

Dimensions of Equity: Undergraduate Research through Vertically Integrated Projects at Five Institutions

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Abstract— In this innovative practice work-in-progress paper, enrollment data from five institutions was used to examine equity in undergraduate research through Vertically Integrated Projects (VIP) Programs. VIP is a model for undergraduate research in which large student teams are embedded in faculty-driven projects. The American Association of Colleges and Universities recognizes undergraduate research as a high-impact experience, associated with higher graduation rates and greater learning gains in college. Participation in multiple high-impact experiences yields cumulative gains to students from all backgrounds, and compensatory gains for minoritized and marginalized students. Nationally however, minoritized students, first-generation college students, and transfer students participate in undergraduate research at lower rates than their peers. In this study, VIP enrollments at five institutions ($N = 6,651$ over two semesters) were compared to demographics of the institutions to determine the degree to which programs achieved equity among historically underserved minorities, transfer students, first-generation college students, and by gender. Analysis accounted for demographics and level of participation of the academic units involved, comparing enrollments with what would be expected under equitable enrollment. Analyses were done for each institution and across the pooled sample. By institution, equity across categories varied. Across the pooled sample, results show small effects sizes for status as a historically underserved minority, very small effect sizes for first-generation students and transfer students, and slightly higher participation among women than men. The large-scale nature of VIP teams enables institutions to scale-up their undergraduate research offerings. This paper begins answering the question of whether this scaling increases access for marginalized populations, and the results are encouraging. The paper is a work-in-progress, because data needs to be collected from more VIP institutions for a wider-ranging study. The chi-square test and the importance of using effect sizes in interpreting results will be explained, so others can apply the same method. Results, implications, and next steps are discussed.

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

I. INTRODUCTION

A. Undergraduate Research

Undergraduate research is one of eleven high-impact experiences identified by the American Association of Colleges and Universities [1]. Participation in high-impact experiences is associated with higher graduation rates and greater learning gains in college, and participation in multiple experiences yields cumulative gains. Students who participate in three or more experiences see greater gains than those participating in one or two [2]. Marginalized students who participate in three or more experiences also see compensatory gains, exceeding white students who participate in the same number of experiences, with greater persistence among black/African American students, and higher GPAs among Hispanic/Latina students [2].

While marginalized students see compensatory gains with participation in multiple high-impact experiences, historically underserved students participate in undergraduate research at lower rates than their peers. Whereas 24% of white and Asian students do research with faculty by the time they graduate, the rates are 18% for black and Hispanic/Latino students [3]. The difference is more pronounced for first-generation college students (students whose parents did not graduate college) and transfer students, with rates of 17% for First-Gen vs. 27% for non-first-gen students, and 15% for transfer vs. 30% for non-transfer students [3]. Traditional undergraduate research tends to be exclusive, typically serving students with higher academic rank (3rd and 4th year students) and high grade point averages [4]. The limited number of opportunities serve only a fraction of students, resulting in competition and selective screening [5]. While many programs target historically underserved populations [6], imbalances in participation persist [3].

B. Vertically Integrated Projects

The Vertically Integrated Projects (VIP) model is a framework for scalable undergraduate research. In VIP, large student teams are embedded in faculty research, design, and development projects. Students can participate for multiple

semesters, with returning students taking on additional leadership responsibilities, such as getting new members up to speed, and leading subteams. This student leadership enables faculty to lead larger teams than otherwise possible. The VIP Consortium identified 8 key elements of the VIP model [7]:

1. Projects are embedded in faculty mentor's scholarship and exploration.
2. Projects are long-term and large-scale, continuing for many years, even decades.
3. Program is curricular and all participating students are graded (A-F; not P/F or S/U).
4. Students can participate and earn credits toward their degrees for at least two years.
5. Learning outcomes focus on the development of both disciplinary and professional skills.
6. Multi-disciplinary teams are encouraged but not required.
7. Dedicated classroom and meeting spaces.
8. Faculty/student participation is based on mutual interest.

While not included in the key elements, most VIP Programs embrace accessibility. Team listings are posted online, and students are actively recruited from across campus. Experience has shown that student success on VIP teams is more closely correlated with enthusiasm for the project than to prior experience or grade point average (GPA), so most VIP programs do not consider GPAs, resumes, or letters of recommendation in student selection.

VIP Programs have been established at 47 colleges and universities, and programs range in scope from department-level to campus-wide. This work-in-progress analysis involves authors from five VIP Consortium institutions who pose the following questions: 1) To what degree are individual VIP Programs achieving equitable enrollment? 2) To what degree is enrollment equitable across the pooled sample?

