Board 357: Psychosocial and Skills-Based Outcomes of Participating in Vertically Integrated Projects (VIP)

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Introduction

Vertically Integrated Projects (VIP) is a well-established experiential learning model [1, 2] that engages undergraduates, from first years to seniors, in multi-scale, long-term research project teams led by faculty and their graduate students [3-6]. Participation in the VIP program is graded, and students receive course credit for at least two years. Participation in VIP teams provides the time and context for students to [1]:

- acquire in-depth experience and insights within their field of study.
- learn and practice research and professional skills.
- make substantial contributions to real-world projects; and
- experience different roles on large, multi-disciplinary teams.

The VIP model provides opportunities for undergraduate and graduate students to develop leadership and collaboration skills through peer support and peer management [2,7]. Additionally, participating students are entrepreneurs, sharing in any intellectual property that results from their VIP work. VIP teams may also work with external partners from government and industry. Because VIP teams support the work of faculty and their graduate students, the VIP model supports scholarship and research. "The VIP program is based on the philosophy that all students can benefit from working on faculty-led teams that are focused on solving real problems, and that all willing/interested faculty can advance their research programs by working with VIP teams" [8].

A study on the impact of the VIP model on student diversity and persistence has shown that making the program accessible to all students helped increase racial and ethnic diversity in undergraduate research [9]. Broad communication and recruitment of undergraduate students and a low-stress application process may have contributed to the higher-than-average participation rates of minoritized students in the VIP program [9]. Other studies have shown that challenge or problem-based learning strategies such as those in the VIP model help students develop deeper STEM knowledge and skills and provide opportunities for learning across multiple learning contexts [10, 11]. Educational interventions that include active learning, mentoring, and role modeling are of particular importance to recruiting and retaining female and minority students in STEM [12].

The purpose of the current study is to report the results from the first year of an implementation of the VIP model at a public urban research university in the southeastern United States. Because the student population comprises a disproportionate number of first-generation and other minoritized students, we are interested in the how participation in the VIP program may positively influence students' STEM identity and other related psychosocial constructs. An underdeveloped sense of STEM identity is a primary barrier to retention and persistence to graduation for STEM majors. First-generation and minoritized students face several challenges to developing a STEM identity, including financial need [13]; off-campus working hours [14]; commuting [15]; and limited STEM role models. Opportunities for collaborative learning, tiered mentoring, and access to role models can successfully engage students and motivate them to remain within a STEM major [16]. Strengthening students' STEM identity is especially important for minoritized students in STEM disciplines (including women) who may lack a 'sense of fit' that is crucial to retention in STEM majors and careers [17].

STEM Identity, Self-Efficacy, and Mindset

STEM Identity is the degree to which students see themselves and are seen by others as "STEM people" --(future) engineers and scientists [18]. Students who do not develop a strong STEM identity are unlikely to persist in STEM majors [19-22]. Women and other minoritized students tend to be less likely to identify with STEM [23, 24]. Identities related to engineering have been shown to predict students' choice of both college major and career in engineering [25, 26].

Developing a STEM identity is not as simple as declaring a STEM major and/or doing well in STEM courses. Developing self-efficacy, or confidence in one's own ability in STEM, is a key factor. Bolstering self-efficacy beliefs may be particularly important when it comes to building and maintaining STEM identity for minoritized students [27]. For example, experience and instrumental mentoring predict STEM self-efficacy, which in turn predicts STEM identity [28].

In addition to self-efficacy, it is also important to consider what implicit theory (or mindset) students hold about their STEM abilities. Dweck and colleagues [29, 30] consider these theories on a continuum between "fixed" and "growth" mindsets. A fixed mindset holds that one's abilities are largely innate and unchangeable whereas a growth mindset holds that one's abilities can be improved with effort practice [29]. Students who hold a growth mindset will tend to see setbacks as an opportunity to grow their knowledge and skills whereas those with a fixed mindset will tend to see such setbacks as evidence that they are "not a STEM person." Therefore, growth mindset should be associated with greater persistence in STEM fields [30].

