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Social Network Analysis: Peer Support and Peer Management in Multidisciplinary, Vertically Integrated Teams

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Abstract

In the Vertically Integrated Projects (VIP) Program, undergraduates earn academic credit for their participation in long-term, large-scale projects. Teams are created at the request of faculty and are embedded in their ongoing research/innovation efforts. Students can participate for multiple semesters and up to three years. Two important elements of VIP teams are peer-to-peer support and peer project management. Encouraging students to assist each other (peer support), and to be aware of each other's work and hold each other accountable (peer management) shifts ownership of key aspects of the project to students, thus decreasing instructor time spent on low and mid-level operational/logistics issues. Through social network analysis of peer evaluations (N=483), this paper quantifies peer support and management between students on VIP teams at the Georgia Institute of Technology, examining patterns within individual teams and across the site. A previous study found that within teams, students interacted more often with students from majors other than their own and more often with students of other races/ethnicities than their own. Another previous study found stronger connections between students within academic ranks (sophomore to sophomore, junior to junior, etc.). To better understand dynamics within VIP teams, this analysis considers how 1) academic rank, 2) student major, and 3) number of semesters in VIP affect student interactions in peer support and peer management. The study looks at team-level interactions as well as program-wide patterns, providing a wide view of VIP student engagement across many different projects and teams. The results and method of analysis would be of interest to current and prospective VIP sites, as well as programs seeking to develop or quantify multidisciplinary student experiences.

Introduction

Multidisciplinary learning provides valuable experiences and excellent preparation for the modern workplace. Twenty-first century challenges are large-scale and wide reaching, spanning academic and professional boundaries. Through multidisciplinary learning, students bring together skills from different fields to solve real problems. This poses the question of how institutions can create realistic multidisciplinary experiences, with students working collaboratively across academic boundaries, and how programs can gauge and describe the multidisciplinarity of their programs. This is important both for program development and improvement, as well as for reporting progress to sponsoring departments and colleges. To these ends, the Vertically Integrated Projects (VIP) Program at the Georgia Institute of Technology (Georgia Tech) is employing social network analysis to quantify student interactions within VIP teams. In social network analysis, individuals within a network serve as nodes, and resources such as knowledge and information flow through the network [1], [2]. Resources do not flow equally, but rely upon the interactions and connections between individuals. A previous study of VIP teams found students interacted more often with students of other majors and more often with students of other races/ethnicities than their own [3]. Across the program, students interacted more often with students of the same gender, but when team composition was taken into account, there was not a correlation between interaction and gender. Another evaluation by Melkers found stronger connections between students within academic ranks (sophomore to sophomore, junior to junior, etc.) [4].

Essential to successful VIP teams are **peer support** and **peer management**, which provide students with leadership development and accountability, while at the same time sharing the responsibility of leadership with instructors. In a study of undergraduate research experiences, both individual and group-based, Lopatto found that peer-mentorship benefited both mentors and mentees [5]. Mentors gained confidence and motivation, deepened their understanding of the project, and improved their communication skills.

Mentees reported that peer mentors understood their concerns about doing research, helped them appreciate the significance of their research, and had positively impacted their research. In terms of working with peers, Lopatto found that for almost 80% of students who did research with other undergraduates, that it enhanced their research experiences moderately or significantly. It is through the lens of peer support and peer management that we seek to understand the role academic majors play. While the previous social network analysis study considered student interaction, this study looks at students helping students, students managing peers, and the role their majors play in these relationships. Instead of looking at specific degree programs, the analysis considers whether students seek help from others of the same major or different majors. Also examined are academic rank and students' status as new or returning students, and whether these factors affect whether students are sought for help and their management ability reported by peers.

Research Questions

Within VIP:

- To what degree do students seek help from students of the same major, as opposed to students from other majors?
- Is there a difference in how often students seek help from:
    - Freshmen, sophomores, juniors or seniors?
    - New or returning students?
- Is there a difference in the management ability ratings students receive with respect to:
    - Academic rank?
    - Status as new or returning students?

The VIP Model

The purpose of the VIP Program is to overcome the fragmentation of higher education by mission, time and discipline. The mission of the modern university is typically partitioned into the three often competing sub-missions of research, education, and service. In terms of time, learning is segmented into semesters and academic years, with few learning experiences lasting more than one semester. Finally, almost all intellectual activity is fragmented by discipline, with the budgetary structure of the university reinforcing these disciplinary boundaries.

Through VIP, the missions of research, education, and service can often be addressed simultaneously. Long-term, large-scale, multidisciplinary teams of undergraduates are embedded in faculty efforts in innovation. Each student can participate for multiple semesters, earning academic credit for their contributions toward the research goals of the faculty and graduate students. Projects also last longer than any one students' participation, further overcoming the boundary of time. Importantly, VIP teams are multidisciplinary by nature, with projects spanning and drawing students from multiple fields and faculty from different departments co-advising teams that cross disciplinary boundaries.

Twenty-six institutions of varying sizes and missions have established VIP programs. They include two Historically Black Colleges and Universities; three Hispanic Serving Institutions; AAU, R1, R2, and R3 universities; public/private and large/small institutions; and, seven institutions outside the US. They are all members of the VIP Consortium, which was formed to facilitate improvement and dissemination via collaboration amongst VIP sites. To this end, the VIP Consortium identified seven key elements of VIP Programs [6]:

> *1. Projects are embedded in faculty mentors' research efforts.* VIP teams are started at the request of faculty. Under their mentoring, the teams learn about and contribute to their research/innovation efforts. This long-term, mutually beneficial engagement between faculty and

students is the foundation of the success of the VIP Program. Teams can be led by more than faculty member, and individual faculty can be involved with more than one team. Of the 123 current team advisors, eight are involved with two teams. Of the 62 current teams, 40% are led by one team advisor, 26% by two team advisors, and 34% by three or more.

2. Projects are long-term and large-scale, continuing for many years, even decades. The VIP model allows for larger-scale and longer-term projects than a single semester or year would permit, allowing faculty to take on more ambitious projects. Some projects are extensions of existing research efforts, such as the Gravitational Wave Astrophysics team, which supports a large research effort in the School of Physics. Other projects support the development and deployment of otherwise lab-based research efforts, such as the Stadium-IoPT team, which develops and deploys a distributed internet of people and things system in Bobby Dodd Stadium at Georgia Tech. Other teams provide a space in which faculty can test new research ideas in a low-risk setting, such as the Humor Genome project led by a professor from Mathematics and a professor from Chemical and Biomolecular Engineering. Common across all teams is a minimum timeframe of three to five years. Teams typically become integral parts of faculty research programs, continually evolving with the team advisor's research.

