Experience vs. Academic Rank: Leadership Growth over Multiple Semesters in Vertically Integrated Project (VIP) Courses

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***Abstract*—This innovative-practice work-in-progress paper explores student leadership development over multiple semesters in team-structured project-based courses. While student growth is expected in a single semester, the study asks if multiple semesters of participation lead to continued leadership growth, and if so, over how many semesters of participation growth continues. The study examined peer evaluation ratings in general leadership (coordination of teams' work) and technical leadership (serving as a technical/content area leader) in a single semester of Georgia Tech's Vertically Integrated Projects (VIP) Program, a multidisciplinary, multi-semester, team-structured, project-based, and credit-bearing program in which student teams support faculty research. Analysis examined means and distributions on two peer evaluation questions (N = 1,073 and N = 1,047) by student academic rank and number of semesters of participation in the program. Findings indicate that within their teams, students' leadership increased through the third semester, with students making their greatest leadership contributions in the third semester and beyond; and students of lower academic rank provided as much leadership (including technical leadership) as older students who had comparable experience on the team. Both the VIP model and the operationalization of leadership represent innovative practices, because the VIP model yields measurable gains in student leadership, and the measurement of student leadership is based on peer-evaluations instead of self-assessments. The educational model and research in this paper are aligned with the FIE values of encouraging mentorship and professional growth, appreciating multidisciplinary approaches, valuing new approaches, and generating new knowledge. The paper addresses limitations and next steps for the study.**

Keywords—leadership, multidisciplinary, transdisciplinary project based learning, team based learning, undergraduate, higher education, Vertically Integrated Projects, VIP.

I. Introduction

Higher education has experimented with project-based learning for decades, from small activities to large-scale projects lasting multiple years [1]. Beyond project-based learning, the National Academies of Science, Engineering and Medicine envision multidisciplinary STEM education that measures student growth instead of knowledge acquisition [1]. Layered upon this is worldwide interest in students' development of professional skills to address workforce needs, , particularly leadership [2]. In a survey of employers, leadership was the fourth most influential attribute sought in prospective employees, outranking high GPA. The only more influential attributes were internships with the employer, internships in the field, and major [3].

Vertically Integrated Projects (VIP) is a scalable, multidisciplinary model for project-based learning, currently in place at 44 colleges and universities in 13 countries [4]. In VIP, large-scale, long-term student teams are embedded in faculty projects. The model enables faculty to tackle more ambitious projects than otherwise possible and gives them access to motivated students from their own and other disciplines. Students earn 1-2 credits per semester, can participate for multiple semesters, and receive grades for their work each semester. Some universities' VIP Programs involve only second year students and above, while others include first year students as well. Teams can also include Master's students, PhD students, and post-doctoral scholars.

Student leadership is a key aspect of VIP, because returning students take on additional leadership and technical responsibilities, including onboarding and mentoring new team members. This enables faculty to work with many more students than otherwise possible, and it is mutually beneficial. Students benefit from mentoring and being mentored by peers.

This study sought to answer two research questions:

- Do undergraduate students in their second and later semesters of VIP provide more peer-leadership than undergraduate students in their first semester of VIP?
- If so, over how many semesters of participation in VIP does student leadership increase?

II. Background

A. Student Leadership Development in Higher Education

Since the early years of higher education in the United States, institutions have been expected to develop future leaders [5]. Chunoo and Osteen found leadership critical to problem solving, community engagement, and career success, with development of student's leadership capacities impacting outcomes across higher education [6]. Unfortunately, Komives and Sowcik found institutions can pay lip-service to student leadership, claiming to create "global citizen leaders" while only

offering leadership programming as an extracurricular activity and not measuring institution-level outcomes [5, p. 13].

