Breaking Down the Silos: Innovations for Multidisciplinary Programs

Dr. Michaela E. Amoo, Howard University

Dr. Michaela E. Amoo is an Assistant Professor in the Department of Electrical Engineering and Computer Science, Howard University. Dr. Amoo designs and develops application-specific Field Programmable Gate Array (FPGA) -based processors to tackle the problem of computational complexity. She has particular interest in High Performance Computing (HPC), remote sensing, autonomous navigation, and extraterrestrial applications wherein size, weight, power, speed, and computational accuracy are criteria. She has expertise in integer, fixed, and floating-point hardware system design, signal processing, controls, and atmospheric radiative transfer modelling.

Dr. Jack Bringardner, NYU's Tandon School of Engineering

Jack Bringardner is the Assistant Dean for Academic and Curricular Affairs at NYU Tandon School of Engineering. He is also an Assistant Professor in the General Engineering Department and Civil Engineering Department where he teaches the First-Year Engineering Program course Introduction to Engineering and Design. He is the Director of Vertically Integrated Projects at NYU. His Vertically Integrated Projects course is on Smart Cities Technology with a focus on transportation. His primary focus is developing curriculum, mentoring students, and engineering education research, particularly for project-based curriculum, first-year engineering, and transportation. He is active in the American Society for Engineering Education and is the Webmaster for the ASEE First-Year Programs Division and the First-Year Engineering Experience Conference. He is affiliated withthe Transportation Engineering program in the NYU Civil and Urban Engineering Department. He is the advisor for NYU student chapter of the Institute for Transportation Engineers.

Prof. Jen-Yeu Chen, National Dong Haw University

Dr. Jen-Yeu Chen's research interests span over the areas of networking, control and communications. In particular, in recent years, he focuses on machine learning, optimization, decision and control problems for effective and energy-efficient designs in next generation wireless communication systems. He has developed energy-efficient and computing-effective protocols/algorithms for next generation IoT applications such as wireless resource allocation and data transmission as well as forwarding mechanisms in 3GPP C-V2X and FeNB-IoT/eFeMTC. For latency-sensitive AIoT systems requiring Mobile Edge Computing, distributed algorithms for optimal resource allocation were proposed. He is also developing practical AIoT systems to solve real-life problems in the fields of smart agriculture and smart healthcare and smart education. Some other problems he tackled were data aggregation/fusion, distributed consensus, power control, scheduling and synchronization in wireless ad hoc networks, intrusion detection in a large scale wireless sensor network with Random Linear Network Coding (RLNC), and coordinated probabilistic map construction by the mobile robotic sensor network (a multi-agent system) such as a group of UAVs. Dr. Chen obtained his PhD from School of Electrical and Computer Engineering, Purdue University, USA. Prior to his PhD study, he was with Chunghwa Telecom Laboratories, CHTL, Taiwan. He is a 3GPP regular meeting delegate by the collaboration with ITRI, Taiwan.

Prof. Edward J. Coyle, Georgia Institute of Technology

Edward J. Coyle is the John B. Peatman Distinguished Professor of Electrical and Computer Engineering at Georgia Tech and a Georgia Research Alliance Eminent Scholar. He is the Director of both the VIP Program at GT and the VIP Consortium. Dr. Coyle was a co-recipient of the National Academy of Engineering's 2005 Bernard M. Gordon Award for Innovation in Engineering and Technology Education; ASEE's 1997 Chester F. Carlson Award; and, the 2019 ABET Innovation Award. He is a Fellow of the IEEE and his research interests include reform of higher education, wireless and sensor networks, and signal and image processing.

Ms. Jillana Finnegan, Boise State University

Jillana Finnegan works in the College of Innovation and Design as a Director of Programs. She supports the Vertically Integrated Projects program as well as other initiatives in the college to shape the future of higher education.

Prof. Charles J. Kim, Howard University

Charles Kim is a professor in Electrical Engineering and Computer Science at Howard University. He received a Ph.D. degree in Electrical Engineering from Texas A&M University in College Station ,TX in 1989, and worked as a researcher at Texas A&M University before he took an assistant professor at the University of Suwon in 1994. Since 1999, he is with Howard University. Dr. Kim's research interests include energy systems, fault detection and anticipation, embedded computing, safety-critical computer systems, and statistical and machine reasoning. Dr. Kim is active in faculty-student team project through the Vertically Integrated Projects program. Also for years he's been in practicing experiential learning through the Inclusive Engineering Consortium in engineering education with personal instrumentation such as mobile studio.

Dr. Patricia D Koman, University of Michigan College of Engineering

Trish Koman is the faculty research program manager at the University of Michigan College of Engineering Multidisciplinary Design Program. She supports over a dozen research teams engaging an average of 200 students and conducts educational research. She is also a research investigator at the University of Michigan School of Public Health Environmental Health Sciences department, where she leads community-engaged multidisciplinary research to create healthier communities.

Trish draws on over 20 years of public service as a senior environmental scientist at U.S. Environmental Protection Agency (EPA) working mainly to improve air quality. She was part of the leadership team for the US EPA's National Clean Diesel Campaign, where she initiated a partnership to reduce diesel emissions at U.S. marine ports and helped create the Clean School Bus USA partnership program to protect children's health. Trish managed multi-disciplinary benefit-cost analyses, regulatory programs, and technological innovation initiatives. Her air quality and policy analyses formed the rationale for setting landmark national ambient air quality standards for fine particulate matter, which withstood a challenge to the U.S. Supreme Court. She has been recognized with four Gold Medals for exceptional service to the country and an EPA Administrator award for excellence. In partnership with community groups, Trish led an environmental education effort in Flint, Michigan. Trish received a University of Michigan Provost award for innovation in teaching. She earned a B.A. with distinction in philosophy and chemistry from the University of Virginia, a masters degree in public policy from the University of California at Berkeley, and a Ph.D. in Environmental Health Sciences at the University of Michigan.

Ms. Magdalini Z Lagoudas, Texas A&M University

Magda Lagoudas, Executive Director for Industry & Nonprofit Partnerships, has been at Texas A&M University since 1992 and served on several capacities across the College of Engineering, including Director for the Space Engineering Institute and Associate Director for the Space Engineering Research Center. Current responsibilities include pursuing strategic partnerships with industry to provide engineering students with opportunities to collaborate on multidisciplinary teams addressing real world challenges and with industry engagement. College signature programs include the Texas A&M I-Corps Site, AggiE_Challenge, INSPIRES, and two annual Project Showcases. Magda is the Principal Investigator of the Texas A&M University I-Corps Site grant and has been active in promoting entrepreneurship both at the local and national level.

Dr. Donna C. Llewellyn, Boise State University

Donna Crystal Llewellyn received her BA (major in Mathematics and minor in Economics) with High Honors from Swarthmore College in 1980. She went on to earn an MS in Operations Research from Stanford University in 1981 and a Ph.D. in Operations Research from Cornell University in 1984. After 30 years at Georgia Tech in a variety of roles, Donna became the Executive Director of the new Institute

for STEM and Diversity Initiatives at Boise State University in January 2015. Donna's current interests center around education issues in general, and in particular on increasing access and success of those traditionally under-represented and/or under-served in STEM higher education.

Dr. Louise Logan, University of Strathclyde

Dr Louise Logan is a Learning Enhancement Officer at the University of Strathclyde and Program Co-ordinator for the University's Vertically Integrated Projects for Sustainable Development program. She completed an Arts and Humanities Research Council-funded PhD in English in 2019.

Julie Sonnenberg-Klein, Georgia Institute of Technology

Assistant Director, Vertically Integrated Projects (VIP) Program, Georgia Institute of Technology; Doctoral student in Education Policy Studies at Georgia State University, with a concentration in Research, Measurement and Statistics; Master of Education in Education Organization and Leadership, University of Illinois at Urbana-Champaign; Bachelor of Science in Engineering Physics, University of Illinois at Urbana-Champaign.

Dr. Nadia Millis Trent, University of Pretoria

Dr. Nadia M. Trent is a senior lecturer and researcher at the University of Pretoria (UP). In 2018 she piloted the first Vertically Integrated Projects (VIP) Programme in Africa with the help of the VIP consortium. The programme has immense potential to improve teaching and learning at UP and other South African institutions. It alleviates many challenges and harnesses opportunities created by extreme diversity (race, religion, economic status, language etc) on campus. Nadia's own VIP team develops multi-agent transportation simulation models to address policy issues in South Africa as a part of ongoing research streams within the Centre for Transport Development.

Dr. Scott Munro Strachan, University of Strathclyde

Scott M. Strachan received his B.Eng. (Hons.) and Ph.D. degrees in 1995 and 2005 from the University of Strathclyde, where he now works as a Senior Teaching Fellow. Since his research appointment within the Institute of Energy and Environment (Inst EE) in 1997, he has conducted and supported numerous research projects with leading UK energy companies, mainly focusing on the areas of plant condition monitoring, asset management, data mining, knowledge management and engineering, and intelligent systems applications for power systems. He has been active in the energy access area of research since 2006. He was a founder of the Electronic and Electrical Engineering (EEE) Department's outreach Gambia Solar Project and Tamil Nadu Solar Project; both staff-student initiatives delivering off-grid solar PV systems to rural schools and health clinics. He is also the co-director of the university's flagship Vertically Integrated Project for Sustainable Development program, which coordinates undergraduate and post-graduate research tackling the UN Sustainable Development Goals. He is a Fellow of the Higher Education Academy and a member of the Low Carbon Energy Development Network.

Dr. Bennett C Ward, Virginia Commonwealth University College of Engineering

Ben Ward is Associate Professor, Chemical and Life Science Engineering, and Director Project Outreach in the College of Engineering at Virginia Commonwealth University. In his role as Director Project Outreach he is director of the College's Capstone Senior Design program. A key part of this responsibility is identifying Health Science, non-profit and industrially sponsored projects for engineering student teams to work on. Dr Ward is also Principal Investigator for the Engineering Critical Patient Care VIP team, which develops medical devices for various constituencies in the VCU Health System. One of the developed devices has been taken private by a company founded by former students.

Prior to joining Virginia Commonwealth University, Ben had an industrial R&D, Engineering and Product Development career spanning 33 years. This includes Hoechst Celanese from 1981 to 2000, and Filtrona (Essentra) Porous Technologies as VP of R&D from 2001 to 2013. He led successful product development activities in very diverse areas, such as ultra-high temperature resistant thermoplastics, gas barrier coatings

for tires, moisture indicating wicks for pregnancy test kits, porous storage and ink release media for ink jet printer cartridges, absorptive components for endoscopic surgical instruments, and specialty filter media. He is inventor or co-inventor of over 30 US patents and foreign equivalents.

Dr Ward is a senior member of the National Academy of Inventors, Sigma XI and the American Chemical Society.

Ben has a Ph.D. in Organic and Inorganic Chemistry from the University of North Carolina, Chapel Hill, where he was an Eastman Kodak Fellow, and a B.S. in Chemistry from Duke University.