3. The program is curricular and all participating students are graded (A-F; not P/F, S/U). VIP is not an extra- or co-curricular activity. It is a sequence of courses whose credits count towards students' degree requirements, and letter grading holds students accountable for their work. In many ways, feedback and grading in VIP is like an evaluation in the workplace. Work is evaluated, guidance is given, and students have the opportunity to improve. The curricular structure and the philosophy that all students can benefit from the experience makes VIP more accessible than traditional apprentice-style undergraduate research experiences, and the program attracts representative proportions of black/African American and Hispanic/Latino(a) students with respect to the campus population [7].

4. Students can participate and earn credits toward their degrees for at least two years. The "Vertical" in Vertically Integrated Projects refers to the inclusion of students from different academic ranks, along with graduate students and faculty. The program at Georgia Tech is aimed at sophomores, juniors and seniors, while some VIP sites also include freshmen. Allowing students to participate for multiple semesters allows teams to maintain continuity, with returning students taking on leadership roles and new students replacing those who have graduated or completed their participation. Graduate students participate with their research advisors to advance their research, or may take the course for credit. While research has shown a correlation between the duration of research experiences and student outcomes [8], students are encouraged but not required to participate multiple semesters. A handful of degree programs at Georgia Tech incentivize multiple semesters of participation in their policies, and analysis of enrollment patterns was recently conducted [9].

5. Learning outcomes focus on the development of both disciplinary and professional skills. VIP teams function much like small start-up companies. While students develop and apply skills from their disciplines, they also develop and apply professional skills important to team functioning, which will translate to their future careers. The large-scale, long-term projects mirror situations students will encounter in the workforce. As they join large ongoing projects, they are onboarded by peers, but also take responsibility for their own learning as they get up to speed. They deal with decisions made in previous years and with documentation developed by others; conversely, their own documentation becomes a resource for the team. They also learn and apply professional communication skills, communicating problems to the appropriate individuals and navigating conflict.

6. Multi-disciplinary teams are encouraged but not required. Multi-disciplinary teams are a hallmark of VIP programs, giving faculty access to the variety of disciplines and skill sets needed for projects to succeed. Multidisciplinary learning is not the primary goal of the VIP Program, but large-scale long-term projects invariably cross disciplinary lines. Indeed, one very compelling aspect of VIP is that it gives faculty access to students from multiple disciplines, without faculty having to directly recruit students. Instructors are not asked to achieve a specific balance of multidisciplinarity, so the degree to which students interact across disciplinary lines is neither a judgement of instructor quality nor on the efficacy of the team. The multidisciplinary aspect of VIP is simply the result of faculty with multidisciplinary problems, who want to work with students from different disciplines (Figure 1). A new VIP site may initially be limited in disciplinary scope by departmental or curricular rules, but examples of successful multidisciplinary projects elsewhere in the Consortium can help overcome these barriers.

7. Dedicated classroom and meeting spaces. VIP teams do not function like traditional classes, so it is important to provide spaces in which the teams can meet and collaborate. Teams typically meet at the same time and day each week each semester, ensuring that team meetings work well with instructors' schedules. Student access to the space outside of scheduled class times allows for sub-team meetings. Rooms are typically set up in conference style to facilitate collaboration.

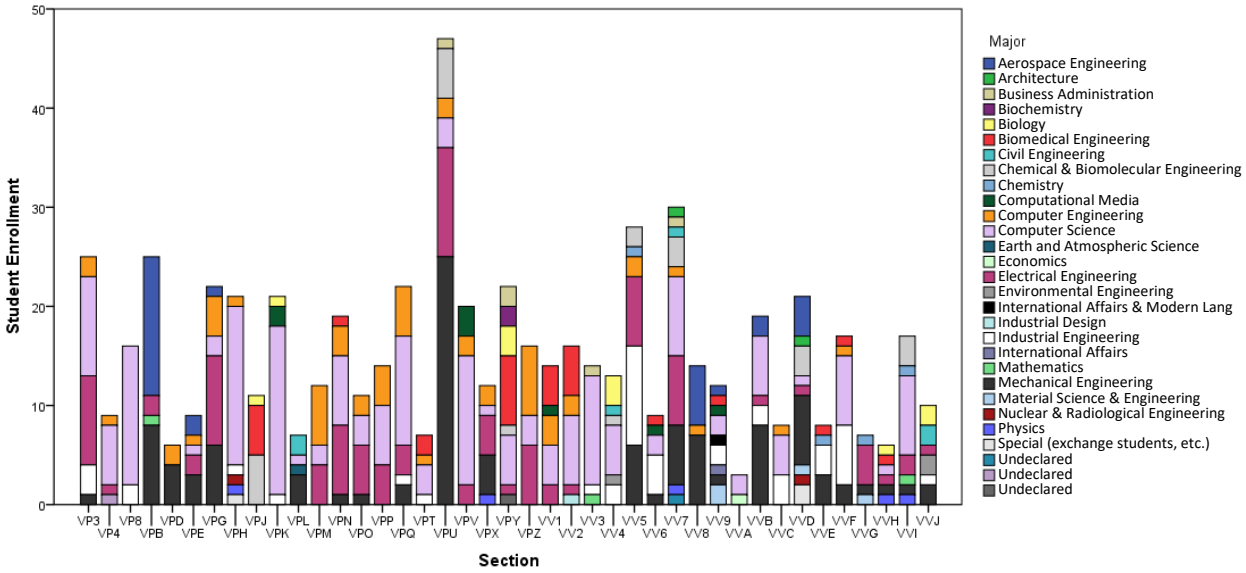

Figure 1. Distribution of Majors by VIP Team, Spring 2017 (Semester Studied)

As a course-based program, VIP teams meet weekly. Team meetings look much like weekly meetings between advisors and graduate students, with students reporting on obstacles and progress, advisors and teammates providing input, and the team identifying tasks for the coming week and beyond.

