, graduate students); or across VIP teams, a particular environment or context. The EI index is calculated as: (external ties – internal ties) / (external ties + internal ties) and ranges from negative one to one, with a negative score indicating that students are within a particular group, or whether it is mixed. The EI index ranges from -

1 to +1 where -1 means that all ties are within a certain group, and +1 would mean that all ties are outside of the identified group. Actual E-I indices fall somewhere between -1 and +1, depending then on the mix of ties.

First, in this baseline data, we are interested in establishing former relationships among VIP students. For example, we might expect that if students had already known one another, that their ability to interact on teams may be facilitated by already existing relationships. To address these items, we provided students with a roster of the sixty-two VIP students and asked them to indicate whether a) they had ever personally interacted with each person, b) whether they had met this person through the VIP Project, or c) whether they knew this person before enrolling in the VIP project. Overall, the results showed the largest number of ties for the first time, that they had never personally interacted with the list of VIP students (1264 ties between 62 nodes (students.) This is to be expected early in the VIP Project, and provides a baseline of ties. In future surveys, we will continue to track this, knowing that while many students enroll in VIP for multiple semesters, new students are engaged in each term.

As expected, more ties are identified that indicate that students met through the VIP Program (349 ties compared to 103 ties). These data are displayed in Figure 8, the network figure for the other two relationships. The E-I indices reveal that these introductions through VIP are concentrated almost exclusively with VIP teams. Reflecting the composition of the teams, individuals who met through the VIP Program reflect a high level of cross student rank introductions (E-I Index = +.387), whereas prior relationships essentially do not cross student rank (E-I Index = -.942).

Within VIP, we are also interested in the extent to which students interact, and across which groups. This reveals the informal dynamics of the group outside of formal VIP courses and meetings. Illustrated in Figure 9, we asked students to indicate the frequency of their personal (email, in-person or telephone) contact with the roster of VIP students outside of any formal VIP group meetings – less than once per week, about once per week, a few times per week, or at least once per day. Frequency of contact is often used to measure the closeness of relationships within a group. Overall, very few ties (11 ties) were identified that reflected high levels of contact (at least once per day. As shown in Figure 8, the contacts that occur within the course of a typical week vary somewhat. There are a number of ties that report interacting a few times per week (97 ties) while many are less than once per week (173 ties.) For VIP leadership, the ways in which students interact across rank on a frequent basis can reveal how students are building collegial and collaborative relationships early in the project. While the students that report interacting on a personal basis less than once per week reflect more cross student rank ties that those who interact more frequently, both reveal definite interaction across rank. Close interactions across teams are low (E-I Index = -.485) which is not surprising given that students have not had many opportunities early in VIP to interact across teams.