As STEM identity is multifaceted, this implementation of the VIP program includes several intervention strategies that focus on academic, mentoring, community, and networking-related activities (see [31] for a description). Academic success and satisfaction with one's major, feeling part of a STEM community, participating in STEM activities, interacting with role models, collaborating and 'STEM communicating,' understanding career opportunities, and developing STEM self-efficacy all play a role in facilitating the development of STEM identity.

Method

Participants

In Fall 2022, 12 students (7 women, 5 men; 4 Black/African American, 2 Hispanic, 6 white) participated on 2 VIP teams. Of these, 5 students (4 women, 1 man; 1 Black/African American and 1 Hispanic) did not continue to the spring 2023 semester. In Spring 2023, a third team was added to the program, resulting in a total of 13 students (4 women, 9 men; 3 Black/African American; 1 Hispanic, 1 Asian, 1 Mixed, 1 other, 6 white). Overall, VIP participants had a mean GPA of 2.99/4.00 (*SD* = 0.86) in Fall 2022 and a mean GPA of 3.29/4.00 (*SD* = 0.87) in Spring

2023. The mean GPA for all undergraduate students in the College of Engineering was 2.81 in Fall 2022 and 2.82 in Spring 2023.

All students in the VIP program were invited to complete (via Qualtrics) a pre-survey (at the beginning of the semester they started) and a post-survey at the end of the academic year.

Measures

Engineering identity was measured using a 10-item scale developed by Godwin et al. [25, 26] comprising three subscales: engineering interest (2 items, e.g., “I am interested in learning more about engineering”), engineering recognition (2 items, e.g., “My parents/relatives/friends see me as an engineering person”), and engineering competence (6 items, e.g., “I am confident that I can understand engineering outside of class”).

Engineering self-efficacy was measured using a 5-item scale developed by Maramil et al. [32] (e.g., “I can master the content in the engineering-related courses I am taking this semester”; “I can do a good job on almost all my engineering coursework”).

Engineering mindset was measured using a 3-item scale adapted from Hong et al. [33] (e.g., “You have a certain amount of *ability in Engineering,* and you really can’t do much to change it”).

Intention to remain in the engineering major was measured using a 4-item scale adapted from Scott et al. [34] (e.g., “I have thought seriously about changing majors since I began in engineering”).

Intention to pursue a career in engineering was measured using a single item from Lichtenstein et al. [35] (“I intend to practice, conduct research in, or teach engineering for at least 3 years after graduation”).

Participants responded to items in each of the above measures using a 5-point Likert-type scale (1 = strongly disagree, 5 = strongly agree).

STEM professional identity was measured using a 6-point single-item measure developed by McDonald et al. [36] (“Select the picture that best describes the current overlap of the image you have of yourself and your image of what a STEM professional is,” followed by six Venn diagrams showing no to nearly total overlap between “me” and “STEM professional”).

Additionally, students responded to 20 items adapted from Melkers et al. [37] assessing their perceptions of their level of knowledge and skills in a variety of areas relevant to their experience in the VIP program. On the post-survey, they also rated the extent to which the VIP program helped them to develop each skill.

Results

STEM Identity, Self-Efficacy, Mindset, and Major/Career Intentions

Pre- and post-survey scores on engineering identity, self-efficacy, mindset, major and career intentions, and STEM professional identity were compared using Wilcoxon Signed Ranks tests. These showed no statistically significant differences on any of the measures. Because the paired comparisons were non-significant, we present descriptive results for all valid responses on these measures from both pre- and post-surveys in Table 1.

Table 1. Pre- and post-survey results on psychosocial measures. Note: Five-point scales with higher scores indicating stronger agreement, except for Mindset, where higher scores indicate higher "fixed" mindsets and STEM professional identity, which was a six-point, single-item measure