Two keys to productive VIP teams are effective peer support and peer management. Encouraging students to help each other, to be aware of each other's work, and to hold each other accountable shifts ownership to students and decreases instructor time spent on lower-level problems. Peer support can include crash-courses on a specific skill or topic, helping teammates debug problems (equipment, software, etc.), or giving suggestions and advice. In terms of peer-management, students are expected to work as a team, as opposed to only focusing on tasks to which they have been assigned. Teams are generally divided into subteams, which often meet outside of regularly scheduled class times. Students on subteams are expected to be aware of each other's progress on the project, and to hold each other accountable. This is especially

true of returning students who help bring new students up to speed on the project. This might include checking-in with new students more often, being aware of and providing feedback on teammates' work, and sharing progress with teammates whose work is related or dependent. Under this model, students are aware of each other's work, are actively engaged, and move the project and the team forward.

VIP Peer Evaluation

One third of student grades are based on personal accomplishments, one third on documentation, and one third on teamwork. Because the team experience is an important part of VIP, students are required to complete peer evaluations at the middle and end of each semester. Students who do not participate face a penalty on their final grade. Results are currently only shared with instructors, which they use to inform their grading and to provide feedback to students. The peer evaluation consists of fourteen questions, with twelve of the fourteen questions on a 1 to 5 point Likert scale. Prompts are provided for the 1-point and 5-point ratings, to define the high and low ends of the ranges, with no prompts for the 2-4 point options (Table 1). The peer evaluation questions were developed by VIP instructors and have evolved over time.

The peer evaluations are web-based, and questions are presented to students one at a time, with a list of teammate names and radio buttons for the Likert scale questions. The first question, "How often do you interact with each person below," is used as a filter, with remaining questions excluding teammates with whom the evaluator does not interact. Students can move forward and backward through the questions, allowing them to go back to the first question and change their mind on who they evaluate. While the online instructions are the same, instructors may give students direction on which classmates to evaluate (evaluate own sub-team, don't evaluate more than five or six teammates, etc.). While the results are useful in understanding the dynamics within the program, the peer evaluations are an instructional tool first and foremost, so instructors are not discouraged from using the evaluations as they see fit in their teams. While the instructions from instructors for the first question (who to evaluate) may vary from team to team, the scales on the remaining questions are consistent, still providing insight into the VIP experience. The evaluation does not require students to balance high ratings with low ratings, but a "quality of answer" bar appears at the top of each page, which ranges from short and red for responses with small standard deviations (i.e. entering all 5s) to full length and green for a wider distribution of scores. There is no consequence for "low" quality answers, other than knowing their instructor will see them.

The study involved peer evaluation question numbers two and twelve, which ask how often reviewers received suggestions/advice from teammates (never to very frequently with a scale of 1-5), and about teammates' management ability (unengaged to knowing what everyone is doing and tackling team problems, again on a scale of 1-5).

Social Network Analysis

Social network analysis is based on the ties (interactions, exchanges) between individuals (nodes), and it can shed light on the flow of information and resources within networks. In the context of this study, we consider the flow of help in the form of suggestions and advice, as well as the flow of peer management, which is also directional. Responses to the peer evaluation were on a scale of 1 (never receiving help from, or unengaged in terms of team management) to 5 (frequently receiving help from, or actively engaged). In the peer evaluation, a rating of 1 corresponds to no relationship. In social network analysis, a 0 represents no relationship. The peer evaluation responses were recoded to match this convention, with all values reduced by one, yielding a range of 0-4.

To quantify student interaction between students of the same major and other majors, the weighted EI index was used, a method used in ego-network analysis [2], [10]. In the case of seeking help, for each student (ego), the weighted EI index compares how often a he/she received help from teammates of the

same major for help (internal ties), as compared to receiving help from students of other majors (external ties). The calculation divides the difference of these numbers (sum of external tie strengths – sum of internal tie strengths) by the sum of the two (both tie strengths). In our analysis, responses on the Likert scale represent tie strengths, ranging from zero for no tie (never seeking help from the person) to four for the strongest tie (frequently seeking help from the person). The EI index ranges from -1 for someone who

Table 1. Peer Evaluation Questions and Likert Scale Prompts

Question	Prompts for 1-5 Point Likert Scale, Provided for Upper and Lower End Only
1. How often do you interact with each person below? *	1 = NEVER: I do not know this person. 5 = VERY FREQUENTLY: More than once a week.
2. How often do you get suggestions/advice from each person below?**	1 = NEVER: I rarely get suggestions/advice from this person. 5 = VERY FREQUENTLY: I get suggestions/ advice from this person very frequently.
3. How often do you give suggestions/advice to each person?	1 = NEVER: I rarely give suggestions/advice to this person 5 = VERY FREQUENTLY: I give suggestions/advice to this person very frequently.
4. Participation in team meetings/class:	1 = UNENGAGED: Always checking phone/laptop, unaware of others' status, efforts and work. 5 = VERY ENGAGED: Listens attentively, constructive participation.
5. Participation in subteam meetings or breakout discussions:	1 = UNENGAGED: Always checking phone/laptop, unaware of others' status, efforts and work. 5 = VERY ENGAGED: Listens attentively, constructive participation.
6. Documentation:	1 = USELESS: Key pieces of information are missing; Someone will need to re-write it. 5 = OUTSTANDING: Documents his/her work well (wiki, team resources); Documentation is very clear and helpful.
7. Quality of work:	1 = INADEQUATE: Late, sloppy or incomplete. 5 = OUTSTANDING: Higher quality than expected.
8. Communication:	1 = HORRIBLE: Doesn't listen to others' ideas or suggestions, does not communicate ideas clearly, does not reply to email/calls/texts. 5 = EXCELLENT: Listens to what others have to say, communicates well with others.
9. Dependability:	1 = UNDEPENDABLE AND UNRELIABLE: Misses deadlines, does not follow through on commitments, often misses or is late for meetings. 5 = VERY DEPENDABLE AND RELIABLE: Can always count on this person to achieve project's goals.
10. When encountering obstacles, how does each person react?	1 = STOPS WORKING: Gives up, does not look at documentation, does not ask teammates for help. 5 = SEEKS ANSWERS: Looks at team documentation Is not reluctant to ask for help
11. Independent Learning:	1 = UNABLE OR UNWILLING: Resists learning new skills. 5 = OUTSTANDING: Eagerly seeks out knowledge and learns skills needed for the project.
12. Team management ability:**	1 = UNENGAGED: Does not pay attention to teammates' progress, unaware of whether the team is meeting its goals, avoids discussing team problems. 5 = ABOVE AND BEYOND: Knows what everyone on the team is doing, always tries to tackle team problems.
13. Imagine your team is a company and you are the manager. VIP, Inc. has asked you to divide $10,000 in bonus money among the members of your team. EXCLUDING yourself, decide how the bonus should be divided.	
14. Comments. Please leave comments on each person below for your instructor(s). Constructive criticism is especially helpful.	