Leadership involves a multitude of skills. Seemiller examined accreditation manuals for 522 types of academic programs in the United States and identified 60 competencies related to leadership development [7]. He grouped the 60 competencies into eight clusters: learning and reasoning; self-awareness and development; interpersonal interaction; group dynamics; civic responsibility; communication; strategic planning; and personal behavior [7]. The scope of this paper's study is limited to two activities: coordination of the team's work, and serving as a technical/content area leader. These would involve competencies from four of Seemiller's six clusters: communication; group dynamics; strategic planning; and personal behavior (includes initiative and confidence).

Komives and Sowcik differentiate between leadership education and leadership development. Leadership education involves structured instruction, which is typically offered through campus offices of student affairs [5], [8]. In contrast, leadership development increases student skills and leadership capacity. This can occur in a variety of contexts such as student organizations, student teams, and potentially in VIP.

B. The VIP Model

In VIP, student teams are embedded in faculty research, scholarship, and creative endeavors. Teams are established by faculty request, and projects must be long term (at least 3-5 years) and large scale (with enough tasks for a team of 10 to 20 or more students). For example, an Electrical Engineering professor who studies lightning has led the "Lightning from the Edge of Space" team for 8 years, with approximately 17 students each semester. The team builds high-altitude data-collection systems, launches them on weather balloons, analyzes the collected data, and works to expand and optimize the systems.

Large-scale projects are multidisciplinary by nature, and VIP gives faculty access to students from other disciplines. For example, in Spring 2022 the Lightening from the Edge of Space team enrolled students from Aerospace Engineering, Computer Engineering, Computer Science, Earth & Atmospheric Science, Electrical Engineering, Mechanical Engineering, and Physics.

VIP is offered as a course for 1-2 credits/semester, with 1 credit for sophomores and 1-2 for juniors and seniors. Offering VIP as a course and allowing credits to count toward degree requirements increases student access, particularly among students who may not otherwise participate in clubs or co-curricular activities (students with work or family obligations, less confidence, etc.). Unlike undergraduate research for academic credit, typically arranged through student-faculty relationships, VIP projects are posted online and students are actively recruited from across campus, also increasing access.

Students apply to join a specific VIP team. Applications are low-stress, with students indicating their academic rank, major, number of credits, and their motivation for wanting to join the team. Student motivation is the strongest predictor of student success in VIP, so grade-point averages, resumés, and letters of recommendation are not considered. Faculty are typically skeptical of the process, but after one or two semesters, they see the value in the accessible nature of the model.

Students can participate in VIP for multiple semesters, with returning students taking on additional responsibilities and helping to onboard new team-members. This enables faculty to mentor large teams. At Georgia Tech, a team size of ten to twenty students ensures enough students return each semester to maintain continuity. Student rates of participation in second and subsequent semesters are correlated with policies on how the credits count toward graduation requirements in their majors [9].

The VIP Program is steadily scaling, with 84 teams in Fall 2022 (https://vip.gatech.edu/teams). Key to the success of the model is that participation is based on mutual interest. Faculty establish teams because they want to, and students join teams because they are interested in the projects. This differentiates VIP from courses in which students are assigned to projects or teams. Those involved in VIP *want* to participate, which supports active engagement and collaboration.

III. Methods

The analysis used data from midterm peer evaluations administered in Spring 2021. Midterm evaluations were used to capture student dynamics in the midst of team establishment. In contrast, final evaluations would reflect performance after a full semester of growth. In the evaluation, students were presented with a list of teammates and asked how often they interacted with each. Teammates that a reviewer indicated not interacting with were excluded from remaining questions. Responses to two questions were used in the analysis:

- Think about how your team is organized. Please indicate whether each student below coordinates (or does not coordinate) the team's work.
- Think about how your team is organized. Please indicate whether each student below is (or is not) a technical/ content area leader on the team.

Responses were on a 5-point Likert scale. Anchors for the scale on the first question were 1 for "does not coordinate the team's work" to 5 for "coordinates the team's work." Anchors for the second question were 1 for "not a technical/content area leader" to 5 for "technical/content area leader."