Breaking Down the Silos: Innovations for Multidisciplinary Programs

Abstract

Universities, colleges and academic departments acknowledge the need for more collaborative, multidisciplinary, entrepreneurial, and global education. Unfortunately, this is no trivial task. Centuries of tradition have produced institutional silos, reinforced by layers of policy and cultural differences between academic departments, between colleges, and between academic and non-academic units. Successful multidisciplinary programs require programmatic and administrative innovation that meet faculty, student and institutional needs and leverage available resources. The Vertically Integrated Project (VIP) model, in place at thirty-seven institutions, has achieved notable success in these areas. This paper profiles innovations from ten VIP Programs in three areas: institutional organization, program organization, and faculty approaches. With these innovations, the programs have broken down silos and cultivated meaningful partnerships to meet the needs of multiple stakeholders. The featured institutions vary in size and mission and represent four countries. Each innovation is presented with a brief background to provide context on how the VIP Program is situated within the larger institution. Together, these backgrounds, innovations, and lessons learned can benefit others seeking to develop and/or maintain cross-campus multidisciplinary programs.

Introduction

Universities, colleges and academic departments acknowledge the need for more collaborative, multidisciplinary, entrepreneurial, and global education. The 2012 ASEE Innovation with Impact report recommended that institutions "expand collaborations and partnerships between engineering programs and (a) **other disciplinary programs** germane to the education of engineers as well as (b) **other parts of the educational system** that support the pre-professional, professional, and continuing education of engineers" [1]. One approach to creating collaborations and partnerships such as these is the establishment of scalable multidisciplinary programs that engage multiple departments, involve students in meaningful multidisciplinary work, and benefit both faculty and students. Unfortunately, this is no trivial task. Centuries of tradition have produced institutional silos, or organizational distance between units. These silos are reinforced by layers of policy and cultural differences between academic departments, between colleges, and between academic and non-academic units [2]. To expand collaborations and partnerships, successful multidisciplinary programs require innovation in institution-level organization, program organization, and faculty approaches. The Vertically Integrated Project (VIP) model, in place at thirty-seven institutions, has achieved notable success in these areas. This paper profiles innovations from ten VIP Programs that have breached silos to cultivate meaningful partnerships between departments to meet the needs of faculty and students, working toward or having achieved institutionalization within their institutions.

The VIP Model: A Brief Background

While the innovations set forth in this paper would be of use to any multidisciplinary program, it is useful to understand the VIP model [3]. The model was developed by Ed Coyle at Purdue University. It grew out of the Engineering Projects in Community Service (EPICS) program, in

which student teams addressed engineering-related problems in the community [4]. The teams were vertically integrated, with students of various academic ranks (sophomore, junior, senior, etc.). EPICS still operates and has spread to many universities [5]. While students benefit from working on authentic multidisciplinary projects over multiple semesters, a limiting factor on the program was the faculty reward structure. Advising teams takes time and energy, and the effort was not rewarded in the faculty review, promotion, and tenure process. Coyle, one of three co-founders of EPICS, valued the vertical integration of the program, and brought this aspect of the program to faculty research. In VIP, faculty establish teams to support large-scale long-term scholarship and exploration efforts, and teams are largely multidisciplinary across the VIP Consortium.

In the Summer of 2014, Georgia Tech hosted a planning meeting for a proposed consortium, supported by the Helmsley Charitable Trust. The meeting was attended by fourteen institutions, including four with existing programs. Meeting attendees identified elements key to the VIP model [6]:

1. Projects are based on 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.

With the submission of a collaborative proposal, the Helmsley Charitable Trust funded a $5 million grant for the establishment and expansion of VIP at multiple sites, to be supported by efforts of the VIP Consortium. The VIP model has now been adopted by thirty-seven institutions (twenty-six US, eleven international), well beyond the fourteen institutions under the initial grant. A more extensive discussion of the VIP model and VIP Consortium can be found in [3], [7]–[9].

Innovations for Multidisciplinary Programs

VIP programs are in place at a wide variety of institutions, each with differing organizational structures and cultures, and differing opportunities and obstacles. While large research institutions may enjoy greater resources, smaller institutions have proven more agile in adopting change. For this reason, each innovation is prefaced with a brief overview of the context in which the program operates, along with a brief background on the Program, with more details included in the appendix. The innovations are presented in three groups, as detailed in Table 1. Due to the length of this compilation, the table also includes section numbers for reference and navigation.

Table 1. Innovations and institutions

Section	Innovation	Institution Name	Student Body Public/Private*
Institutional Organization			
1.1	Centrally housed, novel budget model, interdisciplinary teams	Boise State University	20,767 Public
1.2	Credit use policies: Policy impacts and faculty roles	Georgia Institute of Technology	16,048 Public
1.3	Leveraging resources: Housing multiple models together	The University of Michigan	30,318 Public
1.4	Building multidisciplinary faculty communities	National Dong Hwa University	10,000[+] Public, Taiwan
1.5	Housed in college; campus-wide curricular change; student demand; summer internships	New York University Tandon School of Engineering	26,733 Private
Program Organization			
2.1	Diversity: Departments, majors and academic rank	Howard University	6,243 Private, HBCU
2.2	Using personal coaching to facilitate boundary crossing	University of Pretoria	53,131[++] Public, South Africa
2.3	Focus on sustainable development	University of Strathclyde	18,821[+++] Public, Scotland
Faculty Approaches			
3.1	Strategies for junior faculty	Howard University	6,243 Private, HBCU
3.2	Early recruiting for graduate school	Texas A&M University	53,743 Public
3.3	Crossing disciplinary boundaries	Virginia Commonwealth University	24,058 Public

* From www.petersons.com
[+] From https://epage.ndhu.edu.tw/files/15-1000-45039,c8810-1.php?Lang=en
[++] From https://issuu.com/universityofpretoria/docs/up_in_a_nutshell?fr=sMTI3MTIzMjQ4NA
[+++] From https://www.topuniversities.com/universities/university-strathclyde/more

1. Innovations in Institutional Organization

1.1 Organizational Structure: Centrally Housed, Budget Model, Interdisciplinary Teams

Boise State University
Boise, Idaho USA
Contributors: Donna Llewellyn, Jillana Finnegan

Background

Program Operations: Housed and run in the College of Innovation + Design
Faculty lead in the Institute for STEM and Diversity Initiatives
Financial support for the teams from all of the Colleges on campus
Stage of Establishment: Institutionalized

Boise State established the VIP program in Fall 2015. The College of Innovation and Design (CI+D) was the driving force, but the program was established with the collaboration of

institutional leaders across campus. The Vice President for Academic Affairs/Provost, Associate VP for Strategic Planning, Office of Research, Office of Budget and Planning, and the Registrar's Office all contributed to making VIP a viable program. As an interdisciplinary, degree-granting college, CI+D had the authority, financial, and physical resources to build and nurture the program to grow across campus. Serving as institutional glue, VIP was initially added to the strategic plan in 2016 to minimize potential polarization between teaching and research. Also, key to the establishment of our program was our incentive-based budget model that returned part of the student credit money generated with VIP courses to the teams to purchase equipment and other items to support the team. VIP courses are listed as a separate program in the course catalog, enabling truly cross-disciplinary teams to form.

Innovation: Organizational Structure: Centrally Housed, Budget Model, Interdisciplinary Teams

At Boise State University, there are three main facets of innovation in the way we run the VIP program, and these create a virtuous feedback loop: (a) where VIP is housed and how it is managed; (b) the budget model that is used to support VIP projects; and (c) the interdisciplinary teams that are co-taught by faculty from different colleges.

Where VIP is housed: As mentioned above, VIP is housed in the College of Innovation + Design (CID). This College was created to be an incubator of innovative academic initiatives that live outside of the standard disciplinary units on campus. Because VIP is located in CID, no faculty feel like outsiders - they are all welcome to participate without feeling the need to only educate "their" students. VIP has a program lead in CID who handles program logistics, and a faculty lead who also runs the university's Institute for STEM and Diversity Initiatives. Because the faculty lead has a focus on inclusivity and access, we have program elements specifically designed to create an inviting and non-intimidating program for students across campus. For example, all faculty agree to limiting the barriers to engagement for students at the entry level (200 level course). We also created a web-based interest form for students instead of requiring them to cold call a faculty, which can serve as a barrier. An additional benefit of this webform is that our coordinator can then track student interest in the different VIP courses and follow up to learn more about potential obstacles if they don't ultimately register for a course.

Budget model: In the early days of VIP at Boise State, the Associate Dean of CID had a Memorandum of Agreement (MOA) with the President and the Vice President for Finance that returned the tuition earned through VIP student credit hours back to the VIP program. These funds were then available to the VIP faculty to spend on their teams - for supplies, to pay for students to stay engaged over the summer, for adjunct teaching relief, and for travel - it was up to them to decide how to spend their allocated funds. Since then, the university has changed budget models and this MOA has ended. In its place, an alternative budget model was agreed upon by all of the deans of the academic colleges. The Deans contribute funding based on the number of students from their college participating in a VIP, and faculty can pull from these funds to similarly support their teams. Each semester, we send a note to each dean with the amount that they are due to pay into the "VIP bank." Any VIP lead can then fill in a short proposal template requesting funds from that bank. The withdrawals don't have to be tracked back to the specific deposits - in this way it is the whole campus supports all of the VIPs, and funds are tied to specific disciplines.

Central structure for interdisciplinary work: And finally, at Boise State, we are finding innovation and success with projects co-taught by faculty from different colleges. This has happened organically with faculty proposing VIPs that are truly interdisciplinary and address complex challenges. Having VIP housed within CID provides a structure outside of their home departments under which they can come together. Feedback from instructors is that the VIP created a structure and a vehicle to partner together in new ways that would not have happened if VIP existed inside a traditional, discipline-based college. Examples include a historian and a material scientist exploring the technical challenges and potential educational uses of scent in AR/VR headsets; a coding bootcamp that sends students out to work in science labs across campus; a team of biologists and engineers creating new applications for the use of plasma technology; a health professor partnering with a global non-profit to reduce the environmental and health impacts of indoor wood burning in Kenya; and mathematicians working with a computer scientist and industry partners addressing cybersecurity for implantable devices such as insulin pumps.

Also unique to our structure is the tie between the College of Innovation and Design and the Institute for STEM Diversity and Inclusion (ISDI). CI+D is the academic and program home as it seeks to launch, test, and then export successful programs. The appointment of Dr. Llewellyn, Director of ISDI, to also serve as the Director of VIP has added creditability, visibility, and collaboration across campus that has supported the momentum and adoption of VIP. We are now ready to truly institutionalize VIP into the curriculum of departments across campus as a direct result of the collaboration between CI+D and ISDI.

Institutional benefits: Boise State recently went from being a primarily undergraduate institution to an R3, and now very recently became an R2. There is a strong desire to maintain our focus on undergraduate education while growing our research productivity. We have evidence that VIP works to do this on our campus - the faculty in the plasma group mentioned above were successful with two large federal grants specifically due to their VIP team - this was a new research area for the faculty, and the VIP team allowed them to start the project up and get initial data and results prior to the grants. Faculty from across campus repeatedly tell the leads of the program that VIP allows them to do things that the standard curriculum doesn't permit - it encourages them to be innovative and inclusive in the ways that they engage undergraduate students with their scholarship.

