6-24-2017

Vertically Integrated Projects (VIP) Programs: Multidisciplinary Projects with Homes in Any Discipline

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Prof. Behnaam Aazhang, Rice University

Behnaam Aazhang received his B.S. (with highest honors), M.S., and Ph.D. degrees in Electrical and Computer Engineering from University of Illinois at Urbana-Champaign in 1981, 1983, and 1986, respectively.

From 1981 to 1985, he was a Research Assistant in the Coordinated Science Laboratory, University of Illinois. In August 1985, he joined the faculty of Rice University, Houston, Texas, where he is now the J.S. Abercrombie Professor in the Department of Electrical and Computer Engineering Professor and Director of Center on Neuro-Engineering, a multi-university research center in Houston, Texas. In addition, he holds an Academy of Finland Distinguished Visiting Professorship appointment (FiDiPro) at the Center for Wireless Communication (CWC) in the University of Oulu, Oulu, Finland. He has served as the founding director of Rice's Center for Multimedia Communications from 1998 till 2006. He has been a Visiting Professor at IBM Federal Systems Company, Houston, Texas, the Laboratory for Communication Technology at Swiss Federal Institute of Technology (ETH), Zurich, Switzerland, the U.S. Air Force Phillips Laboratory, Albuquerque, New Mexico, and at Nokia Mobile Phones in Irving, Texas.

His research interests are signal processing, information theory, and their applications to neuroengineering and wireless communication and networks. Particular focus is on the interplay of communication systems and networks; including network coding, user cooperation, spectrum sharing, opportunistic access, and scheduling with different delay constraints as well as millimeter wave communications. In neuro-engineering, his interests are on modeling neuronal circuits connectivity and the impact of learning on connectivity, on real-time closed-loop stabilization of neuronal systems to mitigate disorders such as epilepsy, Parkinson, depression, and obesity, on developing an understanding of cortical representation and fine-grained connectivity in the human language system, and on building microelectronics with large data analysis techniques to develop a fine-grained recording and modulation system to remediate language disorders.

Dr. Aazhang is a Fellow of IEEE and AAAS, a distinguished lecturer of IEEE Communication Society, a recipient of 2004 IEEE Communication Society's Stephen O. Rice best paper award for a paper with A. Sendonaris and E. Erkip. In addition, Sendonaris, Erkip, and Aazhang received IEEE Communication Society's 2013 Advances in Communication Award for the same paper. He received the 2016 IEEE ComSoc CTTC Outstanding Service Award "for innovative leadership that elevated the success of the Communication Theory Workshop". In 2017, he received Honorary Doctorate degree from the University of Oulu, Finland (the highest honor that the university can bestow).

He has been listed in the Thomson-ISI Highly Cited Researchers and has been keynote and plenary speaker of several conferences. Dr. Aazhang is a recipient of the Alcoa Foundation Award 1993, the NSF Engineering Initiation Award 1987-1989, and the IBM Graduate Fellowship 1984-1985, and is a member of Tau Beta Pi and Eta Kappa Nu.

He has served on Houston Mayor's Commission on Cellular Towers 1998-2004, as the Editor for IEEE Transactions on Molecular, Biological, and Multi-Scale Communications since 2015 and for Spread Spectrum Networks of IEEE Transactions on Communications 1993-1998, the Treasurer of IEEE Information Theory Society 1995-1998, the Secretary of the Information Theory Society 1990-1993, the Publications Chairman of the 1993 IEEE International Symposium on Information Theory, San Antonio, Texas, the co-chair of the Technical Program Committee of 2001 Multi-Dimensional and Mobile Communication (MDMC) Conference in Pori, Finland, the chair of the Technical Program Committee for 2005 Asilomar Conference, Monterey, CA, the co-chair of the Technical Program Committee of International Workshop on Convergent Technologies (IWCT), Oulu, Finland, June 6-10, 2005, guest editor for IEEE Journal on Selected Areas of Communication special issue on relay and cooperative communication in

2006 and for KICS Journal of Communication and Network (JCN) special issue on cooperative communication in 2007, the general chair of the 2006 Communication Theory Workshop, Dorado, Puerto Rico, the co-technical program chair of 2008 WPMC in Lapland, Finland, and the co-general chair of 2010 International Symposium on Information Theory (ISIT), in Austin, Texas.

Dr. Randal T. Abler, Georgia Institute of Technology
Dr. Jan P. Allebach, Purdue University, West Lafayette (College of Engineering)

Jan P. Allebach is Hewlett-Packard Distinguished Professor of Electrical and Computer Engineering at Purdue University. Allebach is a Fellow of the IEEE, the National Academy of Inventors, the Society for Imaging Science and Technology (IS&T), and SPIE. He was named Electronic Imaging Scientist of the Year by IS&T and SPIE, and was named Honorary Member of IS&T, the highest award that IS&T bestows. He has received the IEEE Daniel E. Noble Award, and is a member of the National Academy of Engineering. He currently serves as an IEEE Signal Processing Society Distinguished Lecturer (2016-2017).

Prof. L. Franklin Bost, Virginia Commonwealth University

L. Franklin Bost is an experienced executive in the medical device industry and in academic instruction as a professor in biomedical engineering. His industry experience includes medical product development, marketing and sales, international business development, strategic and business planning, and senior management with P&L responsibility.

Currently, Bost is the Executive Associate Dean in the School of Engineering at Virginia Commonwealth University. He oversees development of innovation and outreach programs along with the School's marketing and communications, human resources, information technology, and student career service activities. Bost is also Director of the VCU Institute of Engineering and Medicine located in the Virginia Biotechnology Park. In addition, he is currently CEO of SpherIngenics Inc. an early stage company focused on enhancing stem cell therapies for therapeutic and reconstructive procedures. Previously in academia, Bost was at the Georgia Institute of Technology where he developed the Master of Biomedical Innovation and Development (BioID) Program. For six years, he was also director of the biomedical engineering capstone design courses and sophomore introductory course for medical engineering design. During this time, over 200 BME capstone teams worked on projects with clinicians, surgeons, non-profit medical organizations, and medical industry companies to create unique solutions for improved patient care.

Prior to academia, he was Chief Operating Officer of CeloNova Bioscience, a start-up company developing products for interventional radiology. Earlier as president of Porex Surgical Inc., he led the rapid USA and international growth of this reconstructive biomaterial products company. Direct surgeon contact included specialties in craniofacial, plastic-reconstructive, oculoplastic, otolaryngology, oral-maxillofacial and neurosurgery. Bost has also served in senior management positions with Porex Corporation, a medical, consumer and industrial products company, with Becton Dickinson & Co. in the development and commercialization of hemodialysis products, and with American Hospital Supply in new products for nursing and patient services.

Prof. Joseph R. Cavallaro, Rice University

Joseph R. Cavallaro received the B.S. degree from the University of Pennsylvania, Philadelphia, Pa, in 1981, the M.S. degree from Princeton University, Princeton, NJ, in 1982, and the Ph.D. degree from Cornell University, Ithaca, NY, in 1988, all in electrical engineering. From 1981 to 1983, he was with AT&T Bell Laboratories, Holmdel, NJ. In 1988, he joined the faculty of Rice University, Houston, TX, where he is currently a Professor of Electrical and Computer Engineering and Director of the Center for Multimedia Communication. His research interests include computer arithmetic, and DSP, GPU, FPGA, and VLSI architectures for applications in wireless communications. During the 1996–1997 academic year, he served at the National Science Foundation as Director of the Prototyping Tools and Methodology Program. He was a Nokia Foundation Fellow and a Visiting Professor at the University of Oulu, Finland in 2005 and

continues his affiliation there as an Adjunct Professor. He is an Associate Editor of the IEEE Transactions on Signal Processing, the IEEE Signal Processing Letters, and the Journal of Signal Processing Systems. He is Chair-Elect of the IEEE CASS TC on Circuits and Systems for Communications and a Fellow of the IEEE.

Prof. Edwin K. P. Chong Ph.D., Colorado State University

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Prof. Edward J. Coyle, Georgia Institute of Technology

Edward J. Coyle is the John B. Peatman Distinguished Professor of Electrical and Computer Engineering, directs the Arbutus Center for the Integration of Research and Education, and is the founder of the Vertically-Integrated Projects (VIP) Program. He is a Georgia Research Alliance Eminent Scholar and was a co-recipient of the National Academy of Engineering's 2005 Bernard M. Gordon Award for Innovation in Engineering and Technology Education. Dr. Coyle is a Fellow of the IEEE and his research interests include engineering education, wireless networks, and digital signal processing.

Ms. Jocelyn B. S. Cullers, Boise State University

Jocelyn B. S. Cullers is a Data Analyst at the Institute for STEM & Diversity Initiatives at Boise State University.

Dr. Sonya M. Dennis, Morehouse College
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Dr. Yingfei Dong received his B.S. degree and M.S. degree in computer science at Harbin Institute of Technology, P.R. China, in 1989 and 1992, his Doctor degree in engineering at Tsinghua University in 1996, and his Ph.D. degree in computer and information science at the University of Minnesota in 2003. He is an Associated Professor at the Department of Electrical Engineering at the University of Hawaii at Manoa, and an IEEE Senior member. His research mostly focuses on computer and network security and privacy, especially in security and privacy issues in network design and protocols, cloud computing, smart grid, unmanned aerial vehicles, real-time networks, distributed systems and applications. He has published about 90 refereed research papers in various international journals and conferences. He has also served as associated editors for three international journals, and as organizer and program committee member for many IEEE/ACM/IFIP conferences.

Prof. Prasad N. Enjeti, Texas A&M University

Prasad Enjeti (enjeti@tamu.edu) is a member of Texas A&M University faculty since 1988 and is widely acknowledged to be a distinguished teacher, scholar and researcher. He currently holds the TI-Professorship in Analog Engineering and Associate Dean for Academic Affairs in the College of Engineering. His research emphasis on industry-based issues, solved within an academic context, has attracted significant external funding. Up until now, he has graduated 31 PhD students and 11 of them hold academic positions in leading Universities in the world. He along with his students have received numerous best paper awards from the IEEE Industry Applications and Power Electronics Society. His primary research interests are in advancing power electronic converter designs to address complex power management issues such as: active harmonic filtering, adjustable speed motor drives, wind and solar energy systems and designing high temperature power conversion systems with wide band-gap semiconductor devices. In 2000 he was named an IEEE Fellow and in May 2004 received a distinguished achievement award for teaching from Texas A&M University. He is the recipient of IEEE PELS R. David Middlebrook Technical Achievement Award from the IEEE Power Electronics Society. 2012.