Variable	Pre-Test N	Pre-Test Mean (SD)	Pre-Test Range	Post-Test N	Post-Test Mean (SD)	Post-Test Range
Engineering Interest	17	4.85 (0.24)	4.50-5.00	10	4.80 (0.35)	4.00-5.00
Engineering Recognition	17	3.94 (0.61)	2.50-5.00	10	4.00 (0.75)	3.00-5.00
Engineering Performance	16	4.06 (0.52)	3.17-5.00	10	4.18 (0.70)	2.50-4.83
Engineering Self-Efficacy	16	4.34 (0.57)	3.40-5.00	10	4.20 (1.01)	1.80-5.00
Engineering Mindset	17	1.63 (0.61)	1.00-3.00	9	2.14 (1.06)	1.00-4.00
Intention to Remain in Major	17	4.35 (0.57)	3.25-5.00	10	4.10 (1.08)	1.75-5.00
Engineering Career Intention	17	4.41 (0.80)	3.00-5.00	10	3.50 (1.65)	1.00-5.00
STEM Professional Identity	17	4.06 (1.20)	2.00-5.00	10	4.30 (1.49)	2.00-6.00

Self-Perceptions of STEM Skills

Pre- and post-survey skills ratings were also compared using Wilcoxon Signed Ranks tests. These tests revealed some statistically significant differences between the pre- and post-surveys on six of the items. Specifically, students tended to see themselves as having greater knowledge or skills in: (1) planning a long-term project; (2) communicating technical concepts and designs to others; (3) designing systems, components, or processes to meet practical or applied needs; (4) understanding computer hardware and systems; (5) working on a multidisciplinary team; and (6) making ethical decisions in engineering/research. These results are presented in Table 2 with statistically significant results marked with a double asterisk (**).

Table 2. Pre- and post-survey comparisons on knowledge/skills ratings (N = 10). Note: Each item was rated on a four-point scale (1 = no knowledge or skills; 2 = low knowledge or skills; 3 = working knowledge or skills; 4 = advanced knowledge or skills).

Item	Pre-Test Mean (SD)	Pre-Test Range	Post-Test Mean (SD)	Post-Test Range	Z	p
Identify and solve practical or applied problems	2.80 (0.42)	2-3	2.90 (0.57)	2-4	-0.58	.56
****Plan a long-term project**	2.20 (0.63)	1-3	3.10 (0.57)	2-4	-2.31	.02
Understand how technical solutions are used in an applied context	2.20 (0.42)	2-3	2.70 (0.95)	1-4	-1.41	.16
****Communicate technical concepts and designs to others**	2.50 (0.53)	2-3	3.00 (0.47)	2-4	-2.24	.03
Manage a project team	2.20 (1.03)	1-4	2.70 (0.68)	2-4	-1.3	.19
Collaborate on project team solutions	3.10 (0.57)	2-4	3.20 (0.63)	2-4	-0.38	.71
****Design systems, components, or processes to meet practical or applied needs**	2.10 (0.74)	1-3	2.80 (0.63)	2-4	-2.33	.02
****Understand computer hardware and systems**	2.40 (0.84)	1-4	3.10 (0.74)	2-4	-2.33	.02
****Work on a multi-disciplinary team**	2.10 (0.74)	1-4	3.30 (0.48)	3-4	-2.59	.01
Computer programming	2.60 (0.97)	1-4	2.90 (0.74)	2-4	-1.73	.08
Use the techniques and tools necessary for engineering practice	2.40 (0.97)	1-4	3.00 (0.47)	2-4	-1.73	.08

Work on a project team within my discipline	2.90 (0.74)	2-4	3.30 (0.48)	3-4	-1.63	.10
Make professional presentations	2.70 (0.68)	2-4	3.10 (0.32)	3-4	-1.41	.16
Write professionally	3.10 (0.57)	2-4	3.00 (0.67)	2-4	-0.45	.67
Resolve team conflicts or disagreements	2.90 (0.57)	2-4	2.80 (0.63)	2-4	-1.00	.32
Design/conduct experiments	2.50 (0.85)	2-4	2.90 (0.74)	2-4	-1.63	.10
Design computing algorithms	2.10 (0.88)	1-4	2.50 (0.71)	2-4	-1.41	.16
Analyze or interpret data	2.70 (0.82)	1-4	3.00 (0.67)	2-4	-1.34	.18
Peer mentoring	2.30 (0.82)	1-3	2.80 (0.63)	2-4	-1.89	.06
****Ethical decision-making in engineering/research**	2.30 (0.82)	1-4	3.20 (0.42)	3-4	-2.46	.01

On the post-survey, participants rated the extent to which they perceived the VIP program helped them to develop their skills on the same 20 items as in Table 2. Most participants believed the VIP program helped them to develop each skill either somewhat or a great deal. They believed the VIP program was most helpful to them in being able to identify and solve practical and applied problems; the VIP program was least helpful to them in designing computer algorithms, but this skill was not applicable to all teams. These results are presented in Figures 1-4 below.