1.2 Credit Use Policies: Faculty Roles and Policy Impacts

Georgia Institute of Technology
Atlanta, Georgia USA
Contributors: Julie Sonnenberg-Klein, Edward Coyle

Background

Program Operations: Funded by the College of Engineering
Housed in the School of Electrical and Computer Engineering
Stage of Establishment: Institutionalized

The driving force behind the establishment of the Georgia Tech VIP Program was VIP Director Edward Coyle, Professor in the School of Electrical and Computer Engineering (ECE). The program was established in Spring of 2009, shortly after the department hired Coyle into an endowed chair associated with the Arbutus Center for the Integration of Research and Education. Beyond the endowed chair and center, ECE supported VIP in three ways: with two dedicated classrooms, course release for instructors, and staff support. The instructor release time initially provided 1-course of release time in an instructor's first year of leading a VIP team, which has now increased to 1-course every year. The initial staff support included creation of VIP courses in the student registration system (a time-consuming effort handled by an associate chair), and the issuance of registration permits (handled by a staff member who coordinated another undergraduate research program). Roughly five years after the program began, VIP had 10 teams, and the department provided salary for a full-time academic program manager. Two years later, the VIP Program had 28 teams and was widely multidisciplinary, enrolling roughly 300 students from 19 majors, with only one third from Electrical and Computer Engineering (VIP's home department). The College of Engineering began providing a budget line for VIP Program operations, and VIP has since hired additional staff. In Spring 2020 the program enrolled approximately 1,300 students from 34 undergraduate and 19 graduate degree programs.

Innovation: Credit Use Policies

A key component of the VIP model is student program persistence, or participation over multiple semesters. In second and subsequent semesters, returning students help on-board new students, serve as sub-team leaders, and reinforce team practices around collaboration, accountability, and documentation. In turn, peer-leadership reduces the burden on instructors, freeing faculty to focus on higher-order project issues. Students are attracted to VIP for a variety of reasons – interest in the teams they join, practical experience, applying knowledge beyond "regular" coursework, etc. However, **whether students return for a second semester depends largely on whether the course credits they earn in VIP can be applied toward their degree requirements.** Driven by student demand and faculty interest, 22 degree programs have established policies on how VIP credits can be applied toward degree requirements, with 19 policies in undergraduate programs and 3 in master's degree programs. Without these policies, substantially fewer students would participate for multiple semesters, and the VIP teams would be less stable and sustainable.

Policy and Student Persistence: Because student persistence in the program is key to team stability, a 2017 study examined how student return rates varied under four policies [10]. Mechanisms in the four policies included incentives and thresholds, as detailed in Table 1.2-1. Policy 1, which serves as a baseline, allowed up to 6 VIP credits to count as free electives, with no minimum number of credits required. Since VIP is offered in 1 and 2-credit hour increments, this could range from 3 to 6 semesters. Policy 2 incorporated two incentives and one threshold. It allowed students to use up to 3 VIP credits as technical electives, with no minimum number of VIP credits required. The policy also allowed students to roll their VIP projects into Senior Design, with 2 semesters (3 credits) of VIP required prior to Senior Design. Policy 3 involved two incentives as well, with thresholds for both. The first incentive allowed students to count 6 VIP credits as 3 free electives and 3 in-major electives. Unless a 6-credit (3-6 semester) threshold was reached, the credits could only be counted as free electives. The second incentive

allowed students to roll their VIP projects into Senior Design as well, with 3 semesters (5 credits) of VIP required prior to Senior Design. This threshold can also be thought of a pre-requisite for doing Senior Design through VIP. At the highest incentive level, Policy 4 allowed VIP to fulfill a multi-semester Junior Design requirement. A threshold of sorts was built into the policy, as students would need to earn five credits over three semesters. However, the VIP pathway was comparable to other Junior Design pathways and did not represent additional coursework.

Table 1.2-1. Policies on VIP Credit Use

Policy	N	Enrolled for 2 or more semesters	Incentives & Maximum Credits	Threshold for Incentive	
				In Semesters	In Credits
Policy 1	210	43%	Free elective: up to 6 credits	-	-
Policy 2	117	36%	In-major electives: up to 3 credits	-	-
			Senior Design	2 semesters of VIP prior to Senior Design	= 3 credits
Policy 3	286	52%	Mix of free and in-major electives: 3 free, 3 in-major	3-4 semesters of VIP	= 6 credits
			Senior Design	3 semesters of VIP prior to Senior Design	= 5 credits
Policy 4	256	68%	Junior Design	Fulfills a requirement*	

* VIP is one of multiple options that fulfills a requirement. There is no threshold, but it involves 3 semesters of VIP (5 credits) and is comparable to the other options.

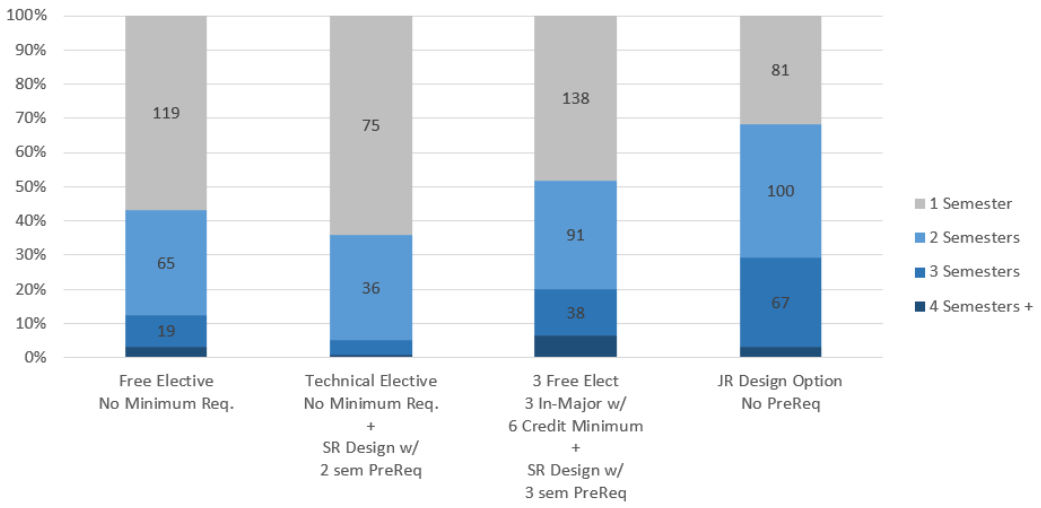

Fig. 1.2-1. Student Program Persistence (Return Rate) by Policy

As shown in Fig 1.2-1 and Table 1.2-1, Policy 4 (Junior Design sequence, no pre-requisite) yielded the highest program persistence, with 68% of students participating for two or more semesters. The next highest level of persistence was under Policy 3 (mix of free and in-major electives and Senior Design option, both with thresholds) at 52%, followed by Policy 1 (free elective) at 43%, and Policy 2 (in-major elective with no threshold, and Senior Design option with threshold) at 36%. Contextual information is helpful in interpreting these results. While we

might expect the lowest persistence for the baseline policy (Policy 1), which only allowed VIP to count as free electives, a major with a higher incentive yielded lower persistence (Policy 2). However, this is unique to the major in Policy 2, in which students often report "only needing 1 (or 2) more technical elective credits to graduate." In this case, the structure of the degree program and policy for VIP credits create an incentive for low persistence. The program attracts students who "just need one more credit," who have no intention of continuing in the program.

Comparing the persistence for Policies 3 (Senior Design option with pre-requisite) and 4 (Junior Design sequence, no pre-requisite), Policy 4 yields higher persistence. The substantive difference between the two policies is that under Policy 4, every VIP credit maps directly to the required sequence. Under policy 3, VIP replaces a single course after students have already participated for multiple semesters. This requires students to 1) have enough room in their program of study for the three semesters of VIP in addition to their the Senior Design semester, and 2) for students to plan far enough in advance to fit these four semesters into their timelines. The department associated with this policy is revising their Senior Design sequence. Under the new model, VIP will map directly to more courses. We will be interested to see if this yields an increase in persistence.

Faculty Role: Instrumental to the adoption of credit-use policies are VIP instructors. While the VIP Director can actively engage academic units, policy adoption falls to the faculty within each department. As more faculty within departments establish VIP teams, their departments become increasingly more likely to adopt policies on VIP credit-use. As illustrated in Fig. 2.1-2, departments that have 11 or more VIP instructors all have policies on how VIP credits count toward degree requirments, with decreasing policy frequency for departments with fewer instructors. To this end it is not a VIP Director who achieves change within the institution, but the faculty who buy into the program and bring about change in their own departments.

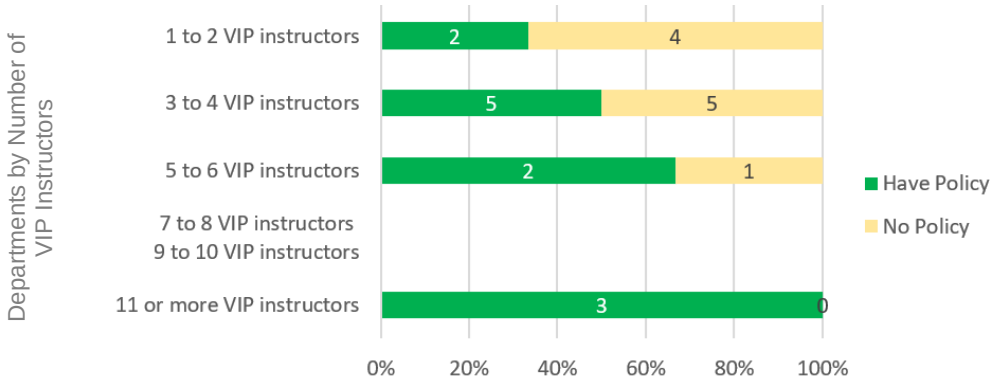

Fig. 1.2-2. VIP Credit-use Policy Adoption by Number of VIP Instructors from Department (Georgia Tech)

1.3 Leveraging Resources: Housing Multiple Models Together

University of Michigan, College of Engineering
Ann Arbor, Michigan USA
Contributor: Patricia D. Koman

Background

Program Operations: College of Engineering, under the Associate Dean for Undergraduate Education
Stage of Establishment: Institutionalized

The University of Michigan Multidisciplinary Design Program (MDP) was established in December 2007. With support from the Provost, Professor Brian Gilchrist and Dean Alec Gallimore started this program to engage undergraduates in research and pre-professional industrial design experiences to prepare engineering students for the modern workplace. The Provost office provided an initial grant, office space and protected faculty time for 3 years. In July 2010, the first MDP Director, Gail Hohner began her leadership, and the MDP program grew to 60 students. An academic advisor was added to the team. In 2011, a research grant started the first project-sponsored project (a Chimpanzee joy stick design project), and in 2012, MDP recruited its first major cohort of students. As shown in Figure 1, MDP now provides over 1,000 experiential learning opportunities for students from across the university every year in four types of programs for academic credit.