Dr. Afroditi V. Filippas, Virginia Commonwealth University

Dr. Filippas received her B.S. in Electrical Engineering from the University of Patras, Greece. After earning her M. S. and Ph. D. from the University of Texas at Austin, she completed post-doctoral research

with the Institute of Accelerating Systems and Applications in Athens, Greece. Post-academically, she worked for Ansoft Corporation as a research scientist spearheading the development of the next generation code for Ansoft DesignerTM. Dr. Filippas joined Virginia Commonwealth University as an Assistant Professor in the School of Engineering in 2004. She went on to achieve the position of Associate Professor and Associate Chair of Electrical and Computer Engineering in 2008. In 2010, Dr. Filippas agreed to serve as interim associate dean of undergraduate studies in the School of Engineering. Dr. Filippas was appointed to the position of associate dean of Undergraduate Studies in 2015, and was promoted to Professor in August, 2016. In this role, she is responsible for all aspects of the undergraduate program. She provides vision and leadership in achieving the School's objectives for substantial growth in the size and quality of its undergraduate enrollment while maintaining its commitment to excellence in undergraduate engineering education. Focus areas include contemporary teaching and learning technologies, capstone, VIP, special degree programs with partnering academic institutions, and K-12 outreach. Dr. Filippas is especially proud of her collaboration with NSBE at VCU, an organization that embodies excellence in academics as well as community service, leadership and diversity. In addition, Dr. Filippas was instrumental in establishing oSTEM on the campus as well as reaching out to other underrepresented minority groups to further the university's commitment to student success and inclusive excellence.

Dr. Jeffrey E. Froyd, Texas A&M University

Dr. Jeffrey E. Froyd is a TEES Research Professor in the Office of Engineering Academic and Student Affairs at Texas A&M University, College Station. He received the B.S. degree in mathematics from Rose-Hulman Institute of Technology and the M.S. and Ph.D. degrees in electrical engineering from the University of Minnesota, Minneapolis. He was an Assistant Professor, Associate Professor, and Professor of Electrical and Computer Engineering at Rose-Hulman Institute of Technology. At Rose-Hulman, he co-created the Integrated, First-Year Curriculum in Science, Engineering and Mathematics, which was recognized in 1997 with a Hesburgh Award Certificate of Excellence. He served as Project Director a National Science Foundation (NSF) Engineering Education Coalition in which six institutions systematically renewed, assessed, and institutionalized innovative undergraduate engineering curricula. He has authored over 70 papers and offered over 30 workshops on faculty development, curricular change processes, curriculum redesign, and assessment. He has served as a program co-chair for three Frontiers in Education Conferences and the general chair for the 2009 conference. Prof. Froyd is a Fellow of the IEEE, a Fellow of the American Society for Engineering Education (ASEE), an ABET Program Evaluator, the Editor-in-Chief for the IEEE Transactions on Education, a Senior Associate Editor for the Journal of Engineering Education, and an Associate Editor for the International Journal of STEM Education.

Dr. David Garmire, University of Hawai'i at Mnoa

David Garmire received B.S. degrees at Carnegie Mellon University, and the Ph.D. at UC Berkeley in 2007 with a certificate in Management of Technology from the Haas School of Business. He won the 2008 Ross N Tucker Award for advancing semiconductor technology and the 2007 Sevin Rosen Funds Award for Innovation. He is currently an Associate Professor in the department of Electrical Engineering at the University of Hawaii at Manoa, where he develops microsensors, microactuators, and technologies for rapid prototyping, visualization, renewable energies and sustainability. He received the 2016 UH Regents Award for Excellence in Teaching and 2014 Frances Davis Award for Excellence in Undergraduate Teaching.

Dr. Jay George
Prof. Brian E. Gilchrist, University of Michigan

Faculty Co-Director, Multidisciplinary Design Programs (MDP), College of Engineering; Director, XTRM Labs/Space Physics Research Laboratory, College of Engineering; Professor, Electrical Engineering and Computer Science Dept; Professor, Atmospheric, Oceanic, and Space Sciences Dept; University of Michigan –

MDP seeks to deepen student disciplinary knowledge and help develop systems-thinking through enabling significant, real-world, experiential multidisciplinary design opportunities.

Gail S. Hohner, University of Michigan

Gail Hohner is the Managing Director of the Multidisciplinary Design Program in the College of Engineering at the University of Michigan Ann Arbor, where she develops multidisciplinary engaged learning experiences in the engineering design process. She teaches the seminar in Leadership/Mentorship in Multidisciplinary Engineering Design and her research focuses on the improvements in the pedagogy of engineering design process instruction. She was the 2016 program chair of the DEED division of ASEE. She has a background of 17 years of industrial experience and holds B.S.E in Chemical Engineering and a M.S. in Food Science/Chemical Engineering from Cornell.

Prof. William L. Hughes, Boise State University

Will Hughes is a founding faculty member and Associate Professor of the Micron School of Materials Science & Engineering at Boise State University. He also serves as the co-founder and Associate Dean of the College of Innovation + Design (CID), as well as the Head of the Vertically Integrated Projects (VIP) program at Boise State. He received his B.S. and Ph.D. in Materials Science & Engineering from Virginia Tech and Georgia Tech. His technical expertise is in the area of molecular self-assembly where his research team programs DNA to perform chemical, physical, and biological work for a host of medical and semiconductor applications that include molecular computing for diagnostics, nucleic acid memory for archival storage, and lithography for sub-10 nm fabrication. Prior to his current appointments, Will served as a National Academy of Engineering (NAE), Center for the Advancement of Scholarship on Engineering Education (CASEE) Postdoctoral Fellow, as well as an Assistant Professor of Materials Engineering at the California Polytechnic State University, San Luis Obispo. While at Cal Poly, Will incorporated multiple intelligence theory, service-learning, and inquiry into the Materials Engineering Department's Triple bottom line Awareness in Design (TriAD) curricular approach. In conjunction with his Ph.D., Will was also sponsored by the National Science Foundation to partner with and teach at TECH High, a metro-Atlanta charter high school. While at Tech High, Will catalyzed organizational changes that promoted a more student-centered organization. His experience provided a comprehensive understanding and appreciation for the complexity/severity of problems within urban education, as well as the unique opportunity to sequentially observe, assess, and address fractures within the said learning environment. For his contributions to teaching, research, and service, Will is the recipient of multiple awards such as: (1) Boise State's Professor of the Year Award in 2015, (2) Boise State's Golden Apple Award in 2011, (3) National Effective Teaching Institute Fellow in 2011, (4) ASEE New Engineering Educators Award in 2011, (5) W.M. Keck Foundation Award in 2011, (6) National Institutes of Health Career Award in 2011, and (7) Cal Poly President's Community Service Award in 2008.

Dr. Amos Johnson, Morehouse College

Amos Johnson is a graduate of Morehouse College and Georgia Institute of Technology, where he received dual degrees in general science (Morehouse) and electrical engineering (Georgia Institute of Technology).Later, he earned a M.S. degree in electrical and computer engineering from Georgia Institute of Technology, and finally a Ph.D. in electrical engineering from Georgia Institute of Technology.

Dr. Charles 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 1989, and worked as a researcher at Texas A&M University before he took an assistant professor position 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 intelligent systems application. Dr. Kim is active in practicing experiential learning in engineering education with personal instrumentation such as mobile studio.

Prof. Hale Kim, INHA University

Dr. Kim received BS degree in Control & Instrumentation Engineering from Seoul National University, Korea, in 1983, and MS and PhD degrees in Electrical and Computer Engineering from Purdue University at West Lafayette, IN, US, in 1985 and 1990, respectively. He is currently a professor of Department of Information & Communication Engineering at Inha University, Incheon, Korea. In 2016, he was awarded Achievement in Engineering Education from Ministry of Education, Korea as recognition of his educational innovation activities as the head of Innovation Center for Engineering Education and the director of Academy of Convergence Education at Inha University.

Dr. Robert H. Klenke, Virginia Commonwealth University

Dr. Robert Klenke is a Professor of Electrical and Computer Engineering at the Virginia Commonwealth University in Richmond, VA. He is also the Director of the Vertically Integrated Projects (VIP) program at VCU.

Ms. Magdalini Z. Lagoudas, Texas A&M University

Magda Lagoudas, Executive Director for Industry and Nonprofit Partnerships, Dwight Look College of Engineering, Texas A&M University. Mrs. Lagoudas holds a BS and MS in Mechanical Engineering. She worked for the State of New York and industry before joining Texas A&M University in 1993. Since then, she developed and taught courses in the Departments of Mechanical Engineering and Engineering Technology. In 2001, she joined the Spacecraft Technology Center as an Assistant Director where she was responsible for the structural and thermal analysis of payloads. She served as Director of the Space Engineering Institute and in 2010 she accepted a position with the Academic Affairs office of the Dwight Look College of Engineering where she oversaw outreach, recruiting, retention and enrichment programs for the college. Since 2013, she serves as the Executive Director for Industry and Nonprofit Partnerships with responsibilities to increase opportunities for undergraduates engineering students to engage in experiential learning multidisciplinary team projects. These include promoting capstone design projects sponsored by industry, developing the teaching the Engineering Projects in Community Service course, and developing curricular and co-curricular programs at the Engineering Innovation Center which promote innovation and entrepreneurship among engineering students and in collaborations with other colleges on campus and partnering with other institutions across the country.

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. Yung-Hsiang Lu, Purdue University, West Lafayette (College of Engineering)

Yung-Hsiang Lu is an associate professor in the School of Electrical and Computer Engineering and (by courtesy) the Department of Computer Science of Purdue University. He is an ACM distinguished scientist and ACM distinguished speaker. He is a member in the organizing committee of the IEEE Rebooting Computing Initiative. He is the lead organizer of the first Low-Power Image Recognition Challenge in 2015, the chair (2014-2016) of the Multimedia Communication Systems Interest Group in IEEE Multimedia Communications Technical Committee. He obtained the Ph.D. from the Department of Electrical Engineering at Stanford University.

Mr. Kevin James Lybarger, University of Washington
Prof. Stephen Marshall P.E., University of Strathclyde

Stephen Marshall obtained his BSc in Electrical and Electronic Engineering from University of Nottingham, England and his PhD in Image Processing from University of Strathclyde in Glasgow, Scotland. He has previously worked for Plessey Office Systems in Nottingham and University of West of Scotland in Paisley. He is currently a Professor in Department of Electronic and Electrical Engineering at University of Strathclyde and Director of the Centre for excellence in Signal and Image Processing.

He is the VIP Champion at the University of Strathclyde with responsibilities for introducing the VIP Program and increasing undergraduate engagement with reseach and industry.

Dr. Subra Muralidharan, University of California, Davis

Subra Muralidharan obtained his B.S. and M.S. in chemistry from Loyola College, Chennai, India and his Ph.D. in chemistry form the University of Notre Dame. He has was a postdoctoral fellow at the Radiation Laboratory, University of Notre Dame and at the Ames Laboratory, Iowa State University. He has held faculty appointments in the Departments of Chemistry at the University of Arizona and Western Michigan University, and in the School of Molecular Biosciences at Washington State University. He is currently a visiting professor in the Department of Molecular and Cellular Biology at the University of California Davis and co-director of the Vertically Integrated Projects (VIP) program at UC Davis. His current research is the study of efficacies and mechanisms of nanoscale drugs for the treatment of glioblasoma.

Dr. Aaron T. Ohta, University of Hawai'i at Mnoa

Dr. Aaron Ohta received a B.S. from the University of Hawaii at Manoa in 2003, an M.S. from the University of California, Los Angeles in 2004, and a Ph.D. from the University of California, Berkeley in 2008, all in the field of electrical engineering. He is currently an Associate Professor of Electrical Engineering at the University of Hawaii at Manoa, where he has been since 2009. Dr. Ohta's research interests include microelectromechanical systems (MEMS) and microfluidics. He has published two book chapters and over 100 peer-reviewed journal and conference papers, and is co-inventor on 2 U.S. patents.