* Filter question. Students do not evaluate teammates for whom they respond "never."

** Items used in the analysis for this study.

only received help from like people (same major), to 1 for someone who only received help from dissimilar people (different major). Zero would represent a perfect balance between the two.

While the weighted EI index describes the flow of help, it does not take team composition into account. If three quarters of a students' teammates were from his/her major, and the student sought help from all teammates equally, the EI index would make it seem as if he/she preferred his/her own major to others. To balance the interpretation of the weighted EI index, the Quadratic Assignment Procedure is used to compare ties (seeking help from a teammate), student traits (majors, year in school, etc.), and the composition of the team (number from each major) [2], [11]. Whereas the weighted EI index is calculated at the individual level, QAP analysis is conducted at the team level, and can indicate whether students are clumping by a particular trait within the team.

To determine whether academic rank or status as new/returning students related to how often a student was sought for help or how students were rated on management ability, in-degree centrality (sum of strength of incoming ties) was calculated for each student on both measures. A student frequently sought for help or highly rated by many teammates would have high in-degree centrality. Because measurements are not independent of each other (Student A's network is interconnected with student B's, making them dependent), standard statistical analysis packages cannot be used. To analyze differences between groups, UCINET provides a test utilizing permutations that is equivalent to an analysis of variance [2], [11]. This analysis of variance equivalent was used to compare in-degree centrality scores by student academic rank and by amount of VIP experience.

Methods

To achieve valid results, analysis was only conducted for teams with peer evaluation completion rates of 80% or higher, the lowest acceptable threshold for social network analysis. UCINET, a network analysis software package, was used for the analysis [11]. The built in NetDraw tool was used to generate diagrams [12]. Enrollment records were obtained for the history of the VIP program through Spring 2017, to determine how many semesters students had participated in VIP. UCINET requires numeric data for categorical groupings, so all fields were coded numerically. Academic rank was coded on a scale of 0-4, with 0 for special undergraduates (exchange students, etc.), and 1-4 for freshmen through seniors. Status as new or returning was coded as 1 for first semester students, 2 for second semester students and 3 for students in their third through sixth semester. Majors were sorted first by college and then by major and then assigned three-digit numbers (first digit for college, and second two digits for major).

E-I indexes were calculated for each student, based on how often they sought help from students of the same major vs. students from other majors. A QAP analysis was done at the team level, to determine if students preferentially went to students from their own major for help, taking team composition into account.

In-degree centrality was calculated for all students on how frequently they were sought for help. Two UCINET Analysis of Variances (ANOVAs) were conducted, comparing in-degree centrality (incoming requests for suggestions/advice) first by student rank, and then by whether students were new or returning students. In-degree centrality was also calculated for students on how teammates rated their management ability. Two UNINET ANOVAs were again conducted in the same way, with one analysis by academic rank and another by status as new or returning students. The metrics used and statistical tests performed are summarized in *Table 2*.

Social network analysis is considered valid for surveys with participation rates of 80%. Even at this rate, information will be missing for those who do not participate. An acceptable convention is network reconstruction, where answers to questions asked in the reverse order are used to populate responses from

non-participants. If person A (who completed the survey) claims to have received help from person B, person B (who did not complete the survey) would have likely reported giving help to person A. As this was our preliminary analysis, we opted to not reconstruct the data, because we only wanted to use information as it was reported. This may result in less complete networks, but we chose to be conservative in our analysis.

Table 2. Summary of Metrics and Statistical Tests

Relationship	Network Analysis Metric	Network Grouping	Network Metric Calculated at	Analysis	Analysis Groupings
Who students went to for help	EI Index	Same Major Different Major	Student Level	Distribution	
	Pearson Correlation*	Same Major Different Majors	Team Level	QAP Analysis	
How often students were sought for help	In-degree Centrality		Student Level	ANOVA	Special undergraduate Freshman Sophomore Junior Senior
				ANOVA	1st semester 2nd semester 3rd semester or more
Ratings of management ability	In-degree Centrality		Student Level	ANOVA	Special undergraduate Freshman Sophomore Junior Senior
				ANOVA	1st semester 2nd semester 3rd semester or more

* The Pearson correlation is the product of the statistical test.

Results

There were 41 teams in Spring 2017, with 640 students. Thirty-four teams had peer evaluation completion rates of 80% or higher, leaving 483 enrolled students. Seven additional students participated in peer evaluations as graduate students through special topics courses, or as undergraduates receiving stipends or hourly payment. Because enrollment information (major, year in school) was not readily available for these students, they were not included in the analysis.

Help-Seeking by Major

For the question on how often respondents went to teammates for help by major, weighted EI indexes were calculated based on the majors of classmates they went to for suggestions and advice (same major vs. different major), and how frequently on a recoded scale of 0-4. The mean weighted EI index was .21 (N = 462, SD = .69), with the distribution illustrated in F
Figure 2. The number of students in this analysis was smaller than 483, because the calculation was based on student reports of receiving help from others, and not every student completed a peer evaluation.

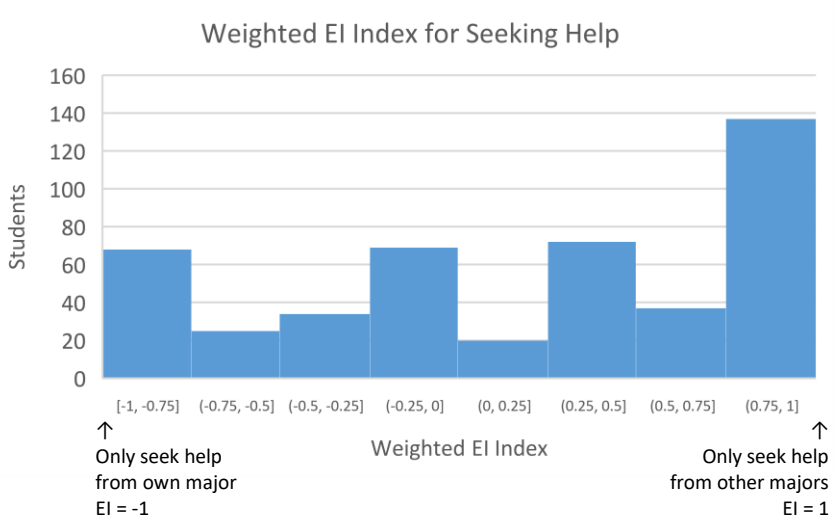

Figure 2. Histogram of Weighted EI Indexes for Students Seeking Help from Teammates by Major

A QAP analysis was conducted for each team, comparing the help seeking patterns within each team by major, with the analysis generating a Pearson Correlation and significance for each. The correlations were significant for seven of the 34 teams at the .05 level, as shown in Table 3.