Innovation: Leveraging Resources: Housing Multiple Models Together

The University of Michigan has a highly multidisciplinary culture as a university, which is supported by programs such as the M-Cubed research initiative and many interdisciplinary centers for research and teaching. Within this context, the MDP brings together students based on their skills to address grand engineering challenges and to promote students experiential learning to bridge the gap between the classroom and professional practice.

Currently, MDP provides over 1,000 experiential learning opportunities for students from across the university every year to prepare students to join the modern workforce. As a part of long-term, team-based projects, students partner with research faculty and industry leaders to bridge the gap between the classroom and professional experience. Established in 2007, MDP is focused on design-based engineering and data science projects, but the program is open to any student on campus through a competitive recruitment process. First year undergraduate to masters students are eligible to participate and are recruited based on skills needed for the projects. The MDP staff has collaborative relationships with multiple colleges across campus, which affords us the opportunity to recruit students with key skillsets beyond the College of Engineering (e.g., Art & Design, Statistics, School of Information) and to offer academic credit for the experience.

MDP offers two types of student experiences: 1) on-going faculty-led research teams and 2) one-year industry-sponsored projects. The MDP research teams are long-term, multidisciplinary organizations with the specific goal of advancing faculty research efforts while simultaneously

producing the maximum number of high-quality educational opportunities for students. In 2020, MDP supported 11 research teams and over 200 students, including opportunities for first year undergraduates through masters level students. On the industry-sponsored project teams, students work with industry leaders and a faculty mentor for a one-year full design cycle experience culminating with a final presentation at the campus Design Expo.

Central MDP resources are efficiently leveraged to support students' educational needs without burdening faculty time. Student recruitment occurs in the fall semester and during in-coming student orientation. MDP uses a matching process similar to matching medical residents to hospital placement to maximize student participation. Students enroll for academic credit (typically committing to 2.0 credits/term for a minimum of 2 terms, Winter and Fall). On research teams, students may return to the team for longer engagement, and more experienced students typically train the newer students and assume team and technical leadership roles. Typical participation in the program for trainees consists of 2 to 6 semesters as a member of an MDP research team, and 2 semesters of 2.0 – 6.0 credits/term often receiving capstone experiences for the industry sponsored teams. Some research students participate in the optional summer MDP fellowship program to conduct research on campus. Undergraduate students may also complete a minor in Multidisciplinary Design awarded from the College of Engineering.

Our students meet together with their mentors for 2 hours per week and are expected to establish work-together times in smaller sub-teams. This face-to-face time facilitates multidisciplinary team-based learning.

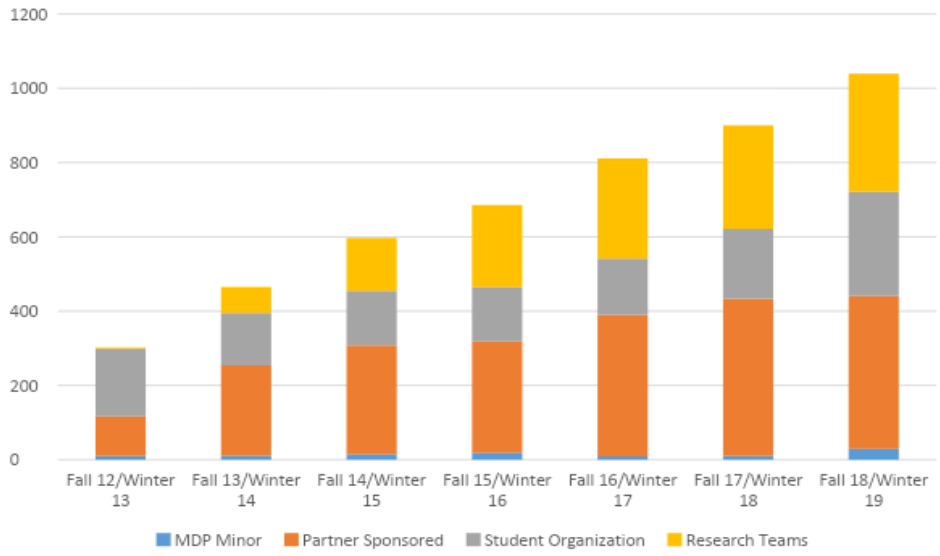

Figure 1.3-1. University of Michigan MDP Student Enrollment

Research teams self-manage day-to-day operational functions including project management, technical sub-team development goals, documentation, team skill development, and recruiting with MDP support. MDP also pilots new models for experiential learning and conducts educational methods research to improve the quality of the experiential learning [11].

The University of Michigan MDP structure is not the only model that provides valuable engaged learning on campus. We use a common administration to support experiential learning in a variety of contexts (e.g., studying abroad, socially engaged design, entrepreneurship programs, student organizations focused on competitions).

1.4 Building Multidisciplinary Faculty Communities

National Dong Hwa University
Hualien, Taiwan, R.O.C.
Contributors: (Cosmos) Jen-Yeu Chen, (Josh) Han-Chieh Chao

Background

National Dong Hwa University currently has three formal university-wide VIP-like programs to credit and foster student development:

Program 1: TTPBL (π-Project Based Learning) program, Proof of concept for VIP model
Program Operations: Run by the College of Science and Engineering for the R&D of various cross-disciplinary applications of Smart Technologies (AI, AIoT); Funded partially by the university and partially by the government (Ministry of Science and Technology, MoST)
Stage of Establishment: Institutionalized, three years old; The first group of undergraduates taking this program from their sophomore year will graduate this summer

Program 2: BRICK (Break/Redefine/Imagine/Catalysis/Kindle) program
Program Operations: Run by the Center of Society Participation of NDHU; Funded partially by the university and partially by the government (University Social Responsibility, USR, Project by the Ministry of Education, MoE)
Stage of Establishment: Institutionalized, two years old

Program 3: VIP Program
Program Operations: Run by the Center of Teaching Excellence of NDHU; Funded by the university.
Stage of Establishment: Newly established, launched 12 teams in Spring 2020

Three multidisciplinary programs have been established at NDHU in quick succession. The first program, π-Project Based Learning (TTPBL), was established in Fall 2017. The program was founded as a "faculty social society/group" for faculty members across the university with the common interest. As they are with the same interest and same goal, collaboration amid them naturally happens. Three professors served as driving forces in the program's establishment: Professor Jen-Yeu (Cosmos) Chen from Electrical Engineering and Professor Shi-Jim Yen as well as Professor Shou-Chih Lo from Computer Science and Information Engineering. While the program does not operate under a mandate from the administration, it is funded by the university and the government (Ministry of Science and Technology, MoST).

The second program, Break/Redefine/Imagine/Catalysis/Kindle (BRICK) program was established in Fall 2018. Driving forces behind this program were Professors Jane Ku, head of the Center of Society Participation, and Professor Shiao-Hua Liu, Department of Counseling & Clinical Psychology. The program is funded by the university and the Ministry of Education, MoE's University Social Responsibility Project.

The VIP Program was established most recently, with teams launched in Spring 2020. The program built upon the TTPBL efforts that began in 2017, and VIP is fully supported by University President Prof. Han-Chieh Chao. The program is being led by Professors Te-Sheng (Ted) Chang, head of the Center of Teaching Excellence, and Professor Jen-Yeu (Cosmos) Chen from Electrical Engineering (also a driving force in TTPBL). The Center for Teaching Excellence coordinates the programs, with teams to receive funding from the institution.

Innovation: Building a Multidisciplinary Faculty Community

It is really not easy to "break down the silos" in particular when we try to carry out some new idea or new system such as "cross-interdisciplinary VIP program" which actually may cause extra loading to the participating faculty members and consume common resource from the others. What we did was first to form several social communities/groups by the common research interest. For example, in the TTPBL (π-Project Based Learning) program, we aimed to apply AI and IoT technologies in various areas. So, faculty members from departments outside of Electrical Engineering and Computer Science who are interested in adopting these technologies would join to discuss possible collaborations and then brought in their students – both graduate and undergraduates. For example, in the project of environmental sensing and protection by AI + IoT, we need not only students from Dept. EE and Dept. CS to setup IoT with sensors to collect environmental data but also students from Dept. of Environmental Studies to analyze the data collected and select the effective spots to deploy the sensors. The common interest shaping the common goal amid the participating faculty is the fundamental and main driving force to break down the silos. We together, not alone, have our resolution to work it out.

The next step, for reality, is to search for financial support. We first applied for the resource outside university to avoid consuming the resource within the department/ university that may easily cause obstacles. Luckily TTPBL (π-Project Based Learning) program obtained funding from the government – the Ministry of Science and Technology, MoST. Then we tried to be institutionalized i.e., to setup formal course program in the college. As we have our own funding source and have the support from the president of the university, although facing some objection, we succeeded to setup this multi-year project learning based program. By the success of this program, more and more faculty understand the benefit of VIP-like program. Now the concept is well known and accepted across the university. Thus, when our university formed a university-funded VIP program and called for proposals of interdisciplinary VIP teams last semester, there were over 25 submissions from eight different colleges containing a variety of research topics. Twelve teams were selected and funded in Spring 2020.

1.5 Top-down and grass roots growth

New York University Tandon School of Engineering
Brooklyn, New York, USA
Contributor: Jack Bringardner

Background

Program Operations: Tandon School of Engineering Office of Undergraduate and Graduate Academics
Stage of Establishment: Institutionalized

The NYU Vertically Integrated Projects Program was established in Fall 2016. The initial champions for the program were the Dean of the School of Engineering and the Associate Dean for Engineering Academics. They worked with the departments to establish policies on how credits would count and to encourage faculty to develop VIP courses. The Dean's Office in the School of Engineering planned to financially support the VIP Program after the initial startup period funded by the Helmsley Grant coordinated by Georgia Tech.

The NYU VIP Program grew primarily through grass roots initiatives led by students, which supplemented the support from the academic administration. Students and faculty had expressed a need for innovation in the curriculum. Students shared with the administration a desire to have more project opportunities on campus and in the classroom. Some faculty were interested in experimenting with problem-based and project-based learning, and the resources and tools offered by the VIP Program accelerated the rate at which faculty were adopting these teaching methods. The initial assistance from the administration allowed for top-down support and the growing call for change from the students initiated bottom-up growth, which led to the perfect environment for VIP to grow at NYU.

Before the VIP Program there was no centralized mechanism for students to participate in undergraduate research other than the summer research program. Some students were able to conduct research during the academic year by informally approaching faculty. The School of Engineering's student leadership approached faculty and the administration with a request to facilitate more research opportunities on campus. And so, the VIP program at New York University has steadily grown since 2016. In Fall 2019, the program enrolled 253 students on 30 different teams.