Dr. Francisco Raul Ortega, Florida International University

Dr. Francisco R. Ortega (fortega@cs.fiu.edu), Visiting Assistant Professor, received his Ph.D. in Computer Science from Florida International University (FIU) in 2014, co-advised by Dr. Naphtali Rishe and Dr. Armando Barreto. He received outstanding graduate student 2014 from Computer Science. His dissertation was one of five nominated for best dissertation award for the college of engineering. Dr. Ortega received his bachelor's degree in Computer Science, cum laude, in December 2008 from FIU and a master's degree in Computer Science from FIU in December 2009. Dr. Ortega has over 17 years of experience in software development and systems integration.

His area of expertise are in 3D User Interfaces, Input Interfaces, Human-Computer Interaction, 3D navigation, input modeling, multi-threaded programming for 3D User Interfaces, and framework development, among others. Dr. Ortega has various publications, with many of them as first author. He is the also the first author of the upcoming book Interaction Design for 3D User Interfaces to be published by CRC Press/Taylor and Francis Group in December, 2015, the editor of the upcoming handbook titled Handbook of Input and 3D User Interaction: Theory and Practice (CRC Press), and a tentative series of 3D User Interfaces and Interaction Design Gems series (CRC Press) for 2017.

Prof. Eve A. Riskin, University of Washington

Eve Riskin received her BS degree in Electrical Engineering from M.I.T. and her graduate degrees in EE from Stanford. Since 1990, she has been in the EE Department at the University of Washington where she is now Associate Dean of Diversity and Access in the College of Engineering, Professor of Electrical Engineering and Director of the ADVANCE Center for Institutional Change. With ADVANCE, she works on mentoring and leadership development programs for women faculty in SEM. Her research interests include image compression and image processing, with a focus on developing video compression algorithms to allow for cell-phone transmission of American Sign Language. She was awarded a National

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J. Sonnenberg-Klein, Georgia Institute of Technology

Academic Program Manager, Vertically Integrated Projects (VIP) Program, Georgia Institute of Technology; Bachelor of Science in Engineering Physics, University of Illinois at Urbana Champaign; Master of Education in Education Organization and Leadership, University of Illinois at Urbana Champaign.

Prof. Seyed Masoud Sadjadi, Florida International University

Masoud Sadjadi received the B.S. degree in Hardware Engineering in 1995, the M.S. degree in Software Engineering in 1999, and the Ph.D. degree in Computer Science from Michigan State University in 2004. Dr. Sadjadi is currently an Associate Professor in the School of Computing and Information Sciences at Florida International University (FIU), where he has been on the faculty since 2004. He is the Director of Master of Science in Information Technology (MSIT) program at FIU. He is also the Director of the Autonomic Cloud Research Laboratory (ACRL) and leads several projects under the Latin American Grid initiative. He has extensive experience in software development and leading large scale software engineering projects both in industry and in academia. Currently, he is collaborating with top researchers in 8 countries and is leading several international collaborative research projects. In the past, Dr. Sadjadi directed the Center of Partnership for International Research & Education (PIRE) funded by the National Science Foundation for $2.3 million, served as a General Chair of SEKE 2012, served as the Program Chair, Co-Chair, and Committee Member of several top-tier international conferences and workshops of his field, and was a referee for several IEEE and SP&E journals and as a referee and panelist for several funding agencies including National Science Foundation (NSF), Luxembourg National Research Fund (FNR), and Florida Sea Grant. His current research interests include Agile Software Development, Autonomic Computing, and Cloud Computing. He has more than 80 refereed publications and is PI or Co-PI of 17 grants from NSF, IBM, Kaseya, TeraGrid, and FIU for a total of about $6 million. He is a member of the IEEE and can be reached at sadjadi@cs.fiu.edu and http://www.cs.fiu.edu/˜sadjadi/.

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Prof. Brian C. Fabien, University of Washington

Professor Fabien joined the University of Washington in 1993 and is currently the Associate Dean for Academic Affairs in the College of Engineering. His research interests include the kinematics of mechanisms, dynamic system analysis and optimization, as well as control system design. Professor Fabien is the Director of the Dynamic Systems Modeling and Controls Laboratory. He also directs the University of Washington EcoCAR program. Professor Fabien has received several awards including: the UW College of Engineering Faculty Award for Teaching (2015); the Valerie Logan Leadership in Science Education Award (2014); the NSF Outstanding Faculty Advisor for EcoCAR (2012), and the NSF Presidential Faculty Fellowship Award (1993).

Dr. Phiilp Johnson, University of Hawaii at Manoa
Robert Collins, Univesrity of Strathclyde at Georgia Tech
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Abstract

A survey of papers in the ASEE Multidisciplinary Engineering Division over the last three years shows three main areas of emphasis: individual courses; profiles of specific projects; and capstone design courses. However, propagating multidisciplinary education across the vast majority of disciplines offered at educational institutions with varying missions requires models that are independent of the disciplines, programs, and institutions in which they were originally conceived. Further, models that can propagate must be cost effective, scalable, and engage and benefit participating faculty. Since 2015, a consortium of twenty-four institutions has come together around one such model, the Vertically Integrated Projects (VIP) Program. VIP unites undergraduate education and faculty research in a team-based context, with students earning academic credits toward their degrees, and faculty and graduate students benefitting from the design/discovery efforts of their multidisciplinary teams. VIP integrates rich student learning experiences with faculty research, transforming both contexts for undergraduate learning and concepts of faculty research as isolated from undergraduate teaching. It provides a rich, cost-effective, scalable, and sustainable model for multidisciplinary project-based learning. (1) It is rich because students participate multiple years as they progress through their curriculum; (2) It is cost-effective since students earn academic credit instead of stipends; (3) It is scalable because faculty can work with teams of students instead of individual undergraduate research fellows, and typical teams consist of fifteen or more students from different disciplines; (4) It is sustainable because faculty benefit from the research and design efforts of their teams, with teams becoming integral parts of their research. While VIP programs share key elements, approaches and implementations vary by institution. This paper shows how the VIP model works across sixteen different institutions with different missions, sizes, and student profiles. The sixteen institutions represent new and long-established VIP programs, varying levels of research activity, two Historically Black Colleges and Universities (HBCUs), a Hispanic-Serving Institution (HSI), and two international universities[1]. Theses sixteen profiles illustrate adaptability of the VIP model across different academic settings.

Introduction

While ABET Engineering Criteria 3-g calls for, "an ability to function on multidisciplinary teams [1]," rich multidisciplinary experiences have yet to become the norm. A multidisciplinary division has been featured at ASEE Annual Conferences since 2006 [2]. The primary focus over the last three years has been on specific projects, individual courses, and capstone design courses [2], but no specific model has proven compelling and/or resilient enough for wide-spread adoption. If institutions of higher education are to offer rich multidisciplinary learning experiences on a large scale across the vast majority of disciplines, and if this is to be achieved at a wide variety of colleges and universities, a new model is required. The model must be

[1] This paper has a companion paper at the ASEE International Forum that discusses VIP implementations outside of the U.S. The overview of the fundamentals of VIP at the beginning of both papers is similar, but the curricular organization and operation of the different VIP sites often vary substantially. Together, these papers show that VIP works in a wide variety of environments.

independent of discipline and institution; it must be scalable enough to serve all students; it must be cost effective; and to maintain long-term sustainability, it must benefit both faculty and students. To test the viability for widespread adoption, the model must be implemented in a variety of settings. The Vertically Integrated Projects (VIP) Program offers such a model.

A central tenant of the VIP model is that undergraduates' work supports the faculty mentor's research, yielding deep long-term faculty engagement. The VIP program grew out of the Engineering Projects in Community Service (EPICS) Program [3-8], established at Purdue University in 1995. EPICS pioneered vertically integrated, large-scale, long-term undergraduate design teams. It was shown to meet nearly all of the ABET 2000 criteria [4, 9], and it provided the *time* and *context* required for teams to solve the technology-based problems confronting local non-profit organizations [7, 8] . EPICS received the Gordon Prize from the NAE in 2005 [8], and it is still operating at Purdue and thirty U.S. universities [7, 10-12]. A limiting factor in EPICS scalability was the disconnect between faculty reward structures and the community focus of the projects they were advising. Unless faculty efforts on these projects are recognized within institutional rewards structures, instructor interest can wane over time [13]. This waning interest can be overcome with financial incentives, but this expense limits scalability. VIP kept the vertically integrated, large-scale, long-term structure of the student teams developed in EPICS, but shifted the focus of projects from community service to faculty research [13-18]. Homing VIP projects in faculty research enabled VIP teams to make meaningful contributions to their instructors' research, thus becoming integral parts of their instructors' funded research activities. The activities and support of the team could then be included as the education, broader outreach, and workforce development elements in proposals and sponsored projects. Together, these benefits establish deep, long-term faculty engagement, making the VIP model sustainable.

The VIP model shifted the focus of projects from community service in EPICS to faculty research in VIP, yielding a model that is scalable, sustainable, cost-effective, and provides rich multidisciplinary learning experiences. With grants from the National Science Foundation and The Helmsley Charitable Trust, the **VIP Consortium** was established to further develop VIP and test its adoption at other universities. There are now 19 U.S. and five international institutions in the VIP Consortium. Continued consortium growth illustrates that VIP works at a wide variety of institutions: large, small, public, private, Historically Black Colleges and Universities (HBCUs), Hispanic-Serving Institutions, undergraduate-only, and R1/2/3 institutions. In this this paper, we present a detailed overview of the VIP model, an overview of the VIP Consortium, and profiles of sixteen institutions and their implementations of the model. The profiled institutions represent new and long-established VIP programs, varying levels of research activity, two HBCUs, an HSI, and two international universities, illustrating the adaptability of the model in different academic settings. Of particular note in all of these profiles is the way that VIP typically starts in one discipline but then spreads rapidly around the entire campus. This process is driven entirely by faculty and students. Faculty in any discipline quickly see how a VIP team can be a valuable partner in their research efforts, and each student browsing the list of VIP Projects can find one about which he or she is passionate.

The VIP Model

The VIP model is novel because it provides **rich multidisciplinary learning experiences**, and it is **cost effective**, **scalable**, and **sustainable**. In VIP, faculty lead student teams on projects that contribute to their research, and teams last for many years, if not indefinitely. Students earn academic credit and can participate for multiple quarters/semesters and years. Projects last longer than any individual student, so teams maintain detailed documentation, allowing returning students to onboard new students, and lower level students to replace upper level students as they graduate.

Rich Learning Experiences

In VIP programs across the consortium, **learning outcomes focus on the development of both disciplinary and professional skills**. VIP students apply skills from their respective disciplines to advance their projects. At the same time, they learn and apply professional skills in planning, teamwork, communication, and conflict resolution. The large-scale, long-term projects mirror situations students will encounter in the workforce. As they join large ongoing projects, they will be onboarded by peers, but will also take responsibility for their own learning as they get up to speed. They will deal with decisions made in previous years and with documentation developed by others; conversely, their own documentation will become a reference for the team in the future. They also learn and apply professional communication skills, communicating problems to the appropriate individuals and navigating conflict. These skills are addressed in peer evaluations, with instructors providing feedback midway through and at the end of each term. This feedback loop allows students to address areas in need of improvement prior to the end of the quarter/semester and prior to the beginning of their next term on the team.

