First-Year Experiences – How the Vertically Integrated Projects (VIP) Model Addresses Grand Challenges and ABET Outcomes

Nichole Ramirez
Vertically Integrated Projects
Purdue University
West Lafayette, IN USA
nramire@purdue.edu

Carla B. Zoltowski
Vertically Integrated Projects
Purdue University
West Lafayette, IN USA
cbz@purdue.edu

***Abstract*— This Innovative Practice, Work in Progress paper examines first-year student perceptions and learning outcomes in an experiential learning program. The Vertically Integrated Projects (VIP) model affords students an opportunity to earn academic credit by working on teams while contributing to faculty-led research and design projects. The real-world context of the VIP projects facilitates student engagement in projects that address Grand Challenges. As part of the innovative model of our VIP Program at Purdue University, we have incorporated student self-reflection of their progress on each of the seven ABET outcomes as part of the student assessment. The VIP model was recently expanded as a pathway for first-year students at our institution, which requires all engineering students to complete a first-year program. This work addresses the ways in which first-year students participating in VIP address Grand Challenges and explores the ways in which these students meet ABET outcomes using the following research questions: 1) How are first-year VIP students reflecting on ABET outcomes? 2) How does participation in VIP affect first-year students' interest, self-efficacy, and sense of belonging in engineering? The study uses a mixed methods approach, triangulating qualitative and quantitative student evaluation data from Fall 2020 – Fall 2021. Survey results indicate that VIP participation has a positive effect on student perception of engineering, and, although they may not address all ABET outcomes as first-year students, students effectively connected their project work with specific outcomes. By understanding how VIP and, more generally, experiential learning affects first-year students' perceptions and connection to ABET outcomes, educators can adopt this model and strengthen student experiences from the beginning.**

Keywords—first-year engineering, experiential education, learning outcomes, student perceptions

I. INTRODUCTION

Experiential learning is gaining traction in engineering education as an effective method for students to gain authentic engineering experience that is embedded in their curriculum, allowing students to reflect on their experiences and to make connections with their long-term goals.

In the Vertically Integrated Projects (VIP) program, undergraduate students from a variety of disciplines and backgrounds work together on interdisciplinary and vertically integrated teams (first-year students through seniors) with faculty and graduate student mentors on authentic projects embedded in faculty scholarship and exploration. The teams are: interdisciplinary – drawing students from the disciplines needed by each project; vertically-integrated – maintaining a mix of undergraduate students from different cohorts; large-scale – often with 10 to 20+ undergraduates per team; and long-term – undergraduates can earn academic credit in VIP for up to four years, and the projects last for many years, even decades.

The VIP model is being implemented at more than 40 institutions across the world as part of the VIP Consortium [1]. Since Fall 2019, the VIP program at Purdue University has more than doubled its undergraduate enrollment, working with 48 faculty/staff mentors across seven colleges in 15 departments across the university. In Spring 2022, 430 undergraduate students across 24 different majors participated on 42 VIP teams.

Undergraduate students in VIP earn academic credit for their participation and can participate multiple semesters or years. The continuity, disciplinary depth, and interdisciplinary breadth of these teams enable the completion of projects of significant scope which benefit both students and faculty who participate. The undergraduate students have an opportunity to gain valuable experience working on these authentic projects and develop a wide range of technical and professional skills, such as oral and written communication, leadership, teamwork, and project management skills.

Course-based research experiences such as VIP have been shown to be more accessible, equitable, and scalable than other research opportunities [2]. Several VIP teams at Purdue are addressing Grant Challenges, including eHealth/AI for Happiness, Data Science for Smart Cities, and other multidisciplinary teams focused on machine learning, like Computer Vision for Forest Inventory Analysis. From their first

semester at the institution, first-year engineering students are mentored by faculty and graduate, and undergraduate students, preparing them to conduct research in different engineering-related fields.

This work will address the ways in which first-year students participating in VIP at Purdue address Grand Challenges and explore the ways in which these students meet ABET outcomes using the following research questions: 1) How are first-year VIP students reflecting on ABET outcomes? 2) How does participation in VIP affect first-year students' interest, self-efficacy, and sense of belonging in engineering? The research questions will be answered using a mixed methods approach, triangulating qualitative and quantitative student evaluation data from Fall 2020 – Fall 2021.