Innovations: Housed in college; campus-wide curricular change; student demand; summer internships

There are four elements of the NYU VIP Program that have enabled a "breaking down of the silos" between departments, disciplinary activities, and schools. The NYU VIP Program is housed in the Engineering Dean's Office of Academics and does not report to the academic departments. A majority of the growth of the Program has come through grass roots initiatives led by students. During the initial expansion of the VIP Program, the School of Engineering was undergoing a revision of its curriculum and VIP was incorporated in strategic plans. This

allowed for institutionalization of the Program, which was also enabled by collaborations inside and outside of the university.

Where VIP is housed: The NYU Tandon School of Engineering had a precedent for multidisciplinary courses not being in a department. The multidisciplinary Introduction to Engineering course, established by the NSF Gateway Coalition, is housed in the Office of Academics. VIP was integrated into the same office and this arrangement prevented departments from coopting the Program. The VIP Program had a discipline independent mission from the start. Outreach to the school intended to address all disciplines through faculty meetings, department meetings, student success committees, academic advising events, and university-wide programs. The VIP Program set a priority to make accessibility paramount and ensure that all students and faculty are welcome to participate.

Student grass-roots efforts: The VIP Program's anti-silo vision set the stage for grass roots growth encouraged by the students. From the outset, faculty from all of the departments in the School of Engineering were involved. Later faculty from the non-engineering schools were also invited into the VIP Program. After the initial teams formed and had completed a few successful semesters, the VIP Program experience began to spread by word of mouth. Students were telling other students, advisors, faculty, department chairs, industry boards, and the deans about the desire to increase the number of these opportunities. The VIP Program employed student workers to understand the student perspective. The student workers coordinated with student organizations and student councils across the university on recruitment efforts. Additional recruitment included sharing information with advisors from every school at the University and participating in university-wide orientations.

Institution-wide curricular change: One of the biggest barriers that formed as the recruitment efforts ramped up was the freedom and flexibility of the credit policies in the degree programs. The faculty governance had established a committee to redesign the curriculum prior to the inception of the VIP Program. This curriculum committee's first initiative was to increase the number of electives in all degrees. This created consistency in the School's policy so that students from any discipline were able to enroll in VIP for the same number of credits that would count towards their degree. In addition to increasing elective options, the faculty sought to add professional skill development opportunities, integration with existing project-based learning in the curriculum including the first-year cornerstone and senior-year capstone design courses, and training for faculty to implement evidence-based best practices for teaching. VIP became a connective tissue between these curriculum initiatives.

Extension into summer internships: As the VIP Program achieved institutionalization in Fall 2019, it aimed to align with the mission of the university and the curriculum change efforts. VIP Teams were developed in some of the large research labs, which were seeking students from disciplines outside of their primary domain. Many of the faculty in these labs participate in the undergraduate summer research program and the VIP Program coordinated efforts so that advisors could continue their VIP team efforts in the summer through paid research internships. These opportunities were commended by industry boards and the career services office because they created pathways for students through collaboration and networking opportunities with

industry partners. These successes and the institutionalization of the VIP Program have led to some departments considering experiential learning, including VIP, as a degree requirement.

2. Innovations in Program Organization

2.1 Diversity: Departments, Majors and Academic Rank

Howard University
Washington, D.C.
Contributor: Charles Kim

Background

Program Operations: Transitioning from the Department Level (Electrical Engineering and Computer Science) to the College Level (College of Engineering and Architecture)
Stage of Establishment: Institutionalized

The Howard University VIP Program was established in 2015, when introduced to the model VIP by the Georgia Institute of Technology in 2014. The driving force behind VIP at Howard was Dr. Charles Kim, a professor of the Department of Electrical and Computer Engineering (ECE) which offered two ABET accredited programs – Electrical Engineering and Computer Engineering. (The department was merged with the department of Systems and Computer Science in 2017 and is now the department of Electrical Engineering and Computer Science offering 3 programs: Electrical Engineering, Computer Engineering, and Computer Science.) When the program was introduced, Kim had been teaching a capstone design course for more than 6 years and had felt that some projects needed more than one school year, due to contents, scope and skill-set requirements. Around the same time, the ECE Department was implementing a new curriculum to offer project/research courses for non-senior students too. Therefore, the introduction of VIP in 2014 was timely and well received. A seed grant from The Helmsley Charitable Trust provided the sole support for the establishment of the Howard VIP program, enabling a launch in 2015. Later, industry sponsorship to VIP projects provided necessary resources to maintain the VIP program. The VIP program at Howard is institutionalized, with measures including substitutable courses for VIP participation, VIP participation option with class attendance exemption, stipend payment for participating students for funded or sponsored projects, and emphasis on freshman participation to increase retention rates, among others.

Innovation: Diversity: Departments, Majors and Academic Rank

VIP at Howard focuses on engagement of all majors in the college of engineering and architecture to make a community of true multidisciplinary innovation environment. To achieve this goal, two target objectives are set: (a) an equal number of VIP advisors from 6 engineering disciplines, (b) an equal number of student participants from each engineering discipline, and (c) an equal number of student participants from first year to fourth year. In assessing the goal achievement, Shannon's diversity index is utilized. Shannon's diversity index (H) in the context of engineering discipline diversity can be defined as

$$H = -\sum_{k=1}^{n} p_k * \ln(p_k)$$

where, p_k is the proportion (n_k/N_k) of individuals of k^{th} discipline in a VIP team (n_k) divided by the total number of individuals in the team (N_k), and *n* is the number of disciplines. The more unequal are the number of professors or students from different disciplines (or levels), the diversity index gets smaller. When the numbers from different majors (or levels) are the same, the diversity index will reach the maximum.

For the diversity in the participating faculty disciplines, Table 2.1-1 shows the number of faculty advisors and their home disciplines. Shannon indexes are calculated for the number of disciplines each semester. For example, in Spring 2015, there are 3 professors in EE and 1 professor in CpE. So the diversity index here is to measure how diverse the faculty advisors in terms of their disciplines. As indicated by the Shannon indexes in the last row, the VIP program has become more diverse in faculty advisor's discipline, improved from 0.24 to 0.65.

Table 2.1-1. Faculty Advisors and Their Home Disciplines

Semester	Sp 15	Fa 15	Sp 16	Fa 16	Sp 17
Number of Teams	5	7	8	9	11
Number of faculty Advisors	4	7	5	6	8
Electrical Engineering (EE)	3	5	3	3	3
Computer Engineering (CpE)	1	1	1	1	1
Computer Science (CS)				2	2
Physics (PHYS)		1	1		
Civil Engineering (CV)				1	1
Mechanical Engineering (ME)					1
Chemical Engineering (CHEM)					
H (Shannon Diversity Index)	0.24	0.34	0.41	0.55	0.65

As for the discipline diversity among student participants, Table 2.1-2 summarizes the details. The table shows the number of students followed by the numbers of their disciplines. As indicated by the Shannon indexes in the last row, the multidisciplinary nature of the VIP program for students has become much more diverse than faculty but its trend has not been clearly established over the 5-semester period.

The diversity in the levels of participating students is summarized in Table 2.1-3. The table shows the levels of student participants for each semester: senior, junior, sophomore, and freshmen. As indicated by the Shannon indexes in the last row, the VIP program has become more diverse in the level of students, improved from 0.493 to 0.895.

Table 2.1-2. Disciplines of Student Participants

Semester	Sp 15	Fa 15	Sp 16	Fa 16	Sp 17
Number of Students	28	45	34	52	51
Electrical Engineering (EE)	14	16	16	20	26
Computer Engineering (CpE)	9	6	9	16	12
Computer Science (CS)	1	7	1	4	3
Civil Engineering (CV)	2	3	1	2	1
Mechanical Engineering (ME)	1	9	7	6	8
Chemical Engineering (CHEM)		3		4	1
Mathematics (MATH)	1	1			
H (Shannon Diversity Index)	0.546	0.735	0.538	0.651	0.563

Table 2.1-3. Levels of Student Participants

Semester	Sp 15	Fa 15	Sp 16	Fa 16	Sp 17
Freshmen	0	22	7	13	4
Sophomores	4	3	3	13	9
Juniors	3	2	7	9	18
Seniors	21	18	17	17	20
Total	28	45	34	52	51
H (Shannon Diversity Index)	0.297	0.450	0.526	0.592	0.539

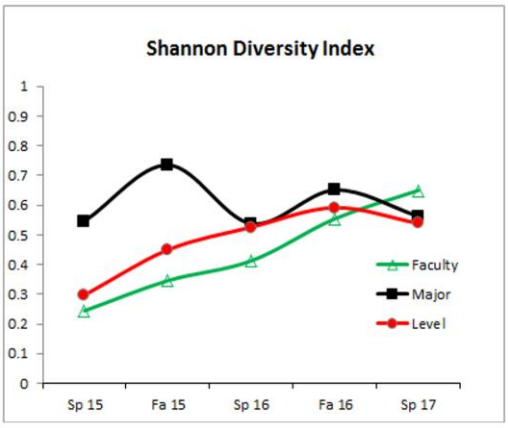

Fig.2.1-1. Shannon Diversity Index for Faculty, Student Majors, and Student Levels

In conclusion, comparing each semester from spring 2015 to spring 2017 as illustrated in Fig. 2.1-1, the diversity index for measuring the range of disciplines for faculty advisers has increased from 0.24 to 0.65. Regarding the diversity in the levels of participating students each semester, the number of first-year through fourth-year students was counted, and the Shannon diversity index measure was applied. The diversity for participating students' year levels has increased from 0.30 to 0.54. However, the diversity for participating students' disciplines has seen a minimal increase from 0.55 to 0.56.

In addition to the increased diversity in multidisciplinary faculty and student participation, the VIP at Howard observed that the participating students gaining soft skills and being gradually acclimated to the real research environment. Implementation of the VIP framework at Howard University has brought a unique opportunity for underrepresented students to acquire practical experiences and skill sets that encourage them to remain in their respective disciplines and graduate, thus leading to increased employment opportunities for the students and workplace diversification for the nation. Presently, VIP at Howard focuses on enrolling more freshmen and initiating more teams sponsored by industry.

2.2 Using Personal Coaching to Facilitate Boundary Crossing

University of Pretoria
Pretoria, Gauteng, South Africa
Contributor: Nadia M. Trent

Background

Program Operations: Housed in the Department of Industrial and Systems Engineering.
Teams housed in various engineering departments.
Funded by:
- Department of Industrial and Systems Engineering
- Engineering, Built Environment and Information Technology Faculty (College)
- Department of Research and Innovation (grants)
- Limited industry funding

Stage of Establishment: Active program working toward institutionalization

The VIP concept was introduced to the Dean of Pretoria's faculty (college) of Engineering, Built Environment and Information Technology (EBIT) in July 2017. At the time, Nadia Trent, an alumna of the Georgia Tech VIP Program, was a lecturer in the Department of Industrial and Systems Engineering. Both the Dean and the Head of Department of Industrial and Systems Engineering saw the potential benefits that a VIP program could bring to EBIT. Thus, Trent was given the mandate to pilot the VIP@Tuks program.

In February 2018, VIP@Tuks kicked off with two pilot teams. From the second semester (July 2018) to date, the number of teams have fluctuated between four and eight. The number of students enrolled in VIP teams per semester have fluctuated between 40 and 120. After two years, the program has crossed all boundaries between engineering departments and next aims to branch out to the rest of the college.