VIP teams include a mix of **lower and upper level students**, even in a team's first quarter or semester, and **each student can participate for at least two years**. With this model for team composition, experienced students help onboard new students through student-developed tutorials, modules, and peer mentoring. This lessens the burden on faculty in getting new students up to speed, creates rich experiences for both new and experienced students, and parallels the work students will do in the workplace as they join existing projects and onboard new colleagues. Maintaining a mix of under and upper level students is important in this cycle, so lower level students can take the place of upper level students as they graduate. To support transitions between quarters or semesters, students maintain rigorous documentation of their efforts, typically in the form of VIP notebooks or institution-approved electronic portfolios. VIP programs also involve peer evaluations, reflecting the team-based nature of the course. Georgia Tech has developed a web-based peer evaluation tailored to VIP, which will soon be piloted with a handful of consortium members.

Cost Effective

Although VIP projects are not limited by quarters or semesters, **the VIP program is curricular, with all students participating for a letter grade**. This differentiates VIP from paid research experiences, as students do not receive stipends or hourly wages. This makes the program cost-effective, allowing faculty to take on the number of students needed, as opposed to the number of

students they can support. The status of VIP as a curricular program also differentiates it from clubs and extracurricular activities. VIP students earn credits toward their degree requirements, engaging students who might not otherwise have time for extracurricular activities. The grading aspect holds students accountable for their performance, with letter grades maintaining a higher level of engagement than do pass/fail grades.

VIP is also cost effective at the faculty level, because the program operates at a new intersection between education and research, with teams integrated into faculty research. In some cases, teams contribute to ongoing research projects; in other cases, faculty use their VIP teams to test new ideas or delve into new areas in a low-risk setting. Because the teams contribute to faculty research, instructors do not receive teaching credit for leading teams. Some departments provide release time in the first year of running a team equivalent to one course, because it takes effort to get a team up and running. After the first year however, returning students assist in onboarding new students, and further release time is not provided. Operating VIP courses outside of departmental course offerings creates new capacity for undergraduate research in a cost effective way. Courses are offered and students earn credit, but the faculty continue to carry the same teaching load outside of VIP.

Scalable

Contributing to the scalability of the model is the **long-term, large-scale nature of VIP projects**. Education is typically limited by quarter or semester, with learning confined to narrowly defined academic terms and years. VIP moves beyond the academic year model. While students join and leave teams at quarter or semester marks, projects last many years, even decades. Projects are also large-scale, with ten to twenty students per VIP team. This ensures that enough students will return each term to maintain the continuity of the project. Beyond being functionally important in team management, large team size creates student-to-faculty ratios that make the VIP model scalable in terms of students-served. With an average team size of 16 at Georgia Tech, it appears possible for ***every*** student on a campus to be involved in a VIP team. As VIP grows at each campus and as the VIP Consortium grows, we look forward to determining if this possible. The fact that this can even be considered makes the VIP Program unique in terms of its potential for systemic reform.

Also contributing to scalability is the fact that VIP works in any discipline. While early programs were established in departments of electrical and computer engineering, the program has consistently spread to other disciplines. More recent sites have been initiated in the sciences (Table C-1), and there exist VIP teams across the entire academic spectrum, including business, philosophy, and the arts. It is possible to assemble uniquely capable teams for a faculty member's project, regardless of the field. Furthermore, many of the institutions and disciplines that are home to these teams have created meaningful ways for VIP credits to count within their disciplines. These precedents make it ease the establishment of VIP sites, both in getting started and in establishing academic credit policies.

Sustainable

The key to VIP sustainability is long-term faculty engagement. Faculty stay engaged because: VIP gives them access to students both within and outside of their departments; teams make significant contributions to their research effort; and having a VIP team opens up new funding possibilities via the education, broader impact, and workforce development elements that are now required in many proposals. Annual release from teaching a regular course is not required to incent faculty to create teams – the additional capabilities that a team brings to faculty research efforts is sufficient. The exceptions to this policy implemented at some institutions include: (1) Release from one course for the ***first*** year that a team is in operation because that is when the burden of educating the team falls entirely on the faculty mentor. After year one, returning students take over the task of bringing new students up to speed. (2) In departments where VIP can be used to satisfy senior design requirements, a VIP adviser receives the same fractional-course teaching credit as regular senior design faculty for each senior design project homed within the team.

Logistical Considerations

Because VIP teams function more like research enterprises than courses, VIP teams need **dedicated, scheduled meeting spaces.** Team meetings for teams of 15 or more students, or subteams of five to eight students, are better suited to conference-style rooms that encourage face-to-face exchanges, as opposed to lecture-style classrooms. Dedicated meeting spaces allow VIP programs to schedule team meetings internally to accommodate instructor schedules, without having to deal with the campus-level scheduling system. The dedicated rooms support subteam meetings outside of regularly scheduled full-team meetings, which gives teams a home-base from which to work. Alternatively, some VIP teams meet in their faculty mentor's labs or departmental conference rooms.

Also logistically related, the Consortium decided that **multidisciplinary teams are encouraged but not required**. Any large-scale, long-term project is by nature multidisciplinary, but the decision to not require multidisciplinary teams was based on two main factors. First, as a faculty-driven program, VIP sites typically begin as pilot programs led by one or two faculty members within a single discipline/department. The Consortium wanted to ensure that small, single-department pilot programs would still be recognized as VIP programs. Second, graduation requirements vary by institution, with some programs leaving little room for electives, either free or technical. It is after seeing how well-functioning VIP teams benefit their faculty and their students that departments typically adopt credit-use policies that allow VIP credits to count in meaningful ways toward degree requirements. Thus, the initial set of VIP teams in a new discipline must often be formed with students who are willing to participate even if their department's initial policies only allow VIP credits to count only as free-electives. From the experiences of many VIP sites, a fraction of faculty and students will participate in VIP regardless of incentives. These early adopters then drive changes in their departments. Indeed, while one of the founding Consortium institutions anticipated being limited to a single department, the program at that institution has become multidisciplinary, attracting both students and instructors from other departments.

VIP Consortium

The VIP Consortium [18, 19] was established in 2015 with a three-year, $5M grant from the Helmsley Charitable Trust. Its goals are to expand VIP to all STEM fields and to a wide variety of institutions, to further evaluate its impact on students and faculty, and to organize an annual meeting for the Directors of all VIP sites. The Consortium initially included five institutions with existing VIP programs, or programs very similar to VIP. These included: Georgia Tech (Lead), Purdue Univ., Texas A&M, Univ. of Michigan, and the Univ. of Strathclyde in Scotland. The programs at Georgia Tech, Purdue, and Strathclyde were similar in structure. The Program at Michigan was part of their large Multidisciplinary Design Program (MDP) which also organizes industry sponsored projects. The VIP Program at Texas A&M, called the Aggie Challenge Program [20], was created to support their implementation of the National Academy of Engineering's Grand Challenge Scholars Program (NAE GCSP). Thus, the most significant difference between the original sites was whether VIP projects were created at the request of faculty (the standard VIP model) or at the request of an organization (a variation on the model), such as a company or the NAE GCSP.

The Consortium has grown to twenty-four institutions in just three years, with 19 in the U.S. and five international. Six of the new institutions are establishing VIP programs with their own resources. Institutions have been brought on in three cohorts, with the first cohort being existing programs, the second being programs initiated in 2015, and the third being programs initiated in 2016. Enrollment across each of the cohorts continues to grow, as illustrated in figure C-1. In all cases, new sites have implemented the approach of creating projects at the request of faculty.

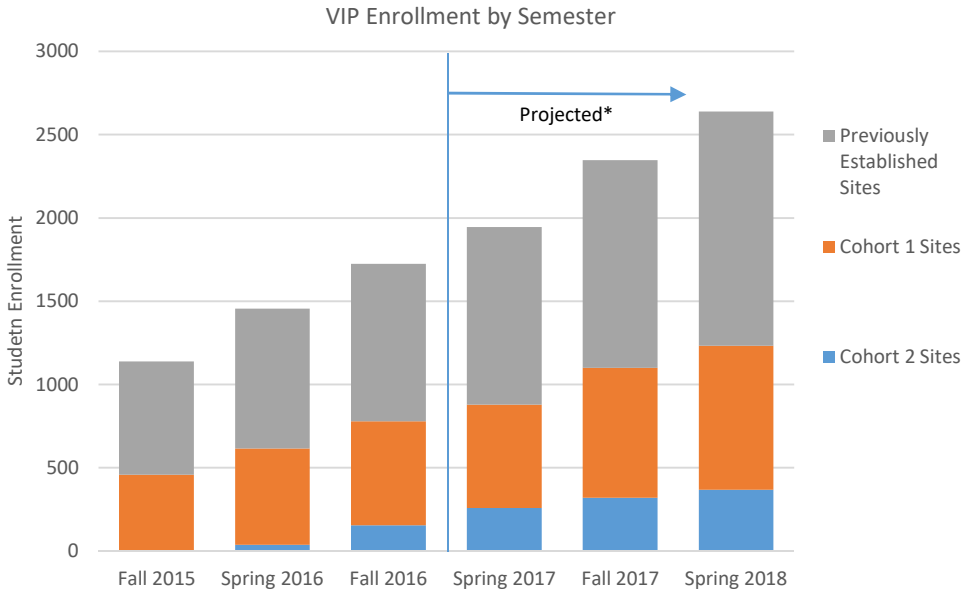


Figure C-1: VIP Consortium Total Student Enrollment by Term

* Projections based on numbers provided by sites. For sites that did not provide projections, the most recent enrollment numbers were carried forward at the same value. Values for Spring 2017 are listed as projections, because they were reported in December and January, when enrollments were still in flux.

Table C-1: January 2017 Snapshot of VIP Consortium Institutions (U.S.)

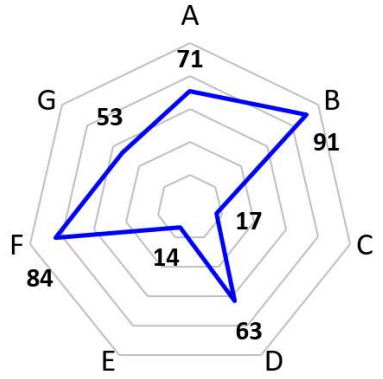
Institution	Undergraduate Enrollment	Hisp	Blck	Wht	Am. Ind	Asian	Nat. Haw.	Campus Housing	Transfer-in Rate
Arizona State University-Tempe	42,477	20	4	51	1	7	0	22	higher
Boise State University‡	20,186	12	2	74	0	2	0	17	higher
Colorado State University-Fort Collins*	25,688	12	2	72	1	3	0	29	higher
Florida International University	45,813	67	12	9	0	3	0	8	higher
Georgia Tech	15,489	7	7	50	0	20	0	53	lower
Howard University	6,883	0	90	2	1	1	0	56	lower
Morehouse College	2,108	1	95	0	0	0	0	74	lower
New York University	24,985	11	5	36	0	19	0	47	lower
Purdue University-Main Campus	30,043	5	3	63	0	7	0	41	lower
Rice University	3,893	14	7	37	0	24	0	72	lower
Texas A&M University-College Station+	57,358	20	4	59	0	6	0	23	lower
University of California Riverside*Sci	19,799	41	4	12	0	34	0	34	higher
University of California-DavisSci	28,384	19	2	28	0	32	0	25	higher
University of Delaware	18,322	7	5	75	0	5	0	43	lower
University of Georgia*Sci	27,951	6	8	70	0	10	0	32	higher
University of Hawaii at Manoa	13,132	2	2	20	0	41	17	25	higher
University of Michigan-Ann Arbor	28,983	5	4	61	0	14	0	32	lower
University of Washington-Seattle Campus	30,933	8	3	41	0	25	0	27	higher
Virginia Commonwealth University	31,212+	9	19	48	0	13	0	-	higher

The 19 U.S. institutions in the VIP Consortium and their undergraduate student populations [21, 22].
* Institutions establishing VIP Programs in Fall 2017; the rest already have teams underway.
Sci VIP Programs started/starting in the sciences, but planning to expand to other disciplines. At most sites, VIP was first established in engineering, and it then spreads to other disciplines.
% Percentages rounded to nearest whole number percent.
‡ Fall 2016 numbers, provided by institution(s).
+ Spring 2017 numbers, provided by institutuion(s).