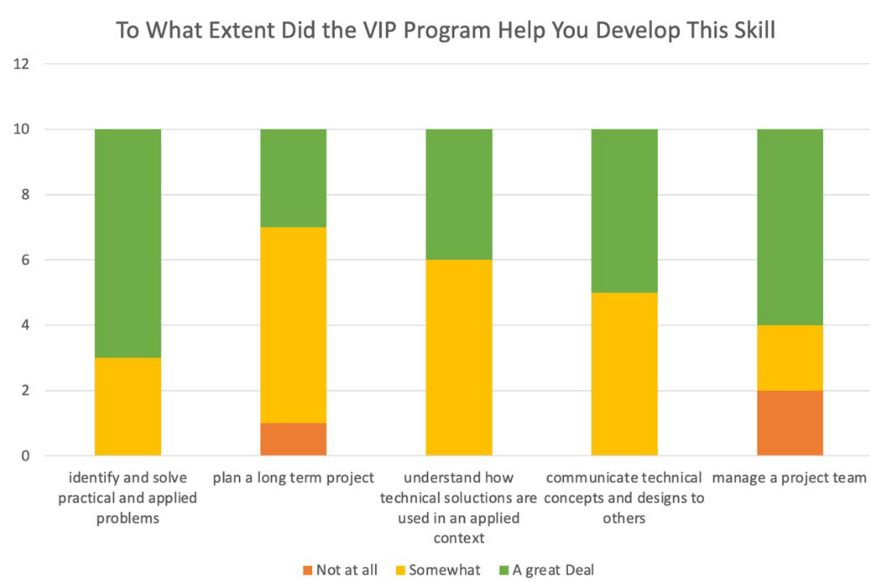

FIGURE 1: Results for survey items 1-5.

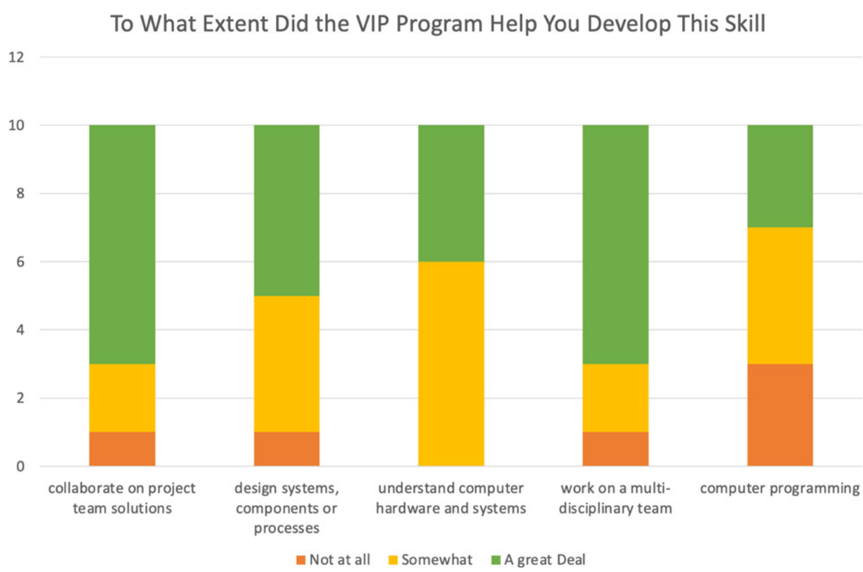

FIGURE 2. Results for survey items 6-10.