Innovation Context

In my experience as an educator, I believe that we are incapable of showing students how to break (or cross) a silo wall if we do not create learning experiences that allow multi-silo immersion. Module-based multidisciplinary projects certainly go further than merely telling students about multidisciplinary thinking. However, the time constraints, performance pressures, and strict guidelines required by the encapsulating modules often short-circuit the silo crossing

process. VIP succeeds where module-based projects fail because it assesses the process, not the outcomes. Crossing silos is a procedural skill, a mindset, that can only be taught by immersion.

Another shortcoming of module-based multidisciplinary projects is that it addresses but one facet of silo-based thinking, namely disciplinary silos. What about other facets? VIP@Tuks has been effective in immersing students into learning experiences that challenge their thinking silos in at least four facets: disciplinary, experiential, cultural, and achievement-based.

Disciplinary silos: In the current stage of its growth, the VIP@Tuks programme recruits students from all over the faculty of EBIT. While the majority of students hail from engineering disciplines, other majors are also represented like computer science and town and regional planning. Each one of our current teams is led by an expert in a specific engineering discipline.

In the VIP teams, students ram into the silo wall from both sides. Those inside the silo (i.e. those students who come from the same discipline as the team leader) are confronted with questions from others that seem obvious to them and contributions that seem foreign or ludicrous to start with. The "other" disciplines may prioritise tasks differently or go off on seeming tangents. It is greatly frustrating to bring these people "up to speed" on the technical elements of the team's work.

Those outside the silos ram into a wall that keeps them from being part of the "inner circle". Just learning the team's jargon and acronyms can feel demoralising. What makes it worse is that even the team leader may not have an idea how to speak these outsiders' languages. Even though she may recognise the need to incorporate their specific skill set, she does not know how to learn her team's discipline from an outsider's perspective.

Experience silos: The magic of vertical integration is that it breaks down the "experience" silos. Students march through their degrees in cohorts where most people have the same experiences and are of the same age. Crossing the experience silos "upward" exposes younger students to bigger-picture perspectives, and to more mature attitudes towards work, team dynamics and leadership. It can be both inspiring and humbling. Crossing experience silos "downward" enriches the older students as they have to develop their mentoring skills. They also have to grow in their empathy to create a welcoming and productive environment for younger members.

Cultural silos: South Africa is very diverse in terms of race and language. An additional cultural dimension is that of varying socio-economic ability. South Africa is (according to the Gini coefficient measure) one of the most unequal countries in the world. The poor have a markedly different lifestyle, community, and upbringing compared to those in the middle and upper classes. These factors greatly influence one's worldview. Thus, the socio-economic inequality in South Africa also creates thinking silos.

The University of Pretoria campus boasts a broad representation of race, language, and socio-economic diversity. Some of our teams – notably those that target more relatable problems like renewable energy or campus mobility – draw students from many cultures. The value of crossing cultural silos is made apparent to these students when the practicality or implementability of their

solutions are discussed. In modules, such discussions can remain theoretical or conceptual, but on a VIP team, implementation is a lived reality.

Thinking across cultural silos is essential for engineers who have to design solutions for society. Every engineer will be a product of his own cultural silo. However, the appreciation that there exists other silos, and the ability to cross the boundaries with empathy, will result in better solutions.

Achievement silos: "Birds of a feather flock together." This is also true in terms of academic achievement. Students often make friends or select project groups based on similar work ethic or academic achievement. The recruitment process allows students from all achievement rungs to be a part of the team. For the overachievers, this is a great opportunity to realise that there are many characteristics of a "brilliant engineer" that cannot be assessed in modules. For those who might not be doing so well academically, VIP can be a tremendous confidence boost! Suddenly they are of value and are doing well despite their inability to solve differential equations under a time cap.

Innovation: Using personal coaching to facilitate boundary crossing

As program director, I often play the role of personal coach or mediator to assist students cross silo boundaries. Looking back, I can extract a generic coaching recipe from my experiences:

1. **Make enough time** for the student and create a comfortable atmosphere so that they know you are not rushed and are willing to listen.
2. **Listen to the student's concerns.** Tease out stories to understand the context. If the student talks vaguely, impersonally, or abstractly, assure him that he is in a confidential discussion.
3. **Validate, empathise and de-escalate.** Validate how the student is feeling. Even if you think they are overreacting, validate that their emotions are real and worth paying attention to. Empathise by telling them of a similar situation you've experienced. De-escalate the issue. Unless there is serious reason for concern (harassment, unethical behaviour), assure them that this is all part of the process.
4. **Jointly create solutions.** Although you have de-escalated the issue to that of "everyday team dynamics", that doesn't mean it should be ignored. Work with the student to come up with strategies they could try.
5. **Follow up.** When you see the student on campus, ask them how things are going and praise any small step forward that they've made.

The process above assumes a personal consultation, but it can be adapted to email correspondence. It also works well when debriefing with team leaders. It's a very simple and almost obvious process, but I think we grossly underestimate the impact of our time and encouragement on students. As Simone Weil said,"Attention is the rarest and purest form of generosity."

2.3 Focus on Sustainable Development

University of Strathclyde
Glasgow, Scotland
Contributors: Louise Logan, Scott Strachan

Background

Program Operations: Housed in the Faculty (College) of Engineering;
Serves 4 faculties at the University
Stage of Establishment: Institutionalized

The Vertically Integrated Projects program at the University of Strathclyde was established in 2012 by Prof Stephen Marshall (who was, at the time, Deputy Head of the Department of Electronic and Electrical Engineering) and Dr Scott Strachan (a Senior Teaching Fellow in the same department). At the time, the project had no financial or resource support to aid its establishment, but a number of department heads and academics were interested in its potential. The program grew through this initial enthusiasm and the work of academics involved. The University Principal (President) also backed the program in its early stages. Financial investment has been limited. However, we have now focused our efforts to scale up, with a mandate from the Principal, and we have been able to appoint a dedicated, full-time Program Coordinator.

The program has made significant progress since its establishment, and now includes 12 projects, all of which focus on research aimed at furthering the UN's Sustainable Development Goals (Agenda 2030). We have recently hired a full time, dedicated Program Coordinator to oversee the program and aid its expansion across the University. We are currently engaging with Vice Dean Academics to scale this program up across the university by identifying pathways for VIP4SD through every degree offering. The program has been cited in the University's Vision 2025 Strategic Plan as an exemplar of embedding Research-Based Education for Sustainable Development in Undergraduate curricula, which the University has committed to delivering more broadly.

Innovation: Focus on Sustainable Development

The University of Strathclyde's VIP program is distinct in that each of our 12 projects are aligned with the United Nations' Sustainable Development Goals (SDGs) to create 'Vertically Integrated Projects for Sustainable Development' (VIP4SD). Each project is comprised of multidisciplinary teams of students and researchers who collaborate on a wide range of initiatives to address these Global Goals. By combining the approach of Vertically Integrated Projects with research-based education (RBE) and education for sustainable development (ESD) – a pedagogical approach which allows students to apply their knowledge and skills in practical ways, all while contributing to the SDGs – our students have a unique learning experience [15].[1] VIP4SD equips students with the research skills and interpersonal skills that come from working collaboratively across disciplines, as well as the competencies that define education for sustainable development. Marco Rieckmann has noted that "ESD equips individuals not only

[1] For further discussion of VIP4SD's application of research-based education for sustainable development, see Strachan et al, 2019 [15].

with the knowledge to understand the SDGs, but also the competencies to engage as informed citizens in promoting the transformation to a more sustainable society" [12, p. 39]. These competencies include integrated problem-solving, critical thinking, the ability to strategies, and self-awareness. VIP4SD students learn these competencies through their group work and the local and international outreach opportunities our projects offer. In effect, the VIP4SD program successfully prepares students 'for the work of the world, not just the world of work' – Sir Jonathon Porritt. Additionally, research has shown that this is what students want. Survey data from the National Union of Students UK and their offshoot organization Students Organizing for Sustainability show that 85% of students agree that "sustainable development is something which universities and colleges should actively incorporate and promote", with 60% additionally agreeing that they would like to see education for sustainable development in their core curriculum[2].

The VIP approach provides the mechanism through which research-based education for sustainable development can be embedded within the undergraduate curriculum, providing students with the time and freedom to make meaningful research contributions to the global goals, while developing a genuine expertise in the area. For example, the Energy for Development VIP4SD project, focuses on providing affordable and clean energy for all, and involves Business, Engineering and Social Science students designing appropriate and sustainable energy solutions. This project also allows students to engage with target communities, giving them the opportunity to develop off-grid systems and test their solutions in these remote rural communities in Africa and India, with 12 village school solar systems having been installed since 2007, providing lighting, ventilation and small power services for around 5,000 pupils.

The VIP4SD program therefore engages students in real-world research and development that can have a lasting impact on communities, but also on the students themselves. This requires students to communicate effectively across disciplinary boundaries, enhancing both their academic and professional skills, whilst also giving them a practical understanding of the challenges of sustainable development. This gives students the opportunity to apply their learning practically, all while contributing to the SDGs. For example, students working on the Energy for Development project help further SDG 7 by providing access to clean and affordable energy. By working with the local community, the aims of this project are truly sustainable, and by engaging in a research project, students become producers of knowledge as well as consumers of it. By becoming active rather than passive learners, students achieve a deeper level of learning, and the outreach element of VIP4SD projects means students are inspired to participate by more than just a grade. This is just one example of the ways in which our projects aim to 'break down the silos'. Not only do we foster cross-disciplinary collaboration and knowledge exchange, VIP4SD also aims to bridge the gap between academia and society.

VIP4SD students also engage collectively by participating in and contributing to our VIP4SD conference, which is hosted at Strathclyde every March, at the end of the second semester. The conference brings together all VIP4SD students to present their work, engage with the other projects, and share what they have learned. The VIP4SD conference has also been an opportunity

[2] Data from c. 50,000 respondents over the last 8 years.

to invite external businesses and academics from other VIP sites to see what our students are able to do, presenting an invaluable opportunity for undergraduates to network with potential employers.

We are currently awaiting ethical approval for an evaluation of the program, which will allow us to gain a broader understanding of the competencies VIP4SD students develop as a result of their participation, and how they are applied. This study will continue over a number of years in order to assess how competency development differs between non-VIP students, VIP students who participate for a short time, and VIP students who participate in the program over a number of years. Gathering this kind of data is part of the ongoing formalization and expansion of VIP4SD into a mainstream academic activity at Strathclyde, which will be aided by our new full-time, dedicated Program Coordinator. The University has fully endorsed this expansion, as embedding ESD more widely in undergraduate curricula will be key to Strathclyde's Vision 2025.