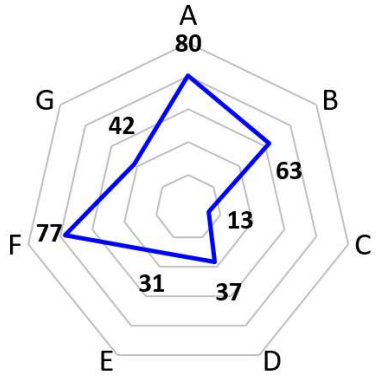
The Consortium includes a wide variety of institutions, including two HBCUs, two HSIs; an institution with significant Native Hawaiian enrollment; ten institutions with higher transfer-in rates; institutions with and without heavy STEM focuses; as well as residential and non-residential campuses. Table C-1 presents data on undergraduate enrollment, demographics and transfer-in rates for U.S. Institutions. The "spider diagrams" in Figure C-2 provide a visualization of additional campus data points across the Consortium:

- Percent of degrees at the Bachelor's Degree level (of Bachelor's and Graduate degrees)
- Percent full-time Undergraduate enrollment
- Percent full-time Undergraduate enrollment in Engineering
- Six-year graduation rate
- Percent of undergraduate adult learners
- Percent admitted (total)
- Published out-of-state tuition and fees

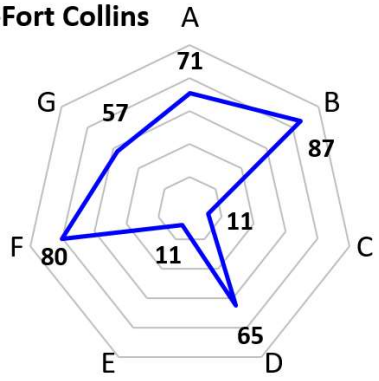
Arizona State University-Tempe



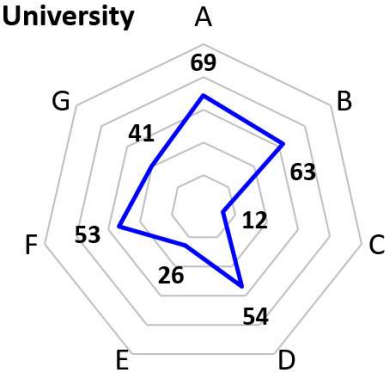
Boise State University



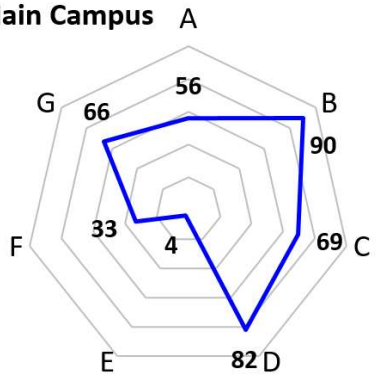
Colorado State University -Fort Collins



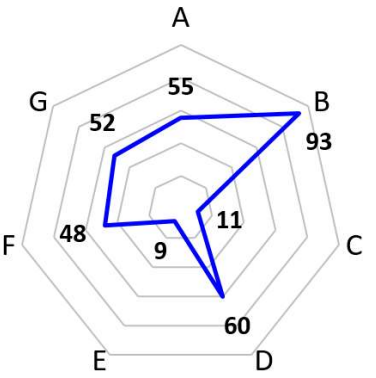
Florida International University



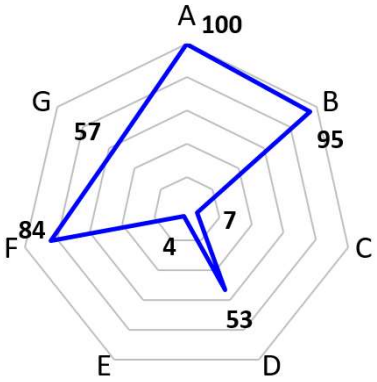
Georgia Institute of Technology -Main Campus



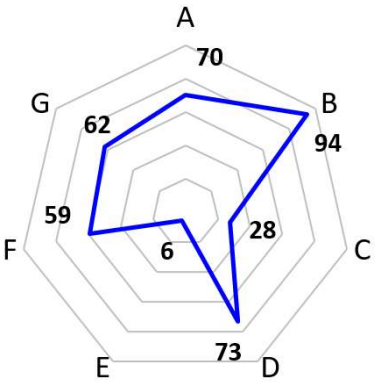
Howard University



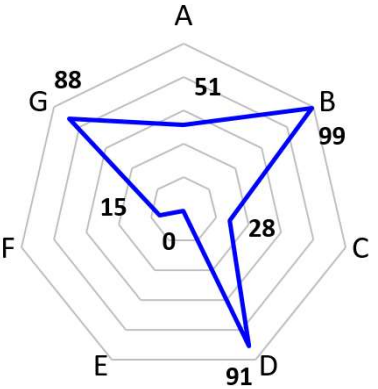
Morehouse College



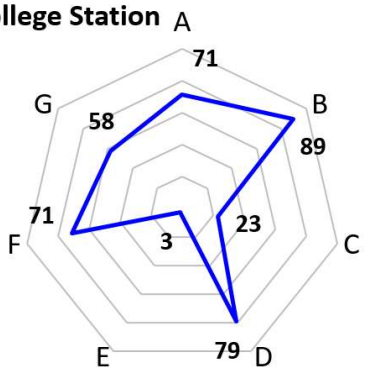
Purdue University-Main Campus



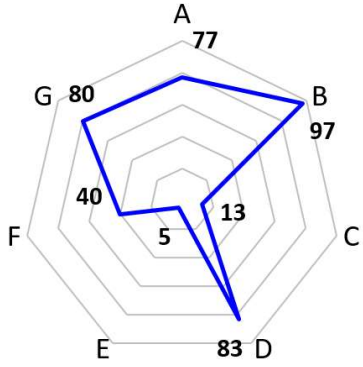
Rice University



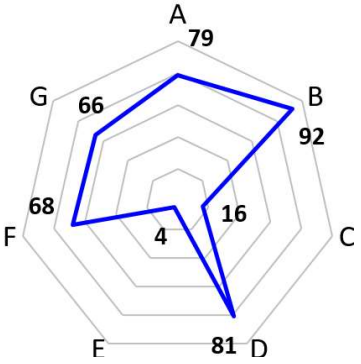
Texas A & M University -College Station

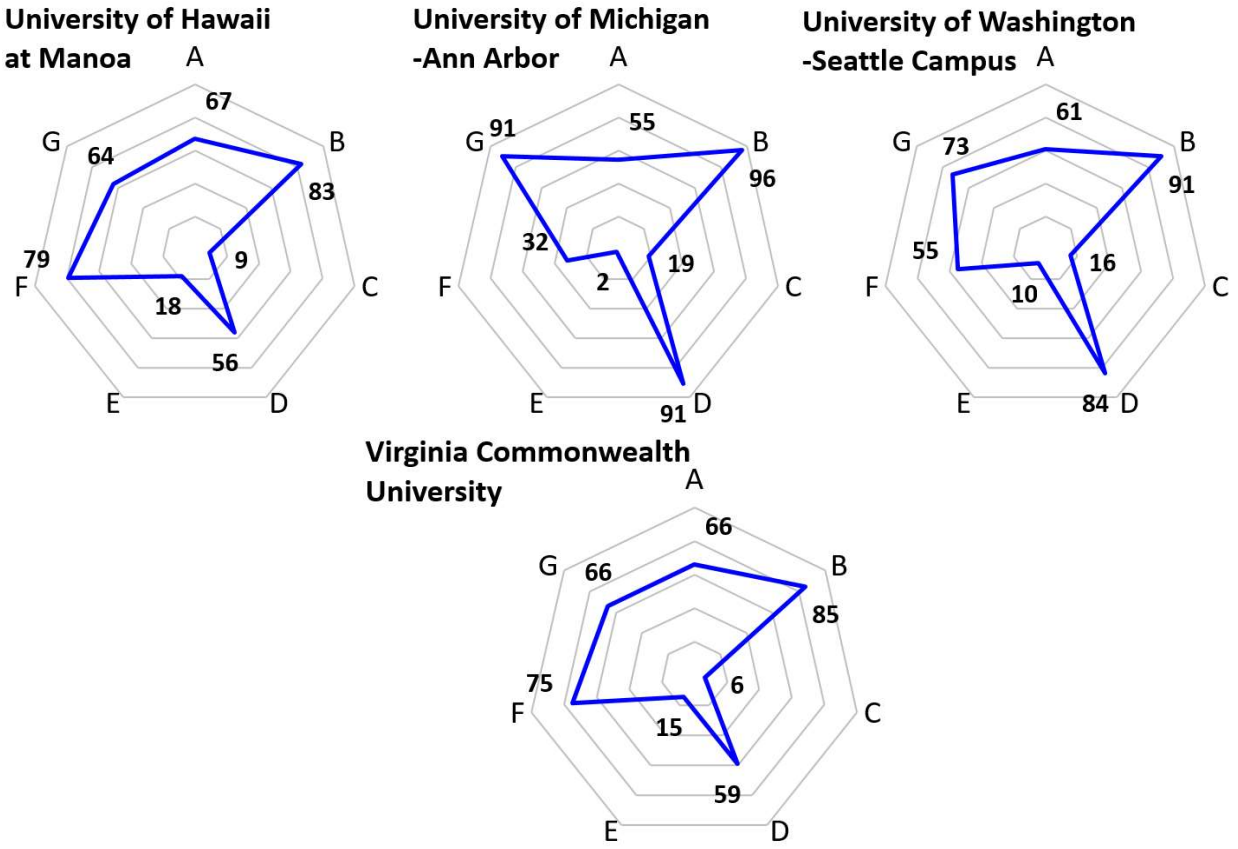


University of California-Davis



University of Delaware





A	% Bachelors Degrees (of Bachelors and Grad degrees)
B	% Full-time Undergraduate enrollment
C	% Full-time Undergraduate enrollment in Engineering
D	Six-year graduation rate
E	% Undergraduate adult learners
F	Percent admitted (total)
G [2]	Published out-of-state tuition and fees (normalized; 100 = maximum among VIP Consortium institutions, $46,170 at New York University)

Figure C-2: "Spider Diagrams" illustrating campus data points across the Consortium.