Because a fourth-year student might provide more leadership than a second-year student, academic rank was included in the analysis along with semesters of participation in VIP. Academic rank was based on university categorizations appearing in class rolls. In the university categorization, first-year students in their first semester of college are listed as freshmen, regardless of the number of college credits or Advanced Placement credits earned in high school. In a student's second semester and forward, academic rank is based on credits earned. As a result, some students classified as sophomores in Spring 2021 were first-year college students. When completing evaluations, reviewers were not given information on their classmates' academic rank or number of semesters in VIP, although they may have already known.

The criteria for semesters of participation in the analysis differed from that used in the campus' institutional research office. In the institutional research office, students who withdraw from a course are considered participants. In this

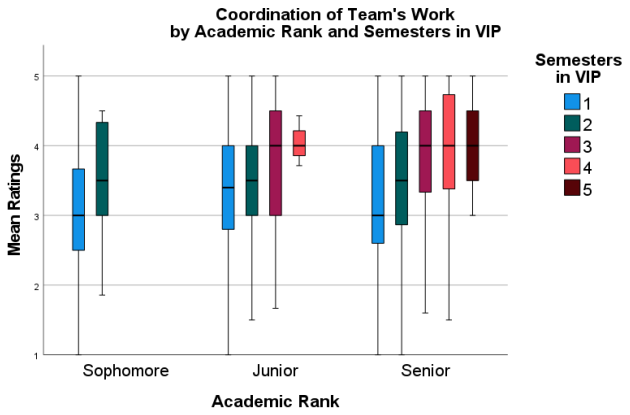

Fig. 1. Mean ratings for coordination of team's work by academic rank and semesters in VIP. Boxes represent 2nd and 3rd quartiles. Whiskers represent top and bottom quartiles.

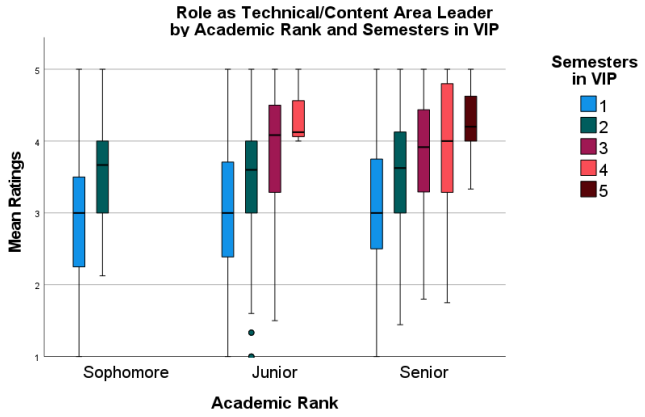

Fig. 2. Mean ratings for role as technical/content area leader by academic rank and semesters in VIP. Boxes represent 2nd and 3rd quartiles. Whiskers represent top and bottom quartiles. Dots represent outliers.

study, semesters in which students withdrew were not counted in their total number of semesters in the program.

Cases were excluded when reviewers rated all teammates with 5s on a question, because the reviews provided no information; when reviewers rated all teammates with 1s on a question for the same reason, along with likely having reversed the scale; and when reviewers reviewed only one person, because the reviewee was not being compared to anyone else. Results for graduate students were excluded because the research questions relate to undergraduate students, but their reviews of undergraduates were included.

Mean ratings were calculated for each student. SPSS was used to conduct a two-way analysis of variance (ANOVA) on mean ratings by academic rank and semesters in the program, with a separate analysis for each question. ANOVA is appropriate when subjects' scores are independent of other subjects' scores. Although students reviewed teammates, their ratings were not influenced by scores received by reviewers, so we treated their mean scores as independent of each other. Where ANOVA results indicated differences by a factor, Tukey's HSD (and in one case Dunnett's test) for multiple comparisons were used as post-hoc tests to determine which subgroups differed from each other.