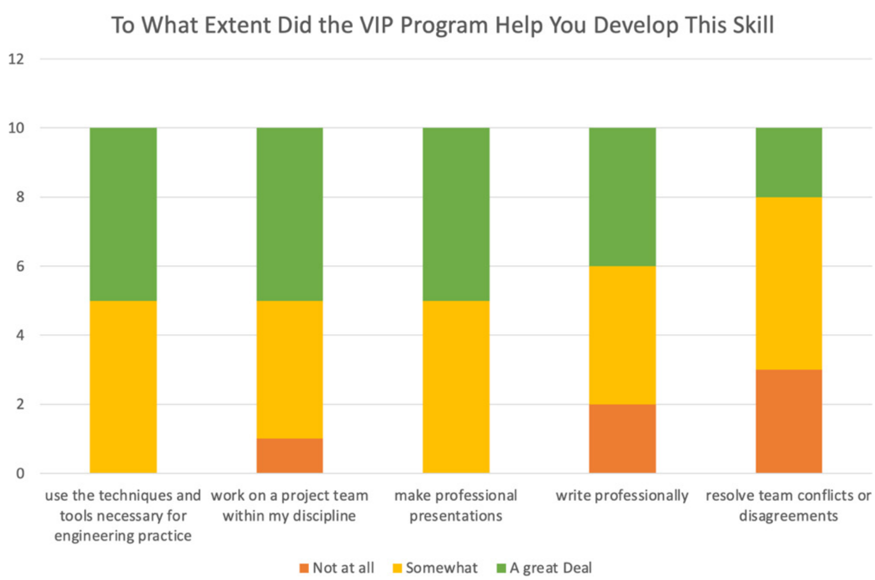

FIGURE 3. Results for survey items 11-15.

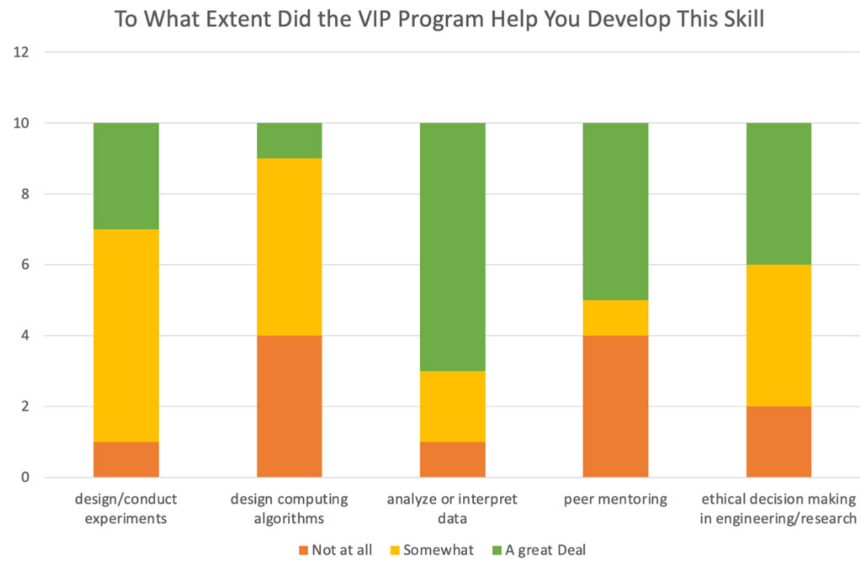

FIGURE 4. Results for survey items 16-20.

Discussion

STEM Identity, Self-Efficacy, Mindset, and Major/Career Intentions

Overall, participation in the VIP program did not seem to impact engineering identity, self-efficacy, mindset, or intentions to remain in the engineering major or pursue an engineering career. Most participants scored highly on these measures, perhaps reflecting a selection bias, with the VIP program attracting students who already have strong sense of themselves as "STEM people." It may also be the case that there is more variability and uncertainty on these constructs than is shown in these quantitative measures [38]. Our participants also completed weekly journals, which we will analyze and compare with our quantitative findings in future studies.

Self-Perceptions of STEM Skills

We did see some evidence that participating in the VIP program increased students' confidence in their knowledge and skills in six areas. Without a comparison group, we cannot attribute these changes solely to the VIP program, but it is encouraging that students tended to agree that their participation in the program helped them to develop skills across all 20 survey items.

In future work, we will continue to report both qualitative and quantitative findings on how the VIP model may improve students' sense of self as "STEM people" as well as the impact of the program on their engineering skills and academic outcomes.

Acknowledgement

This work was supported by NSF IUSE award (#2120819).

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