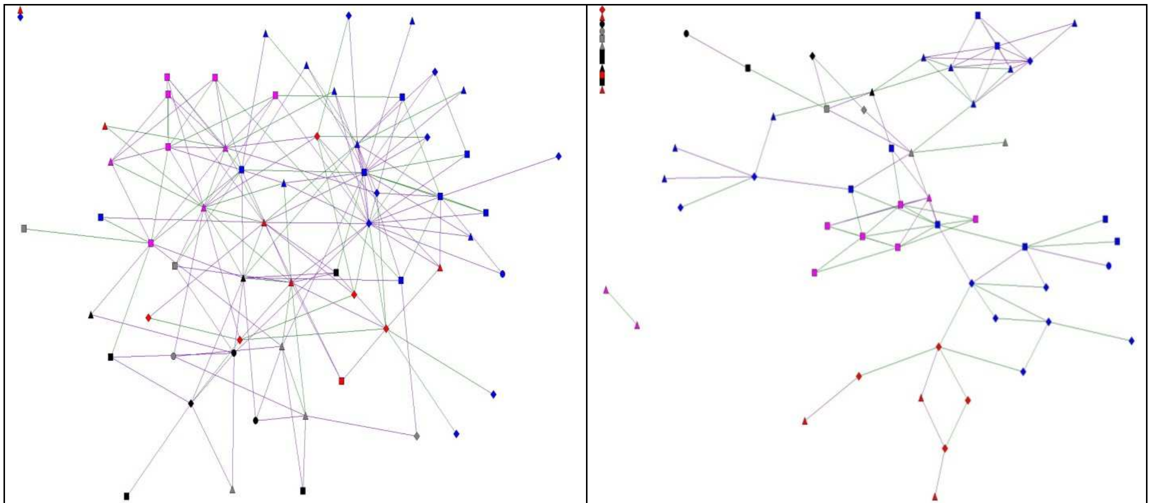


"I met this person through the VIP Program"		"I knew this person before I enrolled in VIP"	
Number of Ties	349	Number of Ties	103
Density	.092	Density	.027
Mean Centrality	9.32	Mean Centrality	2.58
Network Centrality	87.54%	Network Centrality	4.26%
EI-Index (team)	.804	EI-Index (team)	.301
EI-Index (student rank)	.454	EI-Index (student rank)	-.243
EI-Index (Undergrad-Grad)	-.225	EI-Index (Undergrad-Grad)	-.942
Green line: within student rank *Purple line: across student rank* *Node Colors: VIP Teams*		*Circle= Sophomore (UG)* *Square = Junior (UG)* *Triangle = Senior (UG)* *Diamond = Graduate Student*	

Figure 8: VIP Interaction

Finally, while the extent to which students know one another and interact reveals useful information about the development of relationships with VIP, they do not provide information about what is being discussed or exchanged among student colleagues. An essential aspect of the VIP Program is the vertical integration of students around specific design issues. To what extent are students actually integrating in meaningful ways? We would expect the baseline data to reveal limited interactions in this regard, but to grow over time as students learn more in terms of technical details, but also develop socially within teams. In this baseline survey, we asked students to identify other VIP students who were "most important in providing advice or assistance" regarding a set of specific issues related to their VIP Project. Here, we asked them to indicate assistance or advice regarding:

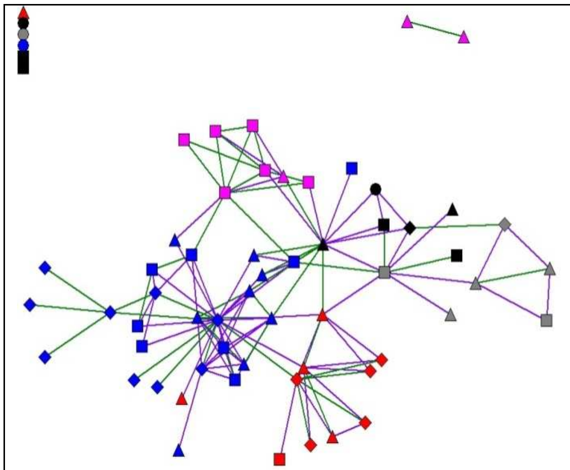
- Technical advice (computer programming, hardware details, etc);
- Advice about engineering concepts (algorithm design for software, hardware infrastructure understanding);
- Advice about technical applications;
- VIP team management issues; and
- Advice about VIP project goals and purposes.

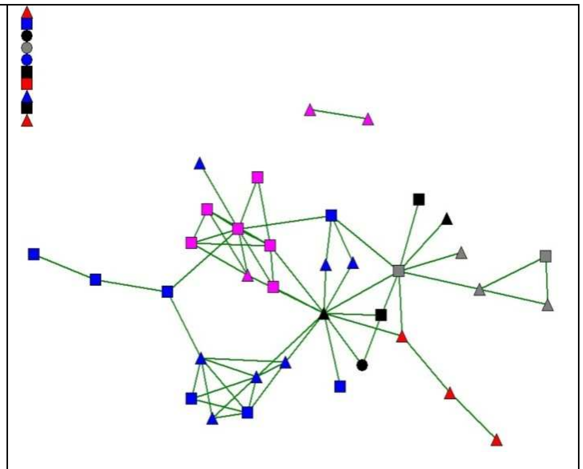


Less than once per week		A few times per week	
Number of Ties	173	Number of Ties	97
Density	.046	Density	.026
Mean Centrality	5.13	Mean Centrality	2.7
Network Centrality	25.19%	Network Centrality	10.66%
EI-Index (team)	-.145	EI-Index (team)	-.485
EI-Index (student rank)	.260	EI-Index (student rank)	-.093
EI-Index (Undergrad-Grad)	-.457	EI-Index (Undergrad-Grad)	-.546
Green line: within student rank *Purple line: across student rank* *Node Colors: VIP Teams*		*Circle= Sophomore (UG)* *Square = Junior (UG)* *Triangle = Senior (UG)* *Diamond = Graduate Student*	