Table 3. QAP Correlation comparing who students went to for help, and whether they were from the same or different majors.

Team	Pearson Correlation	Sig	Team	Pearson Correlation	Sig	Team	Pearson Correlation	Sig
1	-0.01	0.991	13	-0.07	0.632	25	0.21	0.325
2	0.20	0.525	14	0.64	*	26	0.02	0.299
3	0.37	0.532	15	0.10	0.706	27	0.11	0.544
4	-0.04	0.784	16	0.04	***	28□	0.07	0.580
5	0.67	0.590	17	-0.21	0.619	29	0.14	0.190
6	0.15	0.098	18	0.10	0.125	30	0.06	0.638
7	-0.24	0.997	19	0.08	**	31	0.01	0.594
8	-0.08	0.691	20	0.08	0.105	32	0.00^	1.000^
9	-0.12	0.285	21□	0.49	**	33	-0.02	0.420
10	-0.21	0.340	22	0.04	0.260	34	-0.18	0.379
11	-0.06	0.357	23	0.00	**			
12	0.17	**	24	0.29	***			

* p < .05 ** p < .01 *** p < .001 ^ Pearson correlation of zero; every student on team from different majors.

Note: Team size is not reported to maintain confidentiality. □ □ Social network diagrams illustrated below.

To illustrate the meaning of correlations and significance, social network diagrams are included for Team 21 (*Figure 3*) and Team 28 (Figure 4). Team 21 has a moderate Pearson Correlation of .49 and statistical significance of $p < .01$. The moderate clumping by major is not apparent in the first drawing, which includes all ties. The correlation becomes more apparent as weaker ties are removed from the diagram. Team 28 has a low Pearson correlation of .07, indicating almost no correlation, and does not show statistical significance at the .05 level.