IV. Data and Results

Of 1,266 students invited to do evaluations, 1,149 participated, for a response rate of 91%. Cases were excluded as described in the methods section, along with five additional cases. This included four freshmen, because the group was small and the program is intended for sophomores and above. One sophomore was excluded because their semesters of participation in VIP (4) did not align with their academic rank (2nd year), which created a group of 1 by rank and semesters in VIP. After cases were excluded, ratings remained for 1,073 students (85%) on the technical/content area question, and for 1,047 students (83%) on coordination of their teams' work.

For ratings on coordinating the team's work, Levene's test of homogeneity was not significant, indicating ANOVA would be appropriate. In a two-way ANOVA, number of semesters in VIP was statistically significant at the .05 level with a medium effect size ($F(4, 1036) = 13.16$, $p < .001$, $\eta^{p2} = .048$) (Fig. 1). Neither academic rank ($F(2, 1036) = 0.31$, $p = .731$) nor interaction between academic rank and semesters in VIP ($F(4, 1036) = 1.10$, $p = .355$) were statistically significant. Tukey's HSD Test showed statistically significant differences between students in their 1st semester of VIP and all other groups ($p <$ .001 for all comparisons). Tukey's Test results comparing 2nd semester students with 3rd, 4th and 5th semester students were problematic, indicating no difference between students in their 2nd semester of VIP compared with students in their 3rd, 4th and 5th semesters. This seemed unlikely because the difference between these groups was greater than the difference between 1st and 2nd semester students, for which Tukey's Test indicated a difference. IBM indicates that the Tukey's Test in SPSS is the Tukey-Kramer Test, which is appropriate for unequal sample sizes [10], however the addition of duplicate data to small groups confirmed that sample sizes were affecting post-hoc results. However, this is not an accepted method for confirming differences between groups. Dunnett's test is also recommended for unequal sample sizes, so this was used to compare students in their 2nd semester of VIP with students in their 3rd, 4th and 5th semesters. Results of a two-tailed Dunnett's test confirmed that students in their 2nd semester of VIP differed from students in their 3rd ($p = .002$), 4th ($p = .006$), and 5th semesters ($p = .010$). Both the Tukey and Dunnett's Tests agreed that students in their 3rd, 4th and 5th semesters did not differ from each other.

For ratings on being a technical/content area leader, Levene's test of homogeneity was not significant, indicating an ANOVA would be appropriate. In a two-way ANOVA, number of semesters in VIP was statistically significant at the .05 level with a medium to large effect size ($F(4, 1062) = 27.12$, $p < .001$, $\eta^{p2} = .093$). Neither academic rank ($F(2, 1062) = 0.53$, $p = .591$) nor interaction between academic rank and semesters in VIP ($F(4, 1062) = 1.02$, $p = .398$) were statistically significant. Tukey's HSD Test showed statistically significant differences between students in their 1st semester of VIP and all other groups ($p < .001$ on all comparisons), and between students in their 2nd semester compared to 3rd ($p = .006$), 4th ($p = .020$), and 5th ($p = .033$) (Fig. 2). Students in their 3rd, 4th and 5th semesters did not differ.

Because academic rank was not statistically significant for either item, charts for ratings by semester in VIP were generated for both items to aid in interpretation of the results (Fig. 3).

V. Discussion

The first research question asked whether returning VIP students provided more leadership within their teams than students in their 1st semester of the program. On average, students in their 2nd and later semesters of VIP provided more leadership than 1st-semester students, as seen in Fig. 3.

The second research question asked, if returning students provided more leadership, over how many semesters of participation leadership increased. On both coordination of teams' work and serving as technical/content area leaders, students received progressively higher mean ratings with subsequent semesters of participation, plateauing after the 3rd semester. If leadership growth was the sole goal of the program, and if the peer-evaluations accurately captured all aspects of leadership, then 3 semesters of participation would be sufficient to achieve the observed gains. However, VIP aims to support student growth in multiple areas as well as faculty research. The peer evaluations indicate that students make their greatest leadership contributions in their 3rd semester and beyond, carrying value for 4th and 5th semesters.

An unexpected result was the lack of correlation between academic rank and leadership. In their 1st semester, sophomores, juniors and seniors provided similar levels of leadership (Fig. 1 and Fig. 2) despite differences in academic rank and experience outside of VIP. The growth trend over the subsequent semesters is apparent, as is the lack of correlation between academic rank and leadership.

A. Limitations

The scope of the study was limited to enactment of two aspects of leadership as reported by peers. It did not examine underlying competencies (self-awareness, interpersonal interaction, group dynamics, etc.) or other aspects of student development (professional identity formation, disciplinary expertise, etc.).

Because the study relied on peer-evaluations, it did not capture leadership activities observed by instructors that were not observed by peers. This would include collaboration with instructors and graduate student mentors such as planning, problem-solving and decision-making. Leadership growth may continue beyond the third semester, but it may only be apparent to instructors and would not be captured by this analysis.

Another limitation of the analysis is that the two predictor variables, academic rank and semesters in VIP, loosely covaried. While there were juniors (3rd year) and seniors (4th year and above) in their 1st through 4th semesters of VIP, 5th-semester students were all seniors, and all sophomores (2nd year students) were in their 1st or 2nd semesters of VIP, with the exception of one excluded outlier. The lack of correlation between academic rank and ratings and lack of interaction effects made the loose correlation more tolerable.

Another limitation was that the study was not longitudinal, using data from a single semester. A problem posed by this is self-selection. If students uncomfortable who receive low leadership ratings participate for only one semester, this would artificially inflate ratings for returning students. This limitation will be addressed in a future longitudinal study that will examine individuals' ratings over time. The analysis could also focus on degree programs with high re-enrollment rates, potentially yielding less self-selection [9].

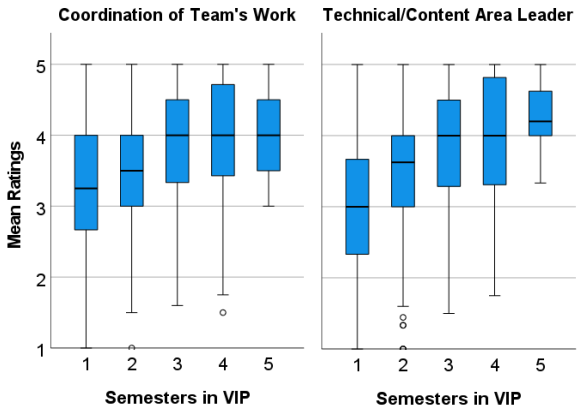

Fig. 3. Mean ratings for coordination of team's work and role as technical/content area leader by semesters in VIP.

VI. Conclusion

While student leadership education is typically offered as an extra-curricular activity through offices of student affairs, student leadership development takes place in applied contexts, such as student organizations and teams [5], [8]. VIP is unique, in that it is a curricular (credit-bearing) context for leadership development.

Rather than using self-reported measures, this study examined leadership activity as reported by peers. In multi-semester project-based VIP courses, peer ratings of coordination of the teams' work and technical/content area leadership were not correlated with academic rank. Instead, peer-reported leadership increased with semesters of experience on the team through the 3rd semester, with the same levels continuing through the 4th and 5th semesters. The analysis did not include assessments from instructors, which could provide more insight, particularly on students in their 3rd, 4th and 5th semesters.

A key aspect of VIP is that teams support faculty research. Based on the findings of this study, faculty should not discount the value of students of lower academic ranks. Within VIP teams, 2nd-year students provide as much coordination and technical leadership as older students with the same number of semesters of experience on the team. Indeed, allowing students to join as 2nd-year students and encouraging two or more years of participation (by allowing credits to count toward degree requirements [9]) would maximize student leadership development and potential benefits to faculty.

Acknowledgment

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