Figure 9: VIP Interaction: Frequency

These items represent knowledge resources, both technical and managerial, that students provide to one another through their VIP Project interaction. These data provide detailed information on the ways in which students interact, and the types of exchange that they have related to their VIP Projects. Results show that the largest number of ties were identified regarding VIP team management (86 ties), while the other categories ranged from 54 to 62 ties. For the purposes of this paper, it is useful to distill the extent to which information is exchanged across student rank. Our early data provide some surprising results. The data show that undergraduate students are engaging across rank regarding technical and project management information and assistance. To illustrate, Figure 10 shows two graphics, one for all five categories of advice combined for *all students*, and one showing *undergraduate students only*. The E-I indices here reveal that when looking at all students together integration across student rank is revealed. To some extent, this is driven by some interaction across undergraduate and graduate student groups (E-I = -250). Looking at undergraduate students only however, also reveals interaction across undergraduate sophomore, juniors and seniors. When categories of the individual interactions are examined (not shown here due to space limitations) results show that undergraduate interaction occurs across all categories of advice and assistance. As the VIP Program develops over the grant period, and also engages with Purdue University, tracking the content of student exchange will provide important interim evidence of student learning and integration.





All Advice Combined: ***All Students***		**All Advice Combined:** ***Undergraduates Only***	
Number of Ties	136	Number of Ties	69
Density	.085	Density	.039
Mean Centrality	9.12	Mean Centrality	4.03
Network Centrality	13.85%	Network Centrality	9.14%
EI-Index (team)	-.618	EI-Index (team)	-.449
EI-Index (student rank)	.176	EI-Index (student rank)	-.159
EI-Index (Undergrad-Grad)	-.250	EI-Index (Undergrad-Grad)	-1.00
Green line: within student rank *Purple line: across student rank* *Node Colors: VIP Teams*		*Circle= Sophomore (UG)* *Square = Junior (UG)* *Triangle = Senior (UG)* *Diamond = Graduate Student*	

Figure 10: VIP Resources: In the fall of 2009, who was most important in providing advice or assistance regarding any of the following issues related to your VIP project?

Challenges for the VIP Program

The baseline data collected to date represents the first set of information that will provide meaningful formative input to improve the VIP program structure and operation over the grant period. It is critical to address what is not working well from the students' perspective, as well as other areas in which they would hope to gain expertise. This is an important aspect of the early evaluation data collection process. Both the qualitative data (interview) and survey data provide data on specific issues that students face in the VIP Program and help to identify areas for improvement.

For example, from the interviews, students pointed to various minor difficulties and challenges that they had experienced, as well as offering suggestions for VIP improvements. In terms of challenges, students reported difficulties with the VIP Course structure itself, difficulties they had learning on a team, difficulties reaching and understanding the goals and tasks of their projects, challenges working with users of their system, and team conflicts. To some extent, some of these issues (as shown in Table 6) have to do with personal time management and socialization in a group research process. For VIP leadership, gathering this information provides input to faculty who in turn may better adapt student mentoring and interaction in assisting students in these processes. The early interviews were also valuable in gaining feedback from students regarding areas for improvement. These ranged from managerial issues such as improving timeliness of meetings and requiring team meetings, to clarifying long terms goals of the projects. In many cases, suggestions such as these point to opportunities for VIP leadership to communicate expectations, goals, and other details to students in order to enhance understanding of the overall process.

Table 6: Challenges Faced by VIP Students

Overall Category	**Challenges Noted by Students**

VIP Course	• Time management between class work and VIP project work
	• Not enough credit hours for course
	    o Discrepancies in course credits among students
	    o Amount of effort goes way beyond one hour
	• Students are unsure of overall grade before end of term

Learning on the Team	• Allocating work between newer students and more expert students (more expert students end up with heavier load, so they shift regularly)
	• Have a lot of newer students on team
	    o Creating a high learning curve, caused by high turnover of students
	    o Long hours
	    o Younger students haven't taken electives yet that would be helpful for project work
	    o Must learn and troubleshoot as they go – professors still expect results
	• Implementing things they know about but have never actually done before
	• Starting from previous work
	• Coordination of additional group members (adding group members to an ongoing project)

Goals and Tasks	• Reaching complex goals (e.g., ensuring system will work under high loads) • Moving goals • Tasks are unclear
Working With Users	• Getting conference paper approved by outside source (their users) before publication
Team Conflict	• Conflicts about what to do (direction of project) with older student (*making his opinions count*)

5. Conclusions

The purpose of the VIP program is to bridge the "intellectual divide" that currently exists in universities, particularly within those categorized as *research intensive* by the Carnegie Foundation. This divide exists between faculty and undergraduate students and is caused by a faculty reward structure that emphasizes research productivity over education outcomes in both promotion decisions and annual pay increases. VIP attempts to bridge this divide by connecting faculty and undergraduates in a program that is explicitly designed to benefits both groups.