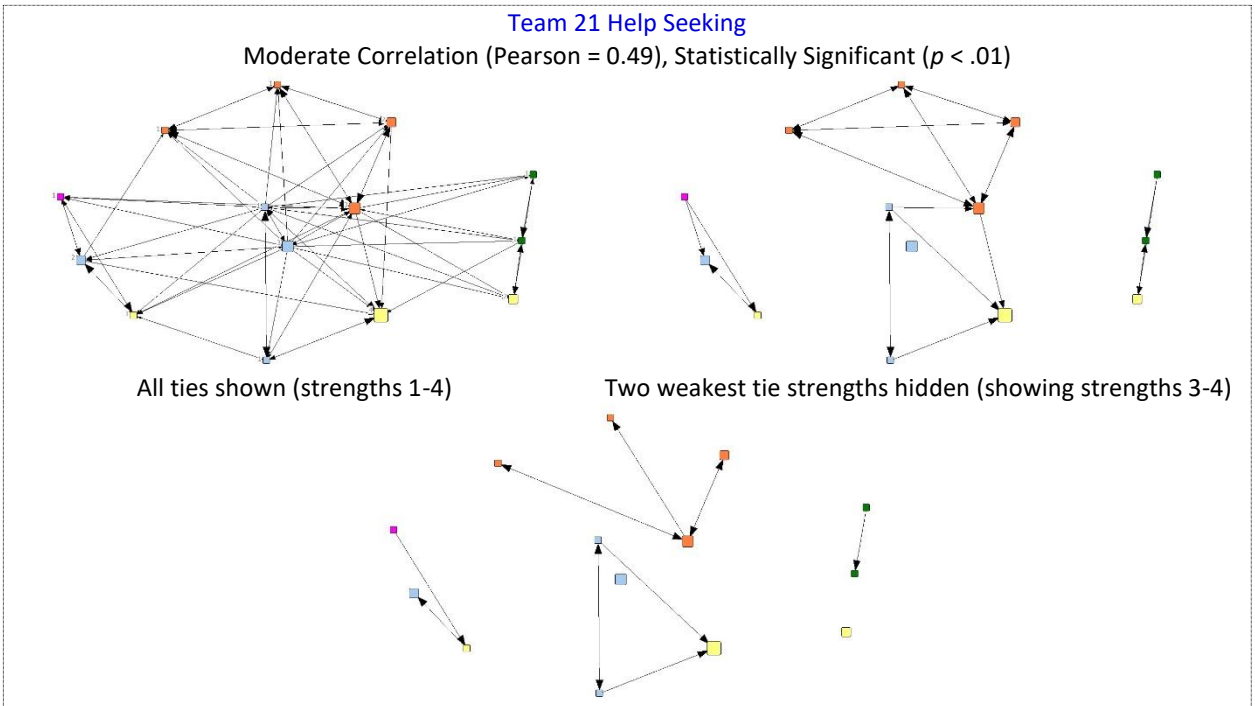

Figure 3. Social Network Diagram of Team 21

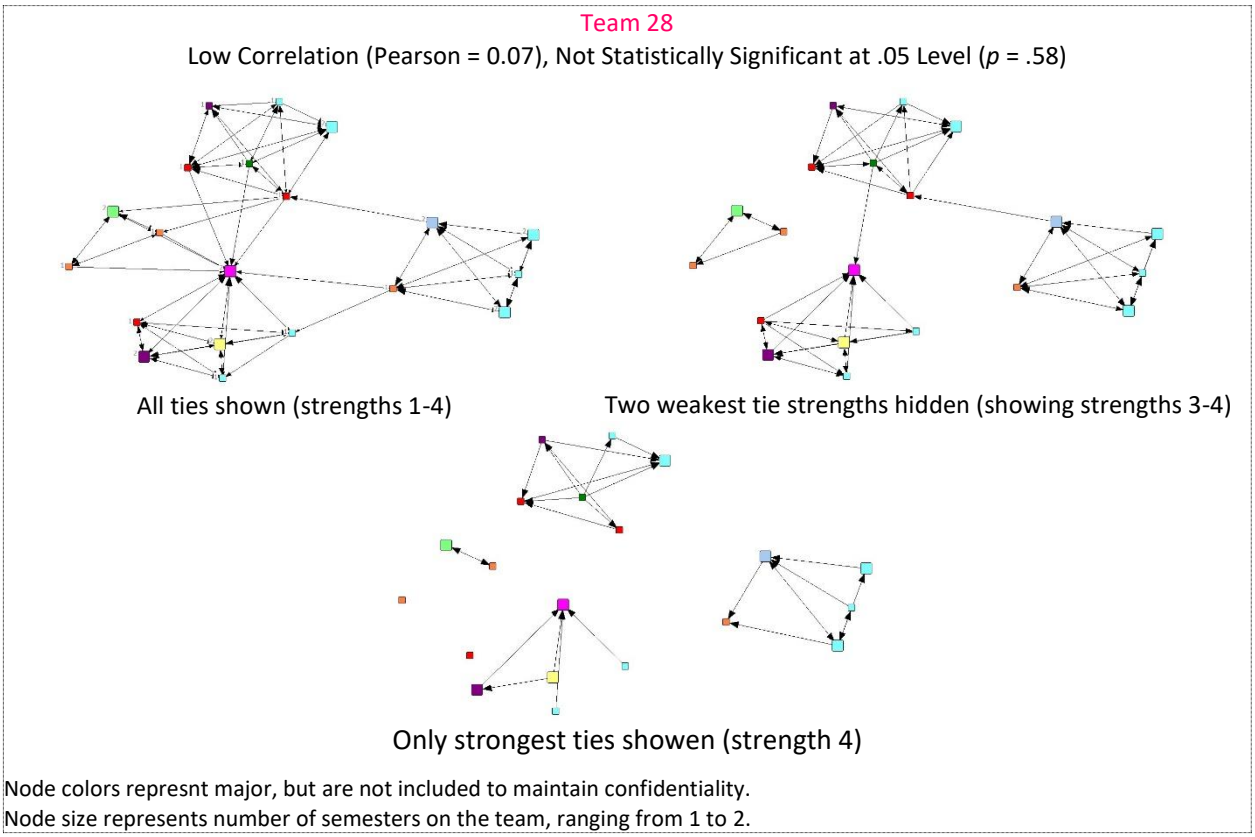

Figure 4. Social Network Diagram of Team 28

Being Sought for Help

By Academic Rank: In-degree centrality was calculated for each student on how often other students sought them out for help. A UCINET ANOVAs was conducted to examine the relationship between being sought for help and academic rank (*Table 4*). Results show statistical significance at the .05 level, with $F(4, 478) = 2.96$, $p < .05$. With an η_p^2 of .024, this represents a small effect size.

Table 4. ANOVA on In-Degree Centrality for being Sought for Help, by Academic Rank

Source	*DF*	*SSQ*	*F*-Statistic[F]	*p*[P]	η_p^2
Between Groups	4	918.74	2.960	*	0.024
Within Groups	478	37088.01			
Total	482	38006.75			

[F] $F_{critical}$ = 2.391 for the given degrees of freedom at the .05 level.
* $p < .05$

By Number of Semesters in VIP: Using the same in-degree centrality as above, a UCINET ANOVA was conducted to examine the relationship between being sought for help and status as first, second, or third or more semester students (Table 5). Results show a statistically significant correlation at the .001 level, with $F(2, 480) = 15.63$, $p < .001$. With an η^2 of 0.061, this represents a small to moderate effect size. Distributions for in-degree centrality for giving help are illustrated in Figure 5. In-Degree Centrality for Giving Help
Note: Shaded boxes represent the inner quartiles. Whiskers extending from the shaded boxes represent the ranges of the top and bottom quartiles, and dots represent outliers..

Table 5. ANOVA on In-Degree Centrality for being Sought for Help, by VIP Experience

Source	*DF*	*SSQ*	*F*-Statistic[F]	*p*	η_p^2
Between Groups	2	2324.14	15.632	***	0.061
Within Groups	480	35682.61			
Total	482	38006.75			

[F] $F_{critical}$ = 7.008 for the given degrees of freedom at the .001 level.
*** p < .001

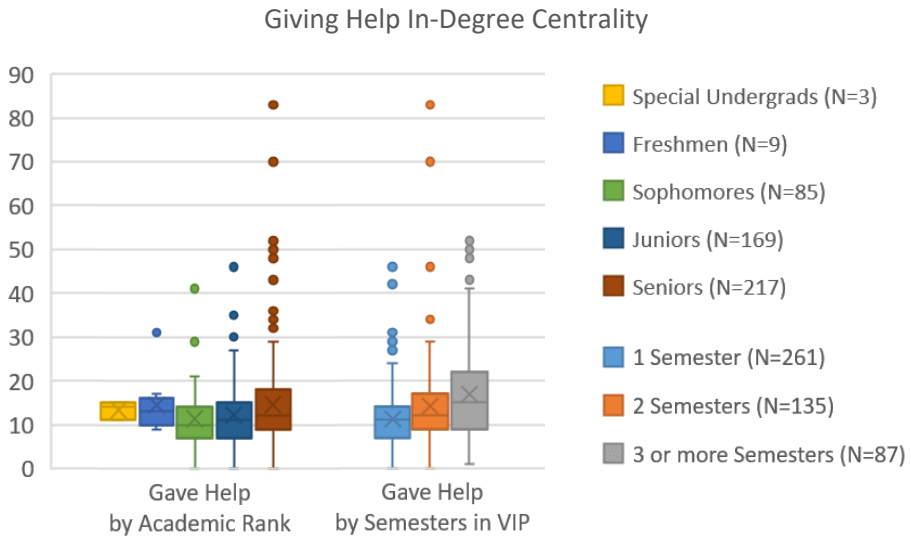

Figure 5. In-Degree Centrality for Giving Help
Note: Shaded boxes represent the inner quartiles. Whiskers extending from the shaded boxes represent the ranges of the top and bottom quartiles, and dots represent outliers.

Management Ability

By Academic Rank: In-degree centrality was calculated for each student for ratings on management ability. A UCINET ANOVA was conducted to examine the relationship between in-degree centrality for management ability ratings and academic rank (Table 6). Results showed no statistical significance at the .05 level, with $F(4, 478) = 1.851$, $p = .12$.

Table 6. ANOVA on Management In-Degree Centrality by Academic Rank

Source	*DF*	*SSQ*	*F*-Statistic[F]	*p*	η_p^2
Between Groups	4	781.21	1.851	0.1204	0.015
Within Groups	478	50434.21			
Total	482	51215.42			

[F] $F_{critical}$ = 2.391 for the given degrees of freedom at the .05 level.