C. Institutions

The five institutions ranged in size from 16.5K to 37.5K undergraduate students [8]. The proportion of minoritized/historically under-served students, non-traditional students, transfer students, part time students, and Pell grant recipients varied substantially across the institutions, as shown in Fig. 1 [8], [9]. To encourage candid reflection, the discussion does not name institutions, but focuses instead on the context within which each program operates.

II. METHODS

The authors requested demographic data from their offices of institutional research on undergraduate enrollment by major and undergraduate enrollment in VIP by major for Fall 2021 and

Spring 2022. The requested data used IPEDs definitions [10]. Because the data involved two semesters, and because students could have participated in one semester, both semesters, or neither semester, the values were treated as enrollment instances instead of as individuals, and the values were summed across both semesters. The proportion of VIP enrollment instances to overall enrollment instances were 1%, 1%, 2%, 9% and 17%.

To determine if enrollment in a VIP Program was equitable, a chi-square test was used to compare observed enrollments with frequencies that would be expected if students were randomly selected from the population. Because student demographics might vary by program of study, the expected enrollments for each VIP program were based on the number of students from each major that participated, and the demographics of students in the major at the institution. If a VIP program enrolled 10 physics students, and 20% of physics students at the institution were women, 2 women would be expected to enroll in VIP. For this reason, proportions in the analysis differ from institution-level demographics in Fig. 1.

A problem with the chi-square test is its sensitivity to sample size. Very large samples will show statistically significant differences even if the differences are quite small. To account for this, effect sizes are used to interpret statistical significance. Statistical significance with a very small effect size implies negligible differences. Chi-square is not appropriate for use on small sample sizes, particularly when there are fewer than five observations for any combination of criteria. For example, if the number of students from a given demographic who participated (or who were expected to participate) was less than 5, chi-square would not be an appropriate test.

To eliminate the need for post-hoc analysis and to avoid small subgroups, demographics were combined into groups traditionally well-represented and under-represented in undergraduate research (Table I). Cases were excluded when status as traditionally well- or under-represented was not known (unknown, or two or more races/ethnicities). Nationally, there is not an imbalance in participation in undergraduate research by gender, but gender was included for thoroughness.

The analysis was done in excel. Four analyses were done for each institution: analysis by race/ethnicity; first-generation status; transfer status; and gender. The same four analysis were

Table I. Categorizations as Traditionally Well- or Under-Represented

Analysis Grouping	Well-Represented in Undergrad. Research	Under-Represented in Undergrad. Research
Race/Ethnicity	White & Asian	All others
Transfer Status	Started at institution as freshmen	Transferred to institution
Status as First-Generation Student	Parents went to College	First-Generation College Student

Institution	Undergrads	Asian	Black	Hisp	White	Non-Trad.	Transfers	Part Time	Pell
Boise State University	17,075	3%	2%	14%	73%	18%	7%	22%	23%
Georgia Institute of Technology	16,566	27%	7%	8%	41%	2%	5%	8%	11%
New York University	28,556	20%	8%	17%	22%	4%	4%	3%	18%
Purdue University	37,658	12%	2%	6%	63%	3%	3%	5%	14%
Stony Brook University	17,900	32%	6%	14%	29%	7%	8%	7%	38%

Fig. 1. Institutions [8], [9]

also done across the pooled sample. Each analysis involved the calculation of:

1. Chi-Square statistic (1) [11].
2. Statistical significance of the Chi-Square test (excel function: ChiSq.Test, 1 degree of freedom) [12].
3. Phi (effect size) when the Chi-Square test was statistically significant at the .05 level (2) [13].

$$\chi^2 = \sum \frac{(O_i - E_i)^2}{E_i} \quad (1)$$

$$\phi = \sqrt{\frac{\chi^2}{N}} \quad (2)$$

In the calculation of chi-square (1) and phi (2), i represents groupings (traditionally well-represented or not), O_i and E_i are the observed and expected frequencies for group i , and N is the total number of observed VIP enrollments. Phi values of .1, .3 and .5 are interpreted as small, medium and large effect sizes.

III. RESULTS

A. Institution-Level

Analyses were done for each institution for each type of grouping, as well as on the pooled sample. At three of the five institutions, historically underserved minority students enrolled in VIP at representative rates, with no statistically significant difference between VIP enrollment and enrollment in the majors that students came from ($\chi^2(1, N = 367) = 0.51, p = .472$; $\chi^2(1,$

$N = 628) = 1.05, p = .305$; $\chi^2(1, N = 544) = 1.35, p = .245$). At two institutions, the difference was statistically significant, with a small effect size for one institution, $\chi^2(1, N = 3192) = 62.04, p < .001, \phi = 0.13$, and a small to medium effect size for the other ($\chi^2(1, N = 350) = 9.55, p = .002, \phi = 0.16$) (Fig. 2).