The success of the VIP program thus depends on its teams' production of both significant research results for faculty and educational outcomes that prepare undergraduates for the complex work environment of a global economy. We are thus committed to continuous measurement of the effectiveness of the program and the use of these measurements to improve the program and help individual teams operate effectively.

The on-going evaluation of the VIP Program is thus fully integrated into its programmatic structure, management, and planning. Having an on-going longitudinal data collection provides important preliminary findings that may be used to make minor modifications to the Program, and meet the interests and needs of the particular. Early findings show that students are experiencing learning-related benefits as part of their VIP experience, particularly in regard to the social aspects of the team-based research process.

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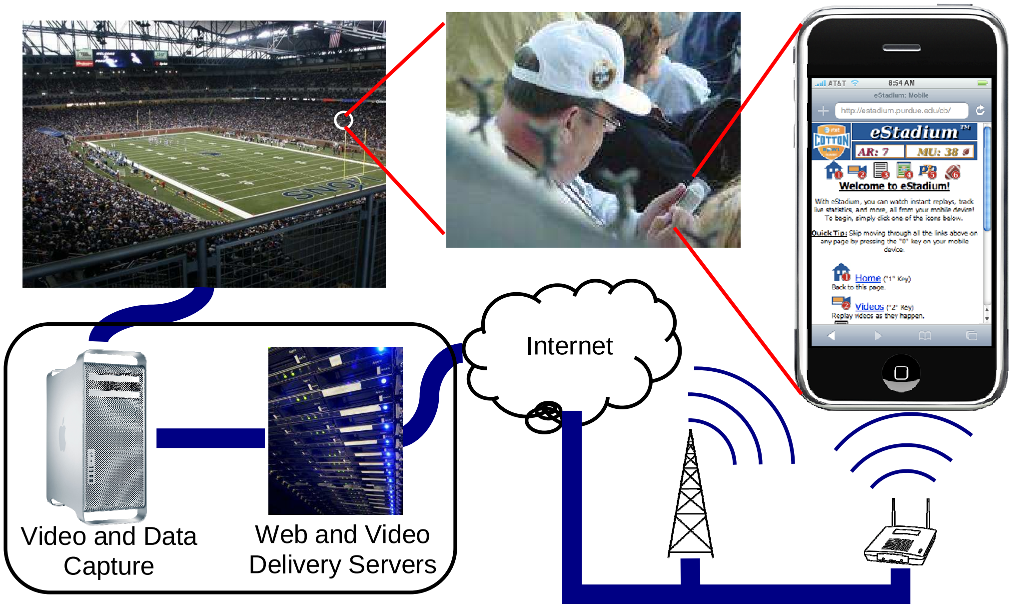
Appendix – Recruiting Document for the eStadium VIP team

The document appearing on the next page is posted on the VIP web site at Georgia Tech, passed out in classes, and pinned to bulletin boards. It helps to recruit sophomores through seniors from a wide variety of disciplines.

THE E-STADIUM VERTICALLY INTEGRATED PROJECTS (VIP) TEAM

TEAM TITLE: e-Stadium VIP Team

GOALS: To enhance Georgia Tech football fans' game-day experience and ensure their safety and security by enabling them to use their mobile devices to access innovative infotainment and venue-related information via WiFi, 3G and 4G data networks.



TECHNOLOGIES: Wireless and sensor networks, multi-media web applications, databases, graphics, sensor networks, embedded systems, sensors, structures, energy scavenging.

RESEARCH ISSUES: Scalable delivery of video over wireless channels; visualization; design and optimization of wireless networks; design and applications of sensor networks, energy harvesting for wireless sensor motes; distributed detection; structural health monitoring.

TEAM ADVISORS: Randal Abler (ECE), Russell Clark (CS), Edward Coyle (ECE), Mary Ann Ingram (ECE), Patrick Traynor (CS), Yang Wang (CE).

PROJECT PARTNERS AND SPONSORS: Georgia Tech Athletics Dept., OIT, TI

DESIRED DISCIPLINES AND PREPARATION:
EE – Background/interest in networking, wireless communication, embedded systems; Programming skills would be helpful but are not required
CmpE, CS – Background/interest in databases, web applications and/or graphics; Database experience would be helpful but is not required.
CE – Background/Interest in structures, instrumentation, smart structures.

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