While the VIP4SD program has enjoyed many successes (most recently a UK and Ireland Green Gown Award for Student Engagement), we continue to face challenges when it comes to implementation. The most common barrier is that there is not a pathway in place for students in certain degree programs to take part in VIP4SD, because, for whatever reason, the curriculum lacks flexibility. However, the University have now tasked Vice Deans (Academic) with identifying pathways, so that all students at Strathclyde will eventually have an opportunity to participate. Gaining institutional support at the highest level has been, and will continue to be, essential for the program's development. Another challenge for us is staff recruitment. UK Higher Education is currently grappling with precarity and excessive workloads, and many academics feel that they cannot commit to the time and energy it takes to launch a VIP4SD project, unless this is fully acknowledged in their teaching duties. Our new full-time Program Coordinator will go some way in helping academics set up their new projects and helping to secure investment in the resource needed to grow and sustain the VIP4SD program.

3. Innovations in Faculty Approaches

3.1 Strategies for Junior Faculty

Howard University
Washington, D.C. USA
Contributor: Michaela Amoo

For background information, please see the Howard entry in section 2.1

Innovation: Junior Faculty: Managing a VIP Team Whilst Engaged in the Tenure-Track Process

One overarching concern for all tenure-track faculty is to establish a core of highly trained students to facilitate research. In general, this involves three challenges: successfully planning and managing a multi-year undergraduate research project, overcoming the knowledge gap, and identifying well-suited students for long-term sustainability [13]. The VIP model can be used effectively to create a scaffolding structure to mitigate all three challenges: Scaffolding requires a collaborative interaction between the learner and the expert. Instruction must be tailored to the current level of knowledge and guide the learner beyond that level. As the learner becomes more proficient, the scaffolding is gradually removed, until the learner is independent [14].

Managing a multi-year undergraduate research project: Time is an important consideration for tenure-track faculty. Training, supervision, directing research, mentoring of students, teaching, and managing a multi-year undergraduate research project takes a considerable amount of time. However, as project complexity increases, student motivation may suffer unless students receive adequate support in the form of strong mentorship and appropriate guidance [16]. To mitigate this, implement a VIP model with a two-tier scaffold of supervisors and mentors: In the first tier, the faculty member directly supervises and trains the graduate students, whose primary research, or skillset, is a subset of the VIP research. In the second tier, under faculty supervision, graduate students then mentor, train, and direct undergraduate VIP team activity to complete small but significant tasks that are directly related to their graduate thesis/dissertation, lead bi-weekly group research meetings, and budget for components and supplies. This allows graduate students to participate within the VIP structure as research assistants and undergraduate team mentors and managers. Over time, the graduate students develop valuable skills such as budget management, project management, and people management, freeing the faculty member from the task of micro-managing and training a large group of diverse abilities and skillsets, and allowing them to concentrate on higher-level research, publications, and overall project management.

Overcoming the knowledge gap: In particular, for junior faculty, overcoming the undergraduate knowledge gap is a slow process with a steep learning curve, because the most challenging aspects of the research includes subjects covered only in upper-level courses [13]. A similar problem exists for the graduate students, who must not only master new skills and knowledge necessary to conduct primary research as they advance through their course work, but also develop a portfolio of skills to ensure that they can fully participate, either in the workforce or academia. Students of all levels become demotivated when they perceive they lack the resources and skills to tackle complex problems. To resolve this, use the overarching VIP goal as the research scaffolding: to prevent the research activities becoming fragmented and unmanageable, all graduate and undergraduate activities should fit under this umbrella.

It is essential to establish a foundational scaffold so that all team members have a basic skillset in common: there should be **basic workshops/tutorials that all team members must complete**, such as instrumentation, lab safety, library resources, software, and CAD design tools. Note, these workshops should utilize existing resources, for instance, team-members can be required to spend a certain amount of time learning instrumentation with the lab technicians, interviewing campus librarians, or completing a software/CAD tutorial. Include advanced workshops for graduate students. Knowledge should be broken down into small, easily digestible chunks by holding **monthly workshops**, specifically tailored to provide the theory, methodology, and skill sets required to complete the current research milestones. The monthly workshops act as reinforcement scaffolding to guide activities. The faculty should focus on communicating effective pedagogies: As the graduate students begin to train, direct, and mentor the undergraduates, they will become more proficient in effective pedagogies. Thus, the faculty can gradually transfer management of the undergraduate teams to them.

Identifying well-suited students for long-term sustainability: A multi-year undergraduate research project requires identifying well-suited students if the project is to have long-term sustainability. Long-term sustainability requires a cost-effective model, so that operations are not

adversely affected through lack of funding; to ensure both long-term faculty engagement and enthusiastic student participation, the model must be mutually beneficial to both faculty and students; the model must be sufficiently scalable to serve departments and programs with differing needs; wherever possible, the model must provide a clear undergraduate-to-graduate program segue; Finally, the model must also support and enhance the mission and priorities of the departments, colleges, university, and partners, to ensure continued institutional support. The VIP model focuses on the lead faculty research; the undergraduate team becomes a fundamental component of both funded and unfunded faculty research. The training, mentoring, and activities of the team are then, naturally, key components in the broader impact, education, and workforce development aspects of the broader research goals. Because the majority of students participate for a letter grade, as opposed to monetary compensation, multi-generational VIP teams are extremely cost effective. These multi-faceted benefits facilitate significant long-term faculty engagement, making the VIP model extremely sustainable over long periods of time [7]. Furthermore, the VIP model can be structured to integrate the Korn Ferry *gold standard* outlined in [17] to developing talent pipelines by:

- **Ensuring the Alignment of talent with academic training and research goals**: A key factor in establishing a talent pipeline is continuous current and future needs assessment [17]. Participation in VIP teams identifies students with existing potential, identify the gaps in training, knowledge, and skill sets; thus, allowing the faculty mentor to develop a plan to close those gaps via coursework, internships, and other available resources.
- **Talent pool assessment:** Both summer internships and VIP activities can be used to monitor student's progress via a debrief with direct supervisors. In this way, skill sets can be assessed relative to a target profile of students at the same level, and key indicators of academic, research, and leadership potential can be identified.
- **Talent pipeline depth:** Via VIP, participating undergraduates can be assessed from freshman through senior years. At the commencement of their junior year, select undergraduates can be prepared for graduate programs.
- **Cross-training:** The academic diversity in VIP teams exposes students to a variety of disciplines. Thus, well-placed internships and elective-course choices can train the students in adjacent or complimentary fields, improving and enhancing the capacity, skill, investigative talent, and encouraging cross-field collaborations.
- **Mentorship:** VIP team members receive formal mentoring and coaching both from faculty and graduate students and also peer-mentorship from within the team. In particular, all interactions are utilized as an opportunity to facilitate the personal development of the student. Fostering the student's belief in achievable career opportunities facilitates student retention.
- **Collaborative research:** All VIP team members should be exposed to collaborative efforts of the lead faculty with other departments and institutions. In addition, the team should be encouraged, where fitting, to collaborate with other VIP teams and industry.
- **Think succession, think risk mitigation:** The final gold standard in [17] stresses the importance of recognizing and nurturing existing talent. In 2014 Hanover case studies of Best Practices for Recruiting Graduate Students, the University of Texas at Austin (UT Austin) focused the majority of its graduate recruiting efforts within Texas Universities, including 6 from the University of Texas system. The University of Georgia (UGA) stated that targeting its current undergraduates remained its most successful strategy.

Via the VIP model, senior students already have the training and subject knowledge to meaningfully contribute to the research. Not only does the VIP model provide a mechanism to determine participants' aptitude and enthusiasm for graduate research, the projects are long-lasting and structured so that the graduating seniors can identify potential areas of research for their Master's/PhD, and segue into the graduate program to continue their research and training.

Since an *Assistantship award with a work obligation attached* is universally recognized as a best practice for graduate recruitment [18], attracting and retaining graduate students is costly and inherently risky, since failure to perform or attrition is a prospective cost. Therefore, the value of targeting current undergraduates for the graduate program, via the VIP program cannot be understated. The aptitude and enthusiasm of the student for the work is already known; the students have already established a relationship with the faculty advisor and are familiar with the ongoing research, thus the recruits are less likely to suffer attrition.

In conclusion, the VIP model can provide an ideal structure for junior faculty to establish, build, and sustain their long-term research projects: If utilized effectively, the VIP model is a cost-effective mechanism that can facilitate successfully planning and managing a multi-year undergraduate research project, overcoming the knowledge gap, and identifying well-suited students for a sustainable talent pipeline.

3.2 Early Recruiting for Graduate School

Texas A&M University
College Station, TX USA
Contributor: Magda Lagoudas

Background

Program Operations: Housed in Engineering Student and Academic Affairs
Funded by the College of Engineering.
Stage of Establishment: Active program working toward institutionalization

The AggiE-Challenge program was established in 2012 in the College of Engineering to provide experiential learning opportunities to students by engaging them in multidisciplinary teams pursuing undergraduate research associated with grand engineering challenges. The program was initiated at the Engineering Student Academic Success office that is overseen by the Senior Dean for Academic Affairs who has the authority to approve programs and courses across the College of Engineering. The program was funded for several years through Activity 1 funds, an initiative led by the Provost's office to promote experiential learning across campus. The program was launched at the college level and invites interested faculty to submit proposals outlining the undergraduate team research project and preferred majors. The proposals are reviewed by a faculty committee and select proposals are recommended for funding. The funding supports a graduate student who provides mentoring support to the team. Program participants enroll in an ENGR 491 section for one or more credit hours and are able to participate in the project for multiple semesters. Since 2012, the program has attracted more than 2,500 registrations and participants represent a very diverse cohort with 25% females, 17% ethnic minorities, and 14%

first generation students. Participants include students from all classifications (53% seniors, 26% juniors, 15% sophomores, and 6% freshman). Furthermore, while the program's main goal is to enable engineering students to engage in research of interest to them (within or outside their major), non-engineering students have participated in the program. Usually these are students involved with non-engineering faculty collaborating with engineering.

The program projects are showcased through two major college events targeting industry and agencies and provide visibility to faculty research.The Engineering Project Showcase takes place every spring and brings to campus 150+ judges from industry to judge projects representing the work of more than 1,000 students and include AggiE-Challenge. In the fall, the Virtual Project Showcase engages judges from industry remotely and it allows us to connect with industries across the country and raise awareness about the work of our students and faculty research.

Innovation: Early Recruiting for Graduate School

AggiE_Challenge was launched with focus to provide engineering students an opportunity to work on a project of interest to them within their major or outside it and gain valuable experiences in applying their engineering skills, acquiring new skills of interest to them, and learning how to become an effective member on a multidisciplinary team. Therefore, the benefits to students are clear and that is supported by the number of students enrolling into the program even when, for the majority of them, participating in this class will not be counted towards degree requirements for their major. On the faculty side, while the program provides incentives to faculty by financially supporting a graduate student mentoring them, now that the program is established we have several faculty who continue to participate without financial gains but because they see the benefits. The program provides faculty an instrument to promote their research across all engineering students and recruit students outside their own department who bring needed skills to support their research such as faculty in Civil Engineering working on digital cities and requiring access to students with substantial programming skills. Furthermore, because the program promotional activities reach all engineering students including close to 4,000 freshmen, it enables faculty to recruit outstanding freshmen and sophomores and engage them in research thus raising awareness about graduate school. While freshman and sophomores represent 21% of program participants, in reality they are a much higher percentage since a significant number of freshmen enter college with many AP credit hours and for that reason are classified as “sophomores”. We expect about a third of program participants are lower classification (freshmen/ sophomores) which represents a great recruiting tool for graduate school. In 2018 a research study was completed with focus on investigating the impact of the program on recruitment for graduate school. Study outcomes indicate that about 25% of AggiE_Challenge participants who completed their BS in engineering by 2018 enrolled in graduate school at Texas A&M University. This does not include students who chose to pursue graduate school elsewhere and represents a significant pipeline of domestic students to graduate school.