[1] Data only includes VIP institutions with active programs in Spring 2016.

[2] Element G, "Published out-of-state tuition and fees," is a relative comparison among the VIP institutions as of April 2016. The maximum value of $46,170 is set as 100 and used as the denominator in calculating values for the institutions. All other elements are actual values for the respective institutions.

While many schools share similar data profiles, others standout in particular elements. For example, Morehouse College is a solely undergraduate serving institution, (100% along axis A); Rice University is nearly half undergraduate and half graduate (51% along axis A); Boise State University and Florida International University serve more adult learners (31% and 26% along axis E) and have lower full-time undergraduate student enrollment (both at 63% along axis B). The diversity of institutions allows the consortium to implement, evaluate and learn from VIP sites in a variety of settings, and learn from effective practices at other institutions.

VIP Program Profiles

In the following sections, individual VIP sites provide overviews of their VIP Programs. The goal is to illustrate unique aspects of VIP Programs at each institution.

Boise State University VIP Program

About the Institution: Historically a community college and traditionally a commuter campus, Boise State has primarily served nontraditional undergraduate and homegrown graduate students, while also recruiting the non-research active faculty member. Boise State was classified a doctoral research institution in 2016 by the Carnegie Classification of Institutions of Higher Education. Since our last evaluation review in 2008-2009, research expenditures have more than doubled, doctoral graduates have more than tripled, and the number of doctoral students enrolled has increased from 82 to 188 — a 129 percent increase. As a consequence, Boise State is 1 of the 3 fastest growing graduate programs in the United States today. In support of progressive growth, Boise State launched the Institute for STEM and Diversity Initiatives (ISDI) in January 2015 and the College of Innovation + Design (CID) in August 2015. The mission of ISDI is to create a culture of inclusive excellence in science, technology, engineering, and mathematics (STEM) – increasing the number of women and other underrepresented groups in these fields and facilitating the success of those already pursuing that pathway. It does this by serving as a central coordinating and support structure for STEM-related activities and as a vigilant advocate for the underserved and underrepresented. The mission of CID is to pilot new models of research, development, and education (RD&E) – without needing to subscribe to the bureaucracies of a state institution. Unlike other colleges, CID creates RD&E programs and then develops a roadmap to integrate viable programs into the university structure. It does this to experiment with how value and relevancy are retained amidst a variety of internal and external pressures facing higher education today.

Initiating Department: College of Innovation + Design (CID)

About the Implementation: As a cornerstone of the College of Innovation + Design, VIP has the potential to seed innovation within our current university, innovate our future university, and innovate workforce and community connections with our university. Serving as institutional glue, VIP was initially added to the strategic plan in 2016 to minimize potential polarization between teaching and research. Summarized in **Table BSU-1**, Boise State has committed to increasing VIP enrollment from 60 students in FY16 to 180 students in FY18. In preparation for this growth, the curriculum committee approved VIP course numbers at the 200, 300, 400, and 500 levels. To motivate faculty to adopt these course numbers over their departmental course options, an incentive-based budget model was created. Briefly described, the incentive-based budget model allots $177 per credit to the College of Innovation + Design for every student participating in the VIP program. This is significant because 60% of a student's tuition and fees will be directly reinvested into their VIP project starting Fall 2016. Conservatively assuming 10 VIP teams with an average load of 15 students per semester and 2 credits per student, CID will generate $106,000 of allocated income each year. From this total, 85% ($90,100) will be passed along to the VIP teams to: (a) motivate faculty participation, (b) provide gap funding, (c) establish need-based scholarships, and (d) explore new ideas. As part of a faculty learning

community, the remaining 15% ($15,900) will be used for annual retreats, workshops, and coaching sessions for new VIP faculty. Current size and projected growth are outlined in Table BSU-1

Table BSU-1: Boise State's institutional commitment to VIP.

Performance Metric	FY 16	FY 17	FY 18
Number of VIP Students	60	120	180
Number of VIP Teams	6	12	18

Unique to this Program: For the first year support is being provided by a federal grant entitled, *Aligning Stakeholders and Structures to Enable Risk Taking (ASSERT).* The goal of ASSERT is to expand VIP from a stakeholder alignment initiative at Boise State to an *ASSERT*ive community for Boise State. Grant objectives include: (a) creating a learning framework for a cohort of VIP faculty who are at various stages of their careers and who are in danger of not taking risks in their research strategies for a spectrum of reasons (Fig. BSU-1); (b) address the structural and cultural issues at the university in order to create a more nurturing environment that encourages faculty to take strategic intellectual risks in their research, attacking global imperatives; and (c) work on a sustainability plan within Boise State that expands our program to other VIP teams while also creating guides for other universities in the VIP consortium so that they can adapt our approach on their campuses. There are several advantages to this approach. One particularly attractive feature of the VIP program is that it engages the full university – undergraduate students, graduate students, postdoctoral fellows, and faculty of all ranks. By

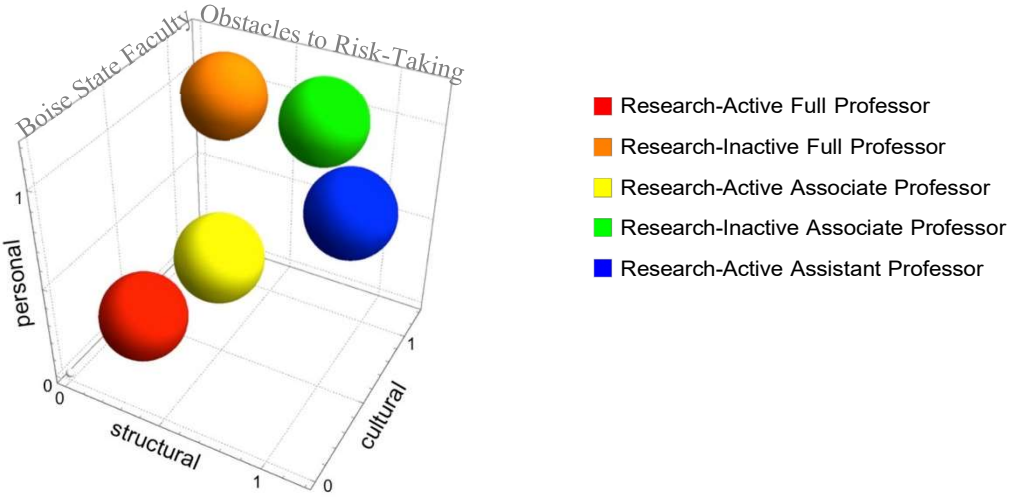


Figure BSU-1: One possible visualization of the relative importance of the structural, cultural, and personal obstacles facing faculty at Boise State that prevent them from tackling high-risk societal problems of global importance and integrating their teaching and research. Importance is normalized to a value of one, where zero and one represent low and high impact, respectively.

using a curricular model, risk is spread across a team and organization – undergraduates will learn a great deal even if their project never turns into a grant for their advisor, graduate students can work on manageable pieces that can be more effectively turned into publications, and faculty can either expand on their current research interests or start to explore new ones. A second attractive feature of VIP is that it is being institutionalized at 20+ other institutions that range

from Morehouse College to the University of Michigan – providing a diverse national network to explore the broader impacts of *Aligning Stakeholders and Structures to Enable Risk Taking.*

Change @ Boise State – The high volume of institutional experiments being conducted at Boise State often creates deep emotions among our stakeholders that include: nervous excitement, optimistic hope, and fear of failure. Stakeholder emotions have been intentionally managed by *throttling* the number and size of VIP teams, while also messaging from the bottom and to the top of the organization that program growth, while possible, is negligent in the absence of real institutional support. Albeit non-traditional, our implementation model has promoted positive tension between Boise State's history – as a teaching-based community college – and its recent mission to become a metropolitan research university of distinction. This tension has also generated growing curiosity among our faculty, who often ask: What is VIP and how is it different from what I already do? What are the incentives to participate? How will it help me, my students, and my department succeed? The work described above gives us confidence that we can answer these questions by pointing to working examples of funding, infrastructure redesign, and strategic commitments.

Colorado State University VIP Program

About the Institution: Colorado State University is a growing, middle-sized public university, with total enrollments of approximately 32,000 students. Almost 4,600 students are either in graduate or professional programs. Research expenditures for fiscal year 2016 reached $331.8 million. At Colorado State University we have used the VIP program to engage both existing projects on campus and encourage new projects.

Initiating Department: Department of Electrical and Computer Engineering

Program Implementation: The Department of Electrical and Computer Engineering implemented changes to satisfy the VIP goal of students receiving credit for their participation. Prior to the VIP program, there was limited freedom to select elective credits for students in this department –a limited group of courses was available. Now students at any stage in the program have a new independent study path, "Open Option Projects," which allows students to work on projects to earn credit for their technical elective credit requirements. This allows VIP students to accumulate credits for their VIP-related efforts over their multiple years of participating on the project. This benefit also now extends to all of the students in the department, extending the impact of VIP beyond the program and to the department curriculum.

Program Composition: There are currently six VIP projects led by faculty from multiple colleges and departments, including:

- Walter Scott, Jr. College of Engineering
    - Chemical and Biological Engineering
    - Electrical and Computer Engineering
    - Mechanical Engineering
- College of Health and Human Sciences
    - Occupational Therapy
- Warner College of Natural Resources

    - Ecosystem Science and Sustainability
- College of Veterinary Medicine and Biological Sciences

Additionally, students from other colleges, e.g. Computer Science students in the College of Natural Sciences are also engaged in our VIP projects.

Unique to this Program: The topics for the VIP projects at Colorado State University are briefly described below.

Snow Varies: Goals are to quantify spatial and temporal variability of snow and related properties.

EcoCar: EcoCar is part of a three-year collegiate engineering competition, reduce the environmental impact of a Chevrolet Camaro without compromising performance, safety, and consumer acceptability.

Advanced Driver Assistance System (ADAS): Goals are to design an advanced driver assistance system (ADAS) for automobiles to enhance driver safety, e.g., by tracking lane markers to keep the driver in the correct lane and alerting the driver to other cars and pedestrians. While image processing algorithms exist to track lanes, cars, and pedestrians, the challenge in this project is to implement these algorithms on an embedded board (with CPUs and GPUs) and a very limited power budget.

Games and Assistive Technologies fOr Rehabilitation (GATOR): Goals are to design games and activities with cutting edge virtual reality and motion tracking technology including Occulus Rift, Leap Motion Controller, and Kinect 2 for low cost and in-home rehabilitation of patients with stroke, cerebral palsy, and traumatic brain injury. The games and activities will be designed to improve hand-eye coordination, motor control, endurance, shoulder strength, range-of-motion, grasp strength, and coordination of grasp and reach.