By Number of Semesters in VIP: Using the same in-degree centrality for management as above, A UCINET ANOVA was conducted to examine differences between in-degree centrality for management and status as first, second, or third or more semester student (Table 7). Results showed a significant correlation at the .001 level, with $F(2, 480) = 12.366$, $p < .001$. With an η^2 of 0.049, this represents a small to moderate effect size. Distributions for in-degree centrality for management are illustrated in Figure 6.

Table 7. ANOVA on Management In-Degree Centrality by Semesters of VIP Experience

Source	*DF*	*SSQ*	*F*-Statistic[F]	*p*	η_p^2
Between Groups	2	2509.57	12.366	***	0.049
Within Groups	480	48705.84			
Total	482	51215.42			

[F] $F_{critical}$ = 7.008 for the given degrees of freedom at the .001 level.
*** p < .001

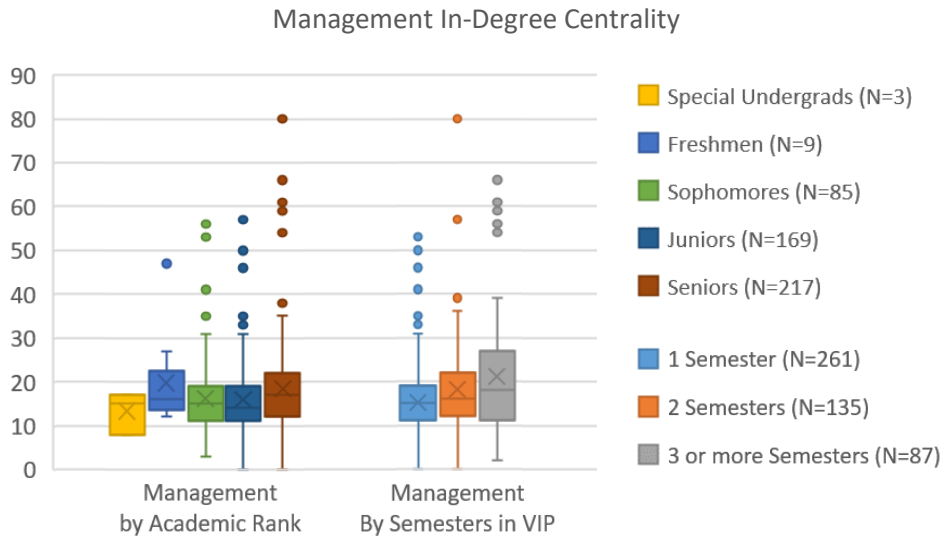

Figure 6. In-Degree Centrality for Management
Note: Shaded boxes represent the inner quartiles. Whiskers extending from the shaded boxes represent the ranges of the top and bottom quartiles, and dots represent outliers.

Discussion

Research Question 1: Helping within vs. across Majors

This study sought to answer three research questions. The first dealt with the help giving and help receiving in teams with respect to student major. While every VIP team is multidisciplinary, putting students from different majors onto the same team does not necessarily mean students' will work across disciplinary lines. A previous social network analysis of VIP peer evaluations found that on average, students interacted more often with students from other majors than their own, with eighteen of twenty-four teams showing no statistically significant correlation between interaction and major [3]. This analysis went a step further, examining who students went to for suggestions and advice, which we generalize as "help." The metric for this analysis was the weighted EI index, which takes tie strength (frequency of seeking help) into account. The mean weighted EI index was approximately 0.2 on a scale of -1 to 1. Since the value is positive yet small, it means that on average, students sought help slightly more often from students who were from other majors. The histogram of weighted EI Indexes in Figure 2 shows a peak at the far right. Thirty-seven percent of students fell within the top quarter of the range, seeking suggestions and advice from students from other majors substantially more often than from students from their own major. This implies meaningful collaboration between students from different disciplines is occurring within the context of VIP.

While the weighted EI index describes the typical VIP student experience, it does not take team composition into account. When considered at the team level, the analysis shows that in seeking help, students show a statistically significant preference for their own major on seven of the thirty-four teams. Again, the degree of multidisciplinarity is not a judgement on team efficacy or the program model, but the result of multidisciplinary projects. At the program level, the results represent a high degree of students helping each other across disciplinary lines.

Research Question 2: Giving Help, Academic Rank and VIP Experience

The second research question asked whether there was a difference between how often students sought help from classmates by academic rank (i.e., do students usually go upper level students for help) and by status as new or returning students. The analysis employed an analysis of variance of in-degree centrality, which is the sum of incoming requests for help. Results by academic rank showed statistical significance with a small effect size. UCINET does not offer post-hoc tests for the permutation-based ANOVA, but visual inspection shows two notable differences. First is a small increase between sophomores and juniors, and a larger increase from juniors to seniors. Each increase is accompanied by an increasing number of outliers with increasingly higher scores. This indicates upper-level students provide comparatively more help to teammates. A second noticeable difference is that special undergraduates and freshmen have higher means than sophomores and juniors. Samples for both were small, making the distributions vulnerable to the effects of outliers, but the differences may be tangible. Special undergraduates are typically exchange students, who may be of any academic rank. Exchange students may also be more eager to interact with teammates, creating more opportunities to give and receive help. Additionally, exchange programs generally attract motivated and high-performing students, who are capable and willing to provide help to teammates. As for freshmen, the VIP Program is intended for students of sophomore rank and above. Freshmen who participate are exceptions to the rule, who often have related experience and high motivation. The higher means reflect these traits. If the program actively recruited freshmen, the mean would likely approach that of or be lower than the sophomore mean.

Analysis of variance on giving help also showed statistical significance for the number of semesters students were in VIP, with groupings of one, two, and three or more semesters. However, VIP experience is related to academic rank, as both increase over time. The correlation is not one-to-one, because students can begin VIP at any academic rank, but they are related. This can be seen by visually mapping upper outliers between the two groupings (*Figure 7*). The five highest in-degree centrality values were all for seniors, with two values mapping to students in their second semester of VIP, and three values mapping to students in their third or later semester. (Each value may correspond with multiple students.) Both the significance and effect size were greater for experience than for academic rank, showing VIP experience has a stronger effect than (or an effect in addition to) academic rank, with an effect size 2.5 times greater.