For First-Generation College Students (Fig. 3), enrollment in VIP was representative in two of the five programs ($\chi^2(1, N = 3674) = 3.02, p = .08$; $\chi^2(1, N = 881) = 1.10, p = .29$). At three institutions, differences were statistically significant with small effect sizes at two ($\chi^2(1, N = 826) = 11.01, p = .001, \phi = 0.11$; $\chi^2(1, N = 401) = 8.29, p = .004, \phi = 0.14$), and a small to medium effect at one ($\chi^2(1, N = 413) = 9.88, p = .002, \phi = 0.15$).

At two institutions, participation among transfer students (Fig. 4) showed no significant difference compared to non-transfers ($\chi^2(1, N = 4093) = 0.06, p = .799$; $\chi^2(1, N = 97) = 0.22, p = .636$). At the three institutions there were statistically significant differences, with small, ($\chi^2(1, N = 765) = 5.23, p = .022, \phi = 0.08$), small to medium ($\chi^2(1, N = 402) = 17.06, p < .001, \phi = 0.2$) and medium ($\chi^2(1, N = 417) = 42.86, p < .001, \phi = 0.32$) effect sizes.

At all five institutions, enrollment differed by gender (Fig. 5). At four institutions, women participated at higher rates than men, with small effect sizes at three institutions ($\chi^2(1, N = 4093) = 56.89, p < .001, \phi = 0.11$; $\chi^2(1, N = 898) = 19.17, p < .001, \phi = 0.14$; $\chi^2(1, N = 432) = 9.31, p = .002, \phi = 0.14$) and small to medium effects at one ($\chi^2(1, N = 402) = 12.99, p < .001, \phi = 0.17$). At the fifth institution, women participated at