Variational Analysis and Reliability Modeling Algorithms (VARMA): With the ever increasing complexity of engineering systems, parametric uncertainty arising due to manufacturing process variations, variations in operating environment, and from simplifying assumptions made during the design process have become crucial in determining the performance, reliability, and life-span of such systems. Modeling the propagation of this uncertainty from the system parameters to the system behavior requires a completely novel and stochastic approach towards characterization of engineering systems. Thus, the objective of this program is to develop new cutting edge mathematical knowledge and computational tools for rapid and accurate uncertainty quantification and reliability analysis of complex engineering systems.

iGems: The CSU iGEM (International Genetically Engineered Machine competition) team gives undergraduate students a chance to participate in student-driven research in the area of synthetic biology. Synthetic biology is an emerging field that spans many different disciplines. The iGEM team historically has attracted sophomores and juniors to participate in undergraduate research. The students have significant input into selecting the project that they pursue. The projects are viewed as a two-year project where at the end of the project the students get to present their work

at the iGEM "Giant Jamboree" which occurs every fall in Boston. This is an international research competition with over 250 teams that compete from all over the world. Each team does both an oral and poster presentation of their work.

Florida International University VIP Program

About the Institution: Florida International University (FIU) is a vibrant, student-centered public research university, located in Miami. FIU is committed to learning, research, and innovation and has been locally and globally engaged for more than four decades. With 54,000 students attending FIU in Spring 2016, FIU is among the top 10 largest universities in the nation. FIU serves a diverse community of students including 61% Hispanic, 15% White Non-Hispanic, 13% Black, 4% Asian or Pacific Islander, and 7% other minority groups.

Initiating Department: School of Computing and Information Sciences (SCIS)

About the Implementation: The VIP projects at FIU are long-term, large-scale projects based on faculty mentor's research, with examples including Modern Touch, Augmented & Virtual Reality, Agricultural Robotics, Affective Computing, and SkillCourt. Faculty members in the School of Computing & Information Sciences (SCIS) and the College of Engineering & Computing (ECE) are very receptive to the VIP model and program. The School of Computing and Information Sciences (SCIS) approved technical electives and the replacement of senior project to count as VIP courses (IDS-2947, IDS-3948, IDS-4993), along with approval for graduate students from SCIS for the IDS-5993 course. The program is also reaching out to other departments, to develop credit use policies to allow VIP to count as their technical electives. A university-wide VIP course is in the pipeline for final approval. In the meantime, the VIP Program makes use of independent studies, senior projects, and other relevant courses to engage students from different majors in VIP.

All students participating in VIP are graded and students earn credits toward their degrees. The main criteria for student evaluation and grading include:

- Daily scrum meeting participation and Bi-Weekly sprint presentations;
- Final Presentation, Videos, Documentation and Showcase;
- Research Project Implementation
- Research Paper

The expected amount of work on the elements above differ for each student. For instance, if a student is interested in doing research more than implementation, the percentage of research changes from 30% to 50% (e.g. Bi-Weekly sprint reviews presentations and Daily Scrums: 10%; Final Presentation, Videos, Documentation, and Showcase: 20%; Final Research Project/Implementation: 20%; Research Paper: 50%).

VIP Program Composition: In the Fall of 2016, 144 students participated in VIP. Figure 1 shows the growth of participating students since Spring 2015.

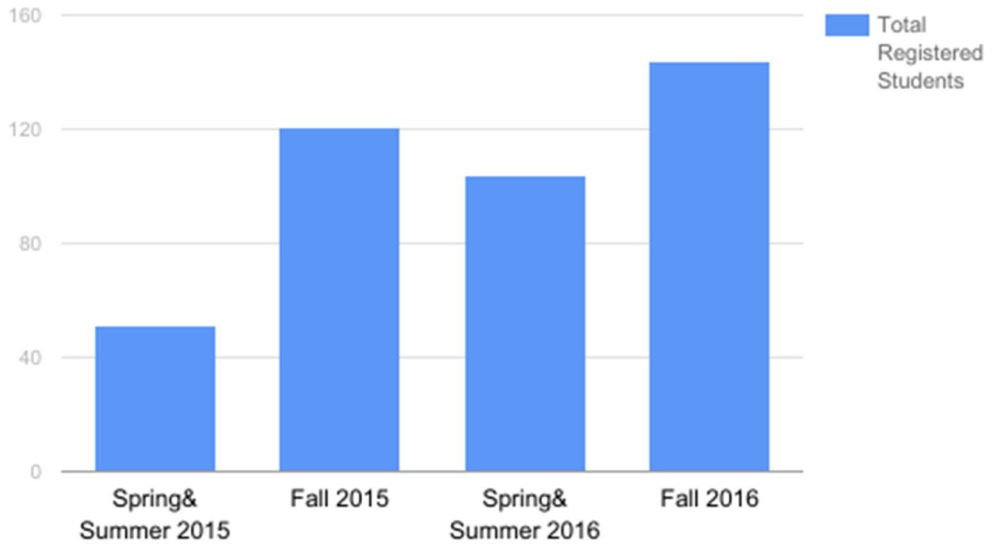


Fig FIU-1: Total Registered Students in VIP each Term

Unique to this Program: The FIU VIP Program has been developing complementary tools to manage our VIP projects. We have made significant progress so far and intend to continue the development of our VIP tools and share them with the rest of our partners in the VIP Consortium. A number of our tools have been placed in production and used in the past years (e.g., Mobile Judge was used during our showcase on Fall 2016). We intend to improve the tools continuously based on the feedback that we receive from the VIP consortium and the open source community. It is important to note that our site http://vip.fiu.edu has been of great use to recruit and maintain the projects. We have adopted some tools (e.g., Mingle from ThoughWorks and GitHub) and created useful templates and guidelines for agile project management.

Mobile Judge (http://mj.cis.fiu.edu) is one the VIP tools that we have developed. Graduating senior Computer Science students partake in a VIP showcase event where they demonstrate and explain their software solution. In an effort to provide a centralized platform that allows the course instructor to administer and invite judges to the event – as well as expedite the process of grading students, Mobile Judge was created. Students, too, would be able to receive real-time updates of judges' grades and get feedback on their demo and presentation.
Senior Project Website Match Maker (http://spws.cis.fiu.edu) alongside the VIP website (vip.fiu.edu) were developed to help VIP students to choose their project. This tool facilitates an intelligent match between users and projects, determining the best project for each student.

Collaboration Platform (http://cp.cis.fiu.edu) is another VIP tool that we have developed. Current students lack a reliable source for answering questions related to their classes or capstone projects. At times, students rely on internet sources that are often unreliable, inaccurate, and incomplete. In efforts to solve this issue we decided to develop the Collaborative Platform in order to connect students (mentees) with the right experts (mentors).

Fig FIU-2: VIP Showcase at FIU

VIP Showcase: On the last week of each semester, our students showcase their projects during a full-day event, starting at 1:00 PM and concluding at 10:00 PM. We usually reach out to more than 1500 individuals from industry and academia and invite them to this event. We accept 10% of them to serve as final judges for this event, and they attend and evaluate the work of VIP students including juniors, sophomores, seniors, and graduate students. Each student's work is judged by at least four invited judges (Figure FIU-2).

Georgia Institute of Technology VIP Program

About the Institution: The Georgia Institute of Technology (GT) is an engineering-focused public research institution. The campus enrolls approximately 25,000 students, and the College of Engineering constitutes 62% of the undergraduate population.

Initiating Department: School of Electrical and Computer Engineering

About the Implementation: The GT VIP Program was established in Spring 2009, originating in the School of Electrical and Computer Engineering. As of Spring 2017, the program has grown to 41 teams, enrolling 640 students from 29 academic majors [23]. Every team at is multidisciplinary, as shown via the bar-chart in Figure GT-1, in which each column represents a VIP team, and majors are represented by color. Even new teams, which tend to be smaller than established teams (6-10 students as opposed to 10-20), are multidisciplinary.

Contributors to student participation are credit-use policies that allow students to use VIP course credits toward their degrees in meaningful ways. As of Spring 2017, seventeen majors had credit use policies in place, representing five of the campus's six colleges. Students from majors without credit-use policies can still use VIP as free electives. While free electives may be less desirable, this is not a barrier to all students, as the program enrolled students from twenty-nine majors, reaching far beyond the seventeen established credit use policies.

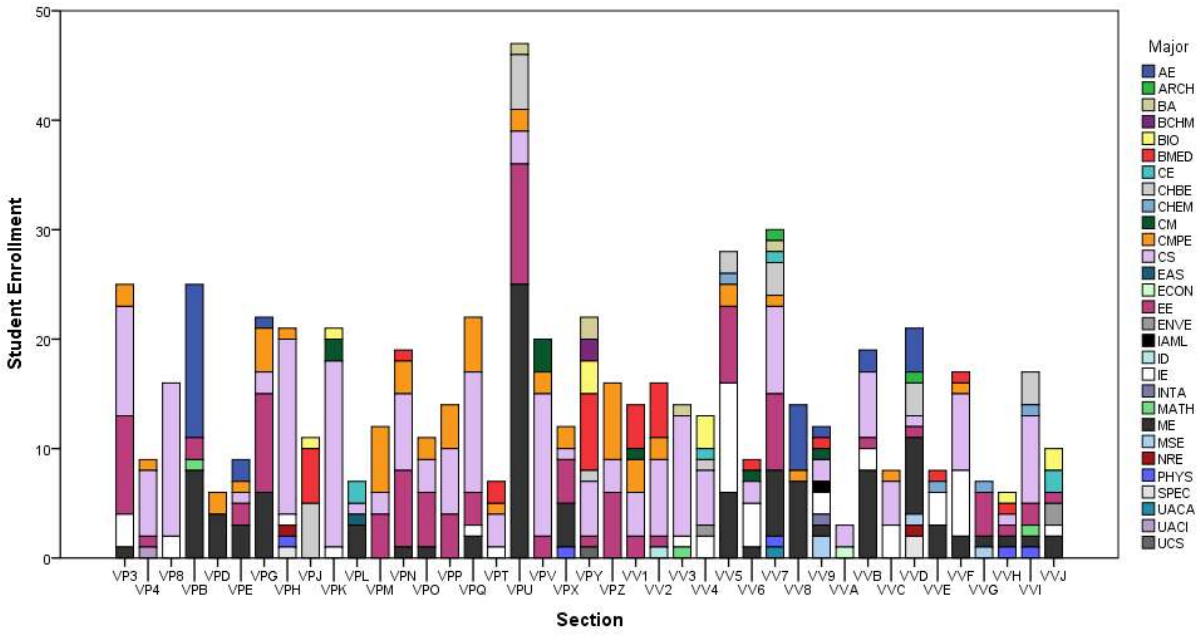


Figure GT-1: Each bar shows the number of students per team for each of 41 teams. The colors in each bar show the disciplines participating in each team