3.3 Crossing Disciplinary Boundaries

Virginia Commonwealth University
Richmond, Virginia
Contributor: Bennett C. Ward

Background

Program Operations: Housed in the College of Engineering
Stage of Establishment: Institutionalized, 19 active VIP teams

The VIP@VCU program was established in 2014 as part of the founding VIP Consortium, supported by the initial grant from The Helmsley Charitable Trust to the eleven-university VIP Consortium. The driving forces behind establishment at VCU were Prof. Franklin Bost, Associate Dean for Innovation and Outreach, who was the PI, and Dr. Robert Klenke, the VIP Director. The first team was under Dr. Klenke in Electrical Engineering for his unmanned aerial vehicle research. Bennet Ward formed the second team in 2015 to focus on unmet needs in patient care. VCU currently has nineteen (19) VIP teams spanning all five (5) of our engineering disciplines.

Based on the successful VIP@VCU program start-up, the College of Engineering was about obtain a $1 million endowment from the Altria Corporation for experiential learning initiatives. This endowment now provides approximately $40,000 annually for support of VIP activities. The Dean of Engineering, Dr. Barbara Boyan, has provided unflagging support. Support has slowly grown primarily via grass roots, word of mouth in other academic departments; in particular, schools of medicine, sciences, business, and arts. Additionally, the VCU da Vinci Center for Innovation's experiential entrepreneurship program has provided funding from VCU Health for several medical VIP projects. Support for the program has grown as technological developments have become more and more successful. This has led to broad-based funding in a number of technology areas. VCU now counts the VIP@VCU program as a key experiential learning experience for students from all disciplines.

Innovation: Faculty Crossing Disciplinary Boundaries

An excellent example of "Breaking Down the Silos" has come from Dr. Ben Ward, who is the founder and PI for the "Engineering Critical Patient Care" (ECPC) VIP project, established in 2015. The ECPC team objective is to apply engineering solutions to operations and unmet needs for medical device solutions. ECPC was initiated during a series of visits to the O.R. suite at the VCU Medical Center which was arranged by a colleague in anesthesiology. The team's initial focus was to address O.R. equipment, organization, and routine of anesthesiologist and nurse anesthetists to identify potential improvements. Additional organizational effort included obtaining buy-in from surgery, O.R. staff, and hospital administration. Including these stakeholders early in the process minimizes false starts and projects progress faster when clinical and surgical practitioners are actively included as true team members.

The Engineering Patient Care VIP team is highly multidisciplinary. While our students are mostly undergraduate BME majors, we also have computer scientists, mechanical engineers,

chemical engineers, plus biology and chemistry majors participating. Also, active participation by medical and dental students, a surgery resident, and art students bring complimentary input to need investigation and solution development. Cultivating advisors from health science departments (including surgery, anesthesia, dentistry, and pediatrics) further engages the student participants in understanding the clinical need and focus open an appropriate solution.

We have measured success with two major metrics: (1) the number of device projects launched as entrepreneurial ventures with IP protection and (2) the number of operations improvements developed. On the entrepreneurship side, our VIP team developed a homing device to guide an injection needle to the very small epidural space found in the spinal column. Data have shown a significant drop in administration failures when this device is used to administer spinal blocking anesthesia. Upon graduation, the core student team formed a business called Durasafe LLC to explore turning the device into a business. Non-provisional patent applications were also filed.

There have been other inventions developed by multidisciplinary Engineering/Medical Science teams. This includes a) a robust methodology for relieving tension pneumothorax (collapsed lung), b) safety devices to prevent embedded guidewires in Central Line procedures, and c) data analysis methodology for patient monitoring in the Neonatal Intensive Care unit.

In operational improvements, the team has been called upon to resolve engineering needs in day-to-day operations support for the medical center. The team resolved: a) a vexing problem involving surgical instrument trays breaking their sterility, b) solution to prevent un-commanded O.R. table movements and c) improve safety of moving a patient from O.R. table to transport stretcher. Also, another VIP team worked with the Bone Marrow Transplant Service to address procedure workflow, service staffing, and patient education. This project included students from biomedical engineering, medicine, data science, and business.

A key point with the success of our VIP team so far has been the ability to build its reputation for being results-oriented. In keeping with VCU's "Make it Real" campaign, we have endeavored to apply experiential learning in an environment purposely designed to mimic the approaches for success used in industry.

The success of the engineering-medical VIP@VCU projects lead the way for formation of the "BEAM Consortium", which includes faculty from Business, Engineering, Arts and Medicine. Over a two-year period, faculty from the BEAM units assembled student teams to address broad operational or product needs presented by medical-clinical departments. Over ten (10) projects were addressed, presented to the medical center administration, and lead to the formation and multi-million-dollar funding of the "VCU Health Innovation Consortium". The Consortium has now expanded to include venture capital funding to advance development of medical solutions coming from VCU and VCU Health.

Conclusion

To achieve institutionalization and lasting change, multidisciplinary programs are challenged to break down the silos – barriers around departments and administrative units that inhibit substantive partnerships. This paper presents silo-crossing innovations from ten

multidisciplinary VIP Programs from a variety of institutions in four countries. At the institutional level, Boise State University houses their VIP Program in a central campus unit, with each college contributing funds to the VIP Program based on their VIP enrollments. At Georgia Tech, twenty-two degree programs have adopted policies on how VIP credits count toward degree requirements, with policy-adoption driven by VIP instructors in their home departments. The University of Michigan houses multiple multidisciplinary programs together, allowing them to leverage resources. At National Dong Hwa University, faculty used the VIP model to establish multidisciplinary faculty communities. This provided a proof of concept for the VIP model and led to a large-scale institution-funded VIP program. The NYU program was established during campus-wide curricular change, with the program housed at the college level. At the same time, student demand led to rapid program expansion and summer internships.

Contributors also provided examples of innovations at the program level. Howard University has worked to maintain a program-wide balance in instructor home departments, student majors, and student academic rank. The University of Pretoria provides personal coaching at the program level for students and instructors. The University of Strathclyde has organized their VIP Program around the UN Sustainable development goals, for which they received the UK/Ireland Green Gown Award for Student Engagement.

Also key to VIP Program success is innovation at the faculty-level. Virginia Commonwealth profiled innovative boundary-crossing in a VIP team that applies engineering solutions to medical device operations and development. The team enrolls students from multiple majors, and while based in engineering, involves advisors from health science departments. Howard University suggests strategies for junior faculty, who can use VIP to build their research programs and cultivate graduate students. Along the same lines, the VIP Program at Texas A&M found that 25% of VIP students who graduated from Texas A&M continued on to graduate school there, a compelling statistic.

As the VIP Consortium partners have found, although one size does not fit all, every innovation can be of use to another institution. The sharing of innovations supports multidisciplinary efforts across the consortium in classrooms, among faculty, within and between departments, and across administrations. This paper presents a range of innovations at the institution, program and faculty-levels that can inform others seeking to institutionalize VIP Programs and multidisciplinary initiatives.

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Appendix

Profiled VIP Programs: Student majors and instructor home departments.

Institution Name	Student Majors Served	Instructor Home Departments
Boise State University	College of Arts & Science, 61 College of Business & Economic, 9 College of Education, 1 College of Engineering, 24 College of Health Sciences, 18 College of Innovation & Design, 4 Graduate College, 1 School of Public Service, 7	Anthropology, 1 Art, 1 Biology, 6 Chemistry, 1 Community and Environmental Health, 2 Computer Science, 3 Electrical Engineering , 2 English, 4 History, 1 Human-Environment Systems, 3 Library Science, 1 Literacy, Language, & Culture, 1 Material Science and Engineering, 2 Mathematics, 2 Mechanical Engineering, 2 Modern Languages, 2
Georgia Institute of Technology	College of Engineering, 15 majors College of Computing, 2 majors College of Sciences, 9 majors College of Liberal Arts, 11 majors College of Design, 6 majors College of Business, 1 major Joint Programs, 8 Special/Non-Degree (1%)	College of Engineering: 8 departments College of Sciences: 7 departments College of Liberal Arts: 5 departments College of Computing: 5 departments College of Design, 3 departments 9 non-academic units
The University of Michigan	Every college at U-M, but about 70% are engineering majors	From most every college in the university
New York University Tandon School of Engineering	Computer Science Mechanical Engineering Chemical Engineering Civil Engineering Electrical Engineering History English Technology Management Integrated Design and Media Education Medical School	Computer Science Mechanical Engineering Chemical Engineering Civil Engineering Electrical Engineering History English Technology Management Integrated Design and Media Education Medical School
National Dong Hwa University	Most students: - Electrical Engineering - Computer Science and Information Engineering Additional Majors: - Department of Physics - Department of Life Science and Biotechnology	Most instructors: - Electrical Engineering - Computer Science and Information Engineering; Also involved: - College of Education - College of Environmental Studies

	Outside Engineering and Science (enroll as independent study): - College of Education - College of Environmental Studies - College of Art and Design	- College of Art and Design
Howard University	Electrical Engineering Computer Engineering Computer Science Mechanical Engineering Civil Engineering Chemical Engineering	Electrical Engineering Computer Engineering Computer Science Mechanical Engineering Civil Engineering
University of Pretoria	Primarily Engineering disciplines: - Industrial and Systems - Mechanical - Electrical - Electronic - Computer - Civil - Chemical - Metallurgical - (only Mining has no traction yet) Scattering from: - Computer Science - Town and Regional Planning.	Industrial and Systems Engineering Mechanical Engineering Chemical Engineering Electronic Engineering
University of Strathclyde	Bearing in mind that the Scottish system is different, of our 12 multidisciplinary projects: - 7 are open to Engineering students (11 degrees have VIP pathways) - 5 are open to Science students (2 degrees have pathways) - 4 are open to Humanities (20 degrees have pathways) - 2 are open to Business students (14 degrees have a pathway)	Electronic and Electrical Engineering Electrical and Mechanical Engineering Computer and Information Science Pharmacy and Biomedical Sciences Government and Public Policy English Speech and Language Therapy Education Business
Texas A&M University	Engineering students, all majors	College of Engineering, 7 Departments
Virginia Commonwealth University	Students from all five engineering majors: - Chemical and Life Science - Biomedical - Computer Science - Electrical and Computer - Mechanical and Nuclear Engineering Also have students from the Schools of: - Arts - Humanities and Sciences - Medicine - Dentistry - Business	Instructors generally come from the College of Engineering