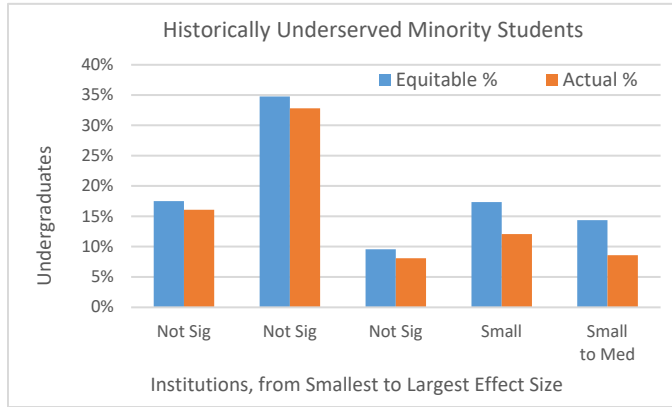


Fig. 2. Historically Underserved Minority Student Participation

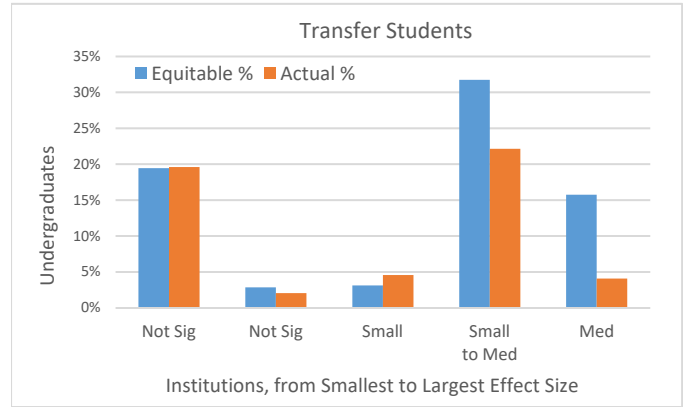


Fig. 4. Transfer Student Participation

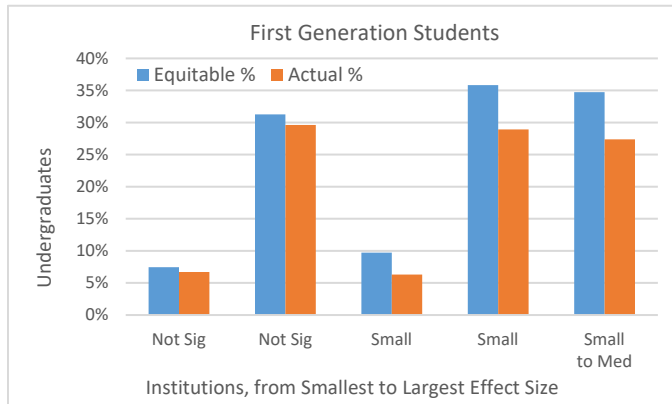


Fig. 3. First Generation College Student Participation

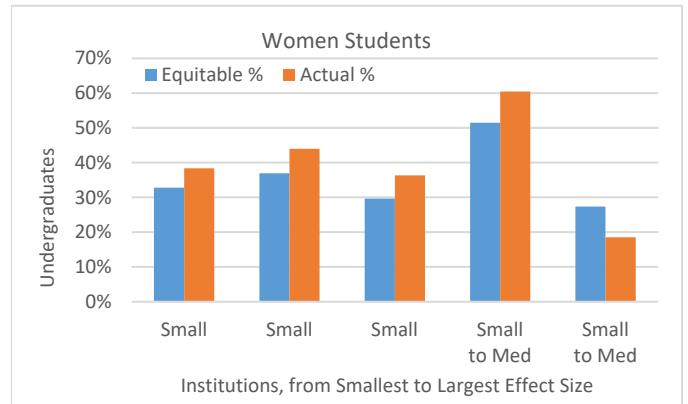


Fig. 5. Women Student Participation

lower rates than men, with a small to medium effect size ($X^2(1, N = 826) = 32.31, p = < .001, \phi = 0.19$).

B. Across the Five Institutions

Across the pooled sample, all of the chi-square tests were statistically significant, as expected with a large sample. Effect sizes were very small to small (Fig. 6). Being a transfer student had a very small effect ($X^2(1, N = 5774) = 5.94, p = 0.014, \phi = 0.03$). Being a first-generation college student, a man, and a historically underserved minority student were associated with small differences in participation ($X^2(1, N = 6195) = 21.12, p = < .001, \phi = 0.05$; $X^2(1, N = 6651) = 53.65, p = < .001, \phi = 0.08$; and $X^2(1, N = 5081) = 59.98, p = < .001, \phi = 0.1$ respectively).

IV. DISCUSSION

The analysis showed equity in URM enrollment at three institutions, and *all three programs report working closely with units that serve minoritized students*. One VIP Program is housed in the same unit as a program that serves minoritized students in STEM; an engineering-focused VIP Program collaborates with their campus' minority engineering program; and another VIP Program coordinates with their campus student affairs office to share recruitment opportunities with underrepresented groups. These partnerships leverage existing campus networks and may support equity.

Nationally, the most dramatic inequity in participation in undergraduate research is among first-generation college students and transfer students [3]. Interestingly, it is in these two areas that the pooled VIP Programs were closest to parity. VIP Program directors generally agree that *online listings and low-stress applications* reduce student intimidation and lower the activation-energy needed to get involved. In addition to these factors, an institution with equitable transfer student enrollment attributes their success to proactive campus-wide email campaigns (explanatory emails prior to registration each semester), and inclusion of VIP in presentations at new student orientations. Another institution is partnering with a feeder community college, to enroll students before they transfer.

Two institutions with large First-Gen populations reported that First-Gen student engagement is part of their institutional cultures. One institution provides an experiential learning center

for all students, eliminating the hidden curriculum that First-Gen and transfer students might not otherwise have access to [14]. A VIP Director at the other institution with a large first-gen population emphasized the importance of lowering barriers to access. They call their VIP application an "interest form," and their form asks students about their motivation for wanting to join the team instead of their qualifications. Notably, another institution in the study copied the program's question wording years ago, and the copying institution has equitable First-Gen enrollment as well.

While there is not inequity by gender at the national level, gender was included for thoroughness. At four of the five institutions, more women participated in VIP than men. One institution attributes their slightly higher rates to a Women in STEM initiative. Another institution reported high female enrollment on VIP teams that directly address health and quality of life issues, which may skew program-level results. The institution with lower enrollment among women operates alongside a service-learning version of VIP, which may attract more women than VIP projects that are based in faculty projects. While women are historically underrepresented in STEM, low participation among men may warrant attention.

V. CONCLUSION & NEXT STEPS

The study examined VIP enrollment at five institutions and across the pooled sample with two notable findings. First, *VIP programs that partner with minority-serving programs saw equity in minority student enrollment*. While this does not confirm cause and effect, undergraduate research programs seeking to equitably serve students of all races/ethnicities may want to work with minority-serving offices and organizations at their institutions, to leverage existing campus networks.