II. Learning outcomes

Throughout the semester students complete a set of assignments focused on individual accomplishments/learning, documentation, and teamwork/interaction. Students conduct peer reviews and individual performance evaluations at mid-semester and at the end of the semester. The individual performance evaluations are designed to be cumulative and reflective. For instance, students reflect on their team experience and self-perceptions at mid-semester, then further reflect on their progress in since mid-semester in the final evaluation at the end of the semester. Students also reflect on their professional development throughout the semester. More specifically, students in VIP at Purdue are required to submit an abstract and present at a conference or to an external stakeholder. The final individual performance evaluation also requires students to reflect directly on the seven ABET learning outcomes [3]:

> i. an ability to apply engineering design to create a product (e.g., device, system, process, software, etc.) that meets the specified needs of this engineering design experience with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.
>
> ii. an ability to develop and conduct experimentation, analyze and interpret data, and use engineering judgment to draw conclusions related to the development of the product of this engineering design experience.
>
> iii. an ability to identify, formulate, and solve complex engineering problems arising from this engineering design experience by applying principles of engineering, science, and mathematics.
>
> iv. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives associated with this design experience.
>
> v. an ability to communicate effectively with a range of audiences appropriate to this design experience in both a written report and oral presentation.
>
> vi. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies to complete the engineering design experience associated with this course.
>
> vii. an ability to recognize ethical and professional responsibilities associated with this engineering design experience and make informed judgments which must consider the impact of the product of this engineering design experience in global, economic, environmental, and societal contexts.

Due to the vertically integrated structure of VIP, students at different levels are engaged. By registering for different course numbers, we are able to align expectations appropriately. For instance, students completing senior design would be expected to reflect on and demonstrate all of the learning outcomes. On the other hand, we expect first-year students to reflect and make connections between some or all of the learning outcomes and their team experience.

III. Theoretical framework

This work will be guided by two theoretical frameworks: self-efficacy and belongingness. Self-efficacy is defined as a person's belief in their capability [4]. Sources of self-efficacy include mastery experiences, experiences provided by social models (seeing similar people succeed), social persuasion, and reducing stress reactions (perception of stress and performance enhancing) [4]. Self-efficacy can increase commitment and motivation as well as ability to cope with failure [4], which are beneficial to students as they complete their engineering degrees and after they graduate. The VIP model can serve as a source of self-efficacy as students complete their first year and beyond.

In addition to self-efficacy we will examine students' sense of belonging in engineering. "When students feel that their identities are valued, or they find connections to others who share similar interests, they are more likely to feel a sense of belongingness and want to solidify their commitments to the field" [5]. When examining belongingness in a first-year engineering course, other researchers found that students enter college with a strong sense of belonging in engineering but that perception decreased after beginning the course [6]. In an effort to increase belongingness throughout students' first-year experience, the VIP model aims to foster student inclusivity in a team-based environment in which students contribute to authentic engineering projects.

IV. Methods

Preliminary analysis of quantitative and qualitative data, using survey responses and final course assessments, included descriptive statistics of survey responses and examples of ways in which students reflect on the ABET learning outcomes from final course assessments. In the future, the data will be further analyzed to examine student perceptions of self-efficacy and belonging as well as progress toward seven ABET learning outcomes.

A. Participants

This paper includes survey and final assessment responses from two cohorts of students participating in the VIP first-year engineering pathway starting in Fall 2020 and Fall 2021 at Purdue. Students participate in VIP for two consecutive semesters during their first year. The VIP first-year pathways includes a three-course sequence, allowing students to take a one credit hour VIP course in the Fall and Spring along with an introductory engineering course in the Fall. Upon successful completion of the course sequence, students matriculate into a chosen engineering major at the institution.

The Fall 2020 cohort includes 99 first-year engineering students, while the Fall 2021 cohort consists of 144 students. The quantitative data is limited to students who fully completed survey responses, resulting in 86 participants in Fall 2020 and 56 participants in Fall 2021. Of the survey respondents, approximately 22% and 21.4% of the Fall 2020 and Fall 2021 cohorts are women. The qualitative data is limited to students who successfully submitted final course assessments.

B. Analysis

Descriptive statistics were used to understand first-year engineering (FYE) students' self-efficacy and belongingness in engineering. We also disaggregated analysis by gender and major to explore potential differences in student experiences. Students were asked the following questions on a five-point Likert scale from Strong Disagree to Strongly Agree:

- Being in the VIP FYE Pathway has increased my interest in doing research or other experiential activities at Purdue in the future.
- Being in the VIP FYE Pathway has increased my confidence in my ability to succeed in engineering.
- Being in the VIP FYE Pathway has provided me skills to be successful in my future career.
- Being in the VIP FYE Pathway has made me feel part of the engineering community.

Content analysis [7] was used to analyze responses to the seven ABET learning outcomes. First, we familiarized ourselves with all responses, then began open coding. Content analysis is an appropriate method since we examined what activities and perceptions students have of completing each learning outcome. Additional content analysis using self-efficacy as a guiding framework will be conducted on the final course assessment responses in future work.

V. Preliminary Results and Discussion

Preliminary analysis of survey results from Fall 2020 – Fall 2021 indicate that student perceptions on self-efficacy and belongingness have been increased with participation in VIP. For example, approximately 83% of students in the Fall 2020 cohort agreed or strongly agreed that "Being in the VIP FYE Pathway has increased my confidence in my ability to succeed in engineering" Additional analysis of means and standard deviations are illustrated in Table 1.