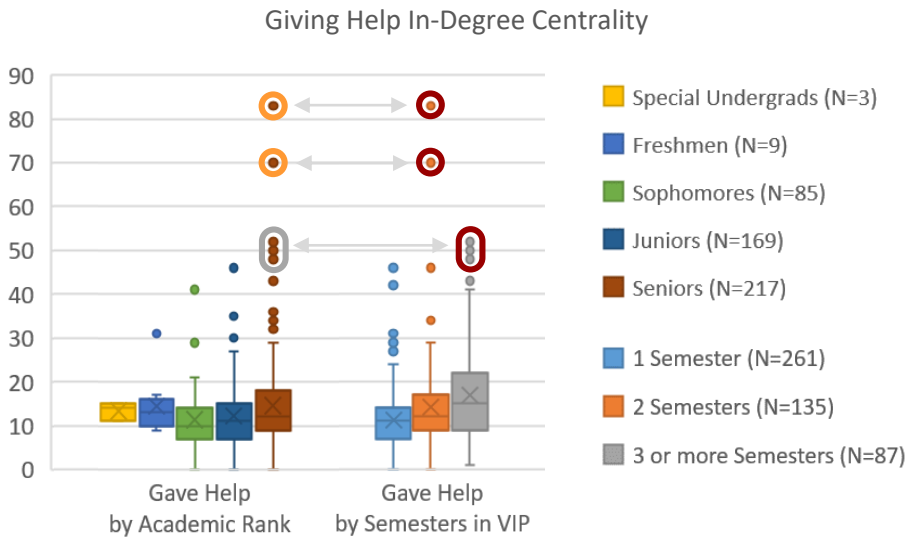

Figure 7. In-Degree Centrality for Giving Help, Noting Correlation between Five Upper Outliers and Groupings

Research Question 3: Team Management, Academic Rank and VIP Experience

The third research question asked whether there was a difference between management ability ratings and academic rank and experience on the team. The peer evaluation described management as being engaged, knowing what everyone on the team is doing, and always trying to tackle team problems. There was no difference for students by academic rank, but there were significant differences in management in-degree centrality by semesters of experience, with a small to moderate effect size. Again, because UCINET does not provide post-hoc tests, we use visual inspection to consider differences. As in the analysis of help-giving, centrality scores increase steadily from sophomores to juniors and from juniors to seniors. The significance for VIP experience indicates that returning students provide leadership within VIP teams. The results imply that social capital within teams is tied to students' VIP experience, and not necessarily their academic rank.

Limitations

To examine student helping by major, we used weighted EI indexes and QAP analysis. Both compare ties (helping) between team members by similarity or difference (in this case major). The weighted EI index is calculated at the student level, and QAP analysis at the team level. A weakness within the VIP context is that some teams have so many different majors, that some students have little or no opportunity to interact with their own major. While the results describe the student experience, some effects may be due to structural limitations.

To examine patterns for giving help and for management, we analyzed in-degree centrality. A weakness in this approach is that in-degree centrality is limited by team size. Teams ranged in size from six to forty-two students. On the adjusted scale of 0-4, this allows maximum possible in-degree centralities of 24 to 168. Side by side comparisons of teams or individual students from different teams would be inappropriate. Our analysis was done by student academic rank and VIP experience. Our assumption is that teams have similar distributions of students by academic rank and experience, evenly distributing this limiting factor across the subgroups.

Conclusion

This study examined helping and management patterns within multidisciplinary VIP teams. Teams are led by faculty in areas contributing to their research. Students from different academic ranks participate, and they can but are not required to participate for multiple semesters. Social network analysis indicates that within VIP, students receive help more often from students from other majors. At the program level, teams did not generally clump by major. The degree to which students helped teammates showed a statistically significant relationship to students' VIP experience, which had the highest significance and largest effect size, as well as student academic rank. The relationship between management ratings and VIP experience was also statistically significant. The results confirm that returning students take on leadership roles within their teams, both in terms of providing help and team management. Academic rank played a role in terms of providing help, but not a statistically significant role in peer management. These findings and method of analysis would be of interest to current and prospective VIP sites, as well as programs seeking to develop or quantify multidisciplinary student experiences.

Addendum: Getting Started with Social Network Analysis

Social network analysis methods can be applied in team settings to help instructors visualize interactions within the team, to measure interaction across disciplinary lines, and to identify factors associated with peer support and leadership. Social network analysis questions can be incorporated into existing peer evaluations, and would not require the administration of additional surveys. We suggest obtaining student attributes (major, academic rank, gender, race/ethnicity) from your campus institutional research office to

ensure completeness of data. This is also helpful, because it will provide consistent wordings and spellings for majors and ethnicities, which will require less data cleaning.

The analysis can be conducted with UCINET, which includes the NetDraw network visualization package [11]. The book *Analyzing Social Networks* provides a solid introduction to social network analysis methods and UCINET [2]. Users can import peer evaluation data as "edge lists" (a table with columns for reviewer, reviewee, and score) and student attributes as "matrices" (a table with columns for reviewer, major, academic rank, etc.). Student names can be numeric, but attribute data must be coded prior to upload. Numeric data can be recoded in UCINET through dropdown menus and dialog boxes. In our case, we recoded the Likert scale from 1-5 to 0-4.

Conventional analysis methods such as ANOVA cannot be applied to social network analysis metrics, because measurements are not independent of each other, which is an assumption of ANOVA. Instead, equivalent UCINET tests that employ permutations can be used. Because the tests use permutations, results will vary with each run of the same data, but the variations are slight.

It is important to note that the EI index available via the dropdown menu in UCINET is a standard EI index. With this method, all ties are dichotomized to values of 0 or 1. To retain tie strength (never, sometimes, very frequently, etc.), the weighted EI index can be run through the command line interface.

If doing the analysis for internal program management and improvement, institutions may not require institutional review board (IRB) approval. If researchers plan to present or publish results, they must obtain IRB approval or be approved as exempt. At some institutions, a retrospective analysis of results from past semesters is easier to arrange and manage than an ongoing study with currently enrolled students. Other institutions may require subject consent for retrospective studies, in which case a study on currently enrolled students would be easier to manage.

Addendum: Piloting or Establishing a VIP Program

The VIP Consortium brings together institutions in varying stages of VIP Program development, from department-level to campus-wide programs. Members attend an annual consortium meeting to share and learn about variations in implementations, and sites share resources and software tools in an online member portal as well as GitHub. Domestic and international departments, colleges, and institutions interested in piloting VIP Programs can contact the Consortium Director for more information [6].

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