Second, the pooled sample showed equity in VIP enrollment among groups most marginalized in undergraduate research at the national level: First-Gen students and transfer students. The programs attribute *equity among First-Gen and transfer students to accessible online project listings, low-stress and non-intimidating applications*, and campus-specific cultures and initiatives. These speculations could be investigated by studying student perceptions of VIP compared to conventional undergraduate research, and the effect of different types of applications on students from different backgrounds.

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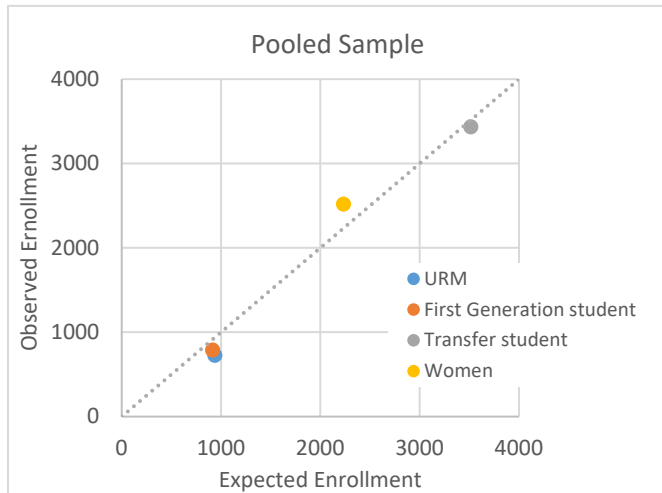


Fig. 6. Participation Across the Pooled Sample

REFERENCES

- [1] American Association of Colleges & Universities, "High-Impact Practices," *AAC&U*, Jan. 16, 2022. <https://www.aacu.org/trending-topics/high-impact> (accessed May 09, 2023).
- [2] G. D. Kuh, "High-Impact Educational Practices: What They Are, Who Has Access to Them, and Why They Matter," Association of American Colleges and Universities, Sep. 2008.
- [3] National Survey of Student Engagement, "Annual Results 2019: A Closer Look at High-Impact Practices," *Evidence-Based Improvement in Higher Education*, 2020. <https://nsse.indiana.edu/research/annual-results/past-annual-results/nsse-annual-results-2019/selected-results/closer-look-hip.html> (accessed Jul. 15, 2021).
- [4] S. H. Russell, M. P. Hancock, and J. McCullough, "Benefits of Undergraduate Research Experiences," *Science*, vol. 316, no. 5824, pp. 548–549, 2007.
- [5] Association of American Colleges and Universities, "College learning for the new global century," Association of American Colleges and Universities, Washington, DC, 2007. Accessed: Nov. 09, 2017. [Online]. Available: https://www.aacu.org/sites/default/files/files/LEAP/GlobalCentury_final.pdf
- [6] E. National Academies of Sciences, *Undergraduate Research Experiences for STEM Students: Successes, Challenges, and Opportunities*. 2017. doi: 10.17226/24622.
- [7] VIP Consortium, "The VIP Model." <https://www.vip-consortium.org/content/vip-model> (accessed Jan. 30, 2023).
- [8] National Center for Education Statistics, "IPEDS Data Center." Accessed: Apr. 28, 2023. [Online]. Available: <https://nces.ed.gov/ipeds/datacenter/InstitutionList.aspx?goToReportId=1>
- [9] U.S. Department of Education, "College Scorecard." <https://collegescorecard.ed.gov/> (accessed Sep. 10, 2022).
- [10] National Center for Education Statistics, "The Integrated Postsecondary Education Data System." <https://nces.ed.gov/ipeds/report-your-data/race-ethnicity-definitions> (accessed May 01, 2023).
- [11] H.-Y. Kim, "Statistical notes for clinical researchers: Chi-squared test and Fisher's exact test," *Restor Dent Endod*, vol. 42, no. 2, pp. 152–155, May 2017, doi: 10.5395/rde.2017.42.2.152.
- [12] C. Zaiontz, "Chi-Square Independence Test," *Real Statistics Using Excel*. <https://real-statistics.com/chi-square-and-f-distributions/independence-testing/> (accessed May 01, 2023).
- [13] C. Zaiontz, "Effect Size Chi-square Test," *Real Statistics Using Excel*. <https://real-statistics.com/chi-square-and-f-distributions/effect-size-chi-square/> (accessed May 01, 2023).
- [14] M. Chatelain, "We Must Help First-Generation Students Master Academe's 'Hidden Curriculum,'" *The Choric of Higher Education*, no. 2018 Innovators: 6 Programs to Change Classroom Culture, Oct. 21, 2018.