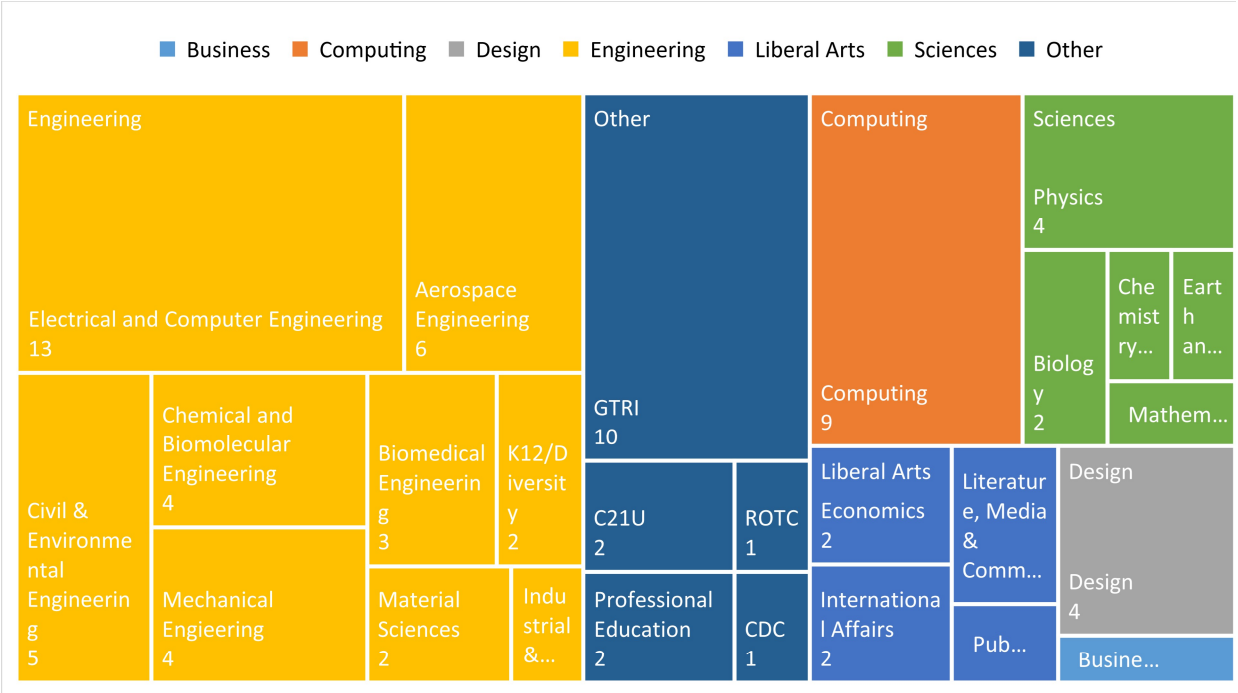


Figure GT-2: Block diagram showing Organization/College/Department of Georgia Tech VIP advisers. The "other" block includes advisers from outside of GT (Georgia Tech Research Institute, the Centers for Disease Control) and non-degree-granting units within GT (Center for 21st Century Universities, Professional Education, and ROTC).

One of our current hypotheses is that VIP works in every discipline. Evidence that this is true appears in the figure above (GT-2), which shows the origin by organization, college, and department of the VIP team mentors at GT. By organization we mean: (1) academic departments within GT; (2) non-degree-granting organizations within GT, such as the Georgia Tech Research Institute, Professional Education, and ROTC; and (3) organizations outside of GT, such as the Centers for Disease Control (CDC). Each VIP team has, on average, 2 mentors, usually from different disciplines.

Unique to this Program: The GT site has focused on developing tools, processes, and services that enable the program to scale to a very large size. These include: grading and peer evaluation tools to ensure ease of grading and uniform approach to grading across all VIP teams; recruiting and advertising efforts that reach every student on campus; web-based student application processing and approval, which is handled by the Director for new teams, but then turned over to faculty mentors once they have two or more years of experience with their teams; and faculty mentor development for both new and continuing mentors. With these elements in place, we believe the GT VIP site can scale to any size – 300 teams is the current target.

These tools and processes for scaling VIP have been developed with portability in mind. The grading and peer evaluation tools, for example, will soon be made available to other sites. Those that have the resources may choose to implement them locally, with installation on a local server. Those lacking resources or simply wishing to simplify their implementation will be able to use a cloud version of these tools that is currently under development.

Howard University VIP Program

About the Institution: Howard University is a federally chartered, private, doctoral HBCU located in Washington DC. Howard enrolls approximately 11,000 students and is classified as a high research activity institution [22].

Initiating Department: Electrical and Computer Engineering

About the Implementation: The scope of the work was to start and establish a VIP framework in the PI's home department and disciplines, Electrical Engineering (EE) and Computer Engineering (CpE), then expand it to the entire College of Engineering and Architecture (CEA), and further to the entire university community. The first year was dedicated to preparation and launch of the VIP framework for EE and CpE programs anchored in the Senior Design project but involving more non-senior students in the program who could participate in the team projects in lieu of the required-for-all Introduction to Engineering course. This kind of institutionalization of the program through substitutable course establishment was very important carrier which allows students to participate in VIP in the early stages of education. After the first year of initiation of the VIP framework, we had 7 VIP teams with 7 faculty advisors from 3 different programs (EE, CpE, and Physics) in the Fall 2015. As for students, a total of 45 students participated in the projects, 18 of them were seniors, 3 sophomores, 2 juniors, and 22 freshmen from 6 different programs (EE, CpE, Civil Engineering (CV), Mechanical Engineering (ME), Computer Science (CS), and Mathematics. Also each project team contains students from, in average, 3 different programs. So VIP framework after the first year became true to the VIP

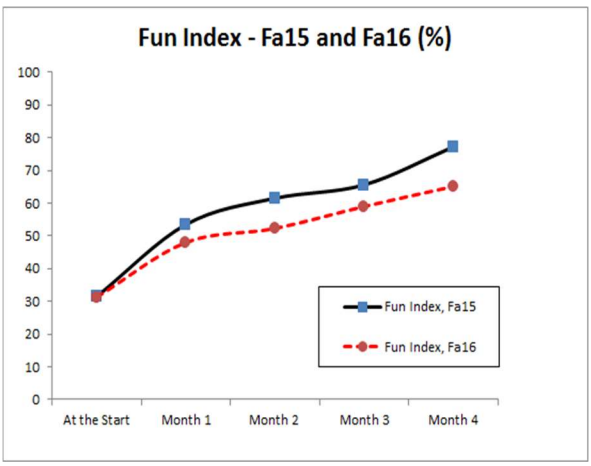
rational and essential elements, and was further expanded to Science disciplines earlier than anticipated even though, at the first, the expansion out of CEA was the second year objective.

The next year period for "growth and expansion" focused on recruiting professors in more diverse programs for initiating new projects and on adding more substitutable courses for VIP participating students. The so-called evangelist approach, with one-on-one recruiting by the VIP Director proved to be the most effective way of recruiting professors. This was particularly true at Howard University where institutionalized faculty compensation for VIP participation, such as 1 credit-hour teaching credit provided by some VIP institutions, was not feasible. Emphasizing the benefits even for professors let alone the importance of better equipping and mentoring students worked satisfactorily. At the end of the second year, Fall 2016, there were 9 VIP teams with 6 professors in 4 programs (EE, CpE, CS, and CV). As for adding more substitutable courses, a junior course for EE and CpE programs, Research Experience for Undergraduate Students, was included. Students of the course were allowed to participate in VIP projects for the course credit. In another program, an Introduction to Mechanical Engineering course also allowed students to opt into the VIP projects in lieu of the course. As for students, a total of 52 students participated in the projects, with 17 seniors, 9 juniors, 13 sophomores, and 13 freshmen from 6 different programs (EE, CpE, CV, ME, Computer Science (CS), and Chemical Engineering (CHEM)). Also each project team included students from, in average, 3 different programs.

So VIP framework after first two years has been successfully rooted at Howard University. Even though not all programs and their faculty and students participated in the VIP framework, and expansion to the entire CEA seems achievable, overarching to the entire campus community not unachievable, and the eventual goal of becoming a "sustainable framework" can become a reality.

Unique to this Program: The VIP framework is expected to make wider impact on retention and graduation rates, as well as technical skill development. Assessment of VIP in the first two years focused on two outcomes, especially for non-senior students: (a) how well students are familiarized with research-based faculty-student team project environments while having some fun, and (b) what skills (hard and soft) they learned from the experience. Participating students, non-senior students in particular, were required to fill out survey questionnaires which were used in evaluating the benefits of the VIP framework. Data retrieved from surveys were analyzed and their interpretations in relation to the key elements VIP were sought.

For the first outcome, the students were asked to indicate how much they enjoyed or felt agony as they moved on each month of the semester in their team environments. In analysis, we call the former a fun index, and the latter a pain index. Fig. H-1 depicts the average fun indexes for Fall 2015 and Fall 2016, respectively, and Fig. H-2 the average pain indexes for the respective semesters.



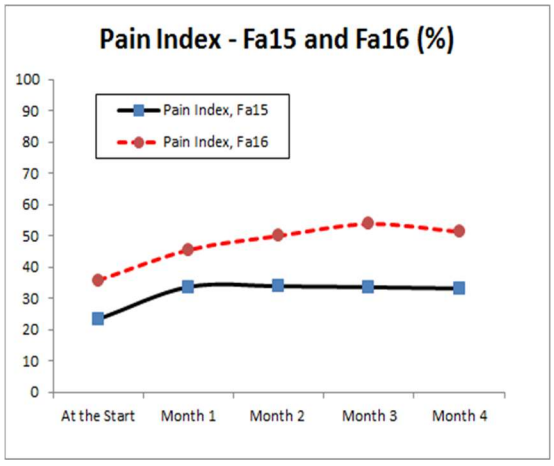


Fig. H-1: Fun Indexes for Fall 2015 and Fall 2016 semester. *Fig.H-2:* Pain Indexes

In both semesters, the fun index picks up gradually as time goes on from very low to high. Pain index similarly follows the gradual increase pattern but, around the middle of the semester, it is gradually going down. It seems that the students' interest and confusion with new team environments grow together until the middle of the semester, from which the two curves start to depart, fun increasing and pain decreasing. As for comparing two semesters, Fall 2015 students enjoyed more and felt less pain than Fall 2016 students, the reason of which is unknown.

As for the second outcome of soft skills the students gained in the VIP project participation, the students were asked to choose top five (5) skills they gained among the provided skills: (a) problem solving skills, (b) teamwork, (c) interpersonal communication, (d) public speaking, (e) personal responsibility, (f) time management, (g) information search, (h) self-learning skills of new subjects, (i) awareness of research and research technique, (j) understanding contemporary technology, (k) working in a multidisciplinary team, and (l) understanding what engineering design is.

The top five skills gained by the students were as tabulated in Table H-1 for Fall 2015 and Fall 2016. The result shows the multidisciplinary team project feature of the VIP framework. Many put teamwork as the most valuable experience of the VIP participation. Professional communication, public speaking, time-management, and personal responsibility are also highly regarded skills the students gained.

Table H-1. Most Valuable Non-Technical/Soft Skills Acquired from VIP projects.

Fall 2015	Fall 2016
1. Teamwork (15%), 2. Understanding Contemporary technology (11%), 2. Understanding engineering design (11%), 4. Working in a multidisciplinary team (9 %), 5. Personal responsibility (8 %) 5. Public Speaking (8%) 5. Self-Learning Skills (8%) 5. Awareness of Research (8%)	1. Teamwork (12 %), 1. Information Search (12%) 3. Awareness of Research (10%) 3. Understanding engineering design (10%) 5. Personal Responsibility (8%) 5. Time Management (8%) 5. Interpersonal Communication (8%) 5. Working in a multidisciplinary team (8%),

Inha University VIP Program

About the Institution: It has been over 60 years since Inha University was established upon the ideals of leadership, expertise, and service to the country. A mainstay in the port city of Incheon, Inha produces professionals for the science and technology sectors. The first classes were held on March, 1954, with six majors. Now, Inha has 56 departments