TABLE 1. LIKERT SCALE SURVEY RESPONSES

Prompt (Strongly Agree = 5,…, Strongly Disagree = 1)	**Mean**	**Std. Dev.**
Being in the VIP FYE Pathway has increased my interest in doing research or other experiential activities at Purdue in the future.	4.14	0.83
Being in the VIP FYE Pathway has increased my confidence in my ability to succeed in engineering.	4.01	0.99
Being in the VIP FYE Pathway has provided me skills to be successful in my future career.	4.24	0.92
Being in the VIP FYE Pathway has made me feel part of the engineering community.	3.99	0.95
N = 171		

The majority of students responded positively to the survey prompts and many provided examples that the VIP program at Purdue should continue implementing. However, some students disagreed. In their survey responses, students provided justification when they strongly disagreed to a prompt, citing communication difficulties within their team, pandemic-related issues, alignment with their interests, and lack of technical skills compared to their upperclassmen peers. We plan to address these concerns by streamlining access to resources, communication, and expectations across teams.

Furthermore, preliminary results indicate that students are reflecting on each ABET learning outcome in different ways. The following are examples of student responses and corresponding ABET outcomes:

> iii. an ability to identify, formulate, and solve complex engineering problems arising from this engineering design experience by applying principles of engineering, science, and mathematics:

- "I did not have any previous experience working with robot so everything about this project is new to me and all the deliverables our team needed to accomplish seemed very complicated. However, I, along with my team members, were able to apply what we learned before, such as how to program using MATLAB, in addition to new knowledge gained, such as how to add static obstacles to the robot's navigation map using built-in functions from MATLAB's Lidar toolbox to complete almost all the deliverables."
- "We decided that using solar panels would be more beneficial than using conventional batteries, because it would be environmentally friendly and allow the submarine to be used for a longer period of time. We analyzed different factors like weight, shape and size to develop a soil sampler and determine the materials

used, number and spacing of turns, speed of rotation, and mechanism of suction/drill. We also decided to use an auger to drill through harder surfaces and overcome the immense pressure underwater."

iv. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives associated with this design experience:

- "The ability to function effectively as a team came from the class. I learned a lot about how I didn't have to do everything and I could rely on the other members of my team to do their part. We learned to take different roles on and how to make each of our parts fit together. We established meetings, made goals, and held ourselves to deadlines. This helped us get assignments such as the presentation done on time."

These examples illustrate how first-year students reflect on and demonstrate the learning outcomes, including the use of research/project tools, engineering design process, and teaming/group roles.

While this work is limited to a single institution, incorporating reflection on learning outcomes can be applied at any institution. Both survey responses and final course assessments are limited to student perceptions. In order to support student responses, additional consideration may be given to academic performance and other long-term outcomes, including major retention and career outcomes.

Experiential learning opportunities, including VIP, are effective ways for students to gain authentic experience before they graduate. First-year engineering students in the VIP program have reflected on seven ABET learning outcomes while conducting research and participating on design teams. While they may not have demonstrated all learning outcomes, we have shown the various ways in which first-year students connect their team experience with the learning outcomes. Using self-efficacy and belongingness as guiding frameworks, we examined the effectiveness of the VIP model on students, which can contribute to their retention in engineering and overall success. This work also contributes to engineering education by presenting a strategy for incorporating reflection in experiential courses and ways to gather evidence of students' learning and ability to connect with course learning outcomes.

REFERENCES

[1] "Vertically Integrated Projects," VIP Consortium. [Online]. Available: https://www.vip-consortium.org/. [Accessed: 14-Jul-2022].

[2] J. Sonnenberg-Klein, R. T. Abler, and E. J. Coyle, "Diversity and Student Persistence in the Vertically Integrated Project (VIP) Course Sequence," 2018 Collaborative Network for Engineering and Computing Diversity (CoNECD) Conference, April 29-May 2, 2018

[3] ABET, "Criteria for Accrediting Engineering Programs, 2021-2022," Criterion 3. Student Outcomes. [Online] Available: https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2021-2022/ . [Accessed April 11, 2022].

[4] Bandura., "Self-efficacy" in Encyclopedia of human behavior, V. S. Ramachaudran, Ed. New York: Academic Press, 1994, Vol. 4, pp. 71-81. (Reprinted in H. Friedman [Ed.], Encyclopedia of mental health. San Diego: Academic Press, 1998).

[5] B.W.L. Packard, Successful STEM mentoring initiatives for underrepresented students: A research-based guide for faculty and administrators. Stylus Publishing, LLC, 2015.

[6] N. Pearson, A. Godwin, and A. Kirn. "The Effect of Diversity on Feelings of Belongingness for New Engineering Students." In 2018 IEEE Frontiers in Education Conference (FIE), 2018, pp. 1-7.

[7] H.F. Hsieh and S.E. Shannon, "Three approaches to qualitative content analysis," Qualitative health research, vol. 15, no. 9, pp. 1277-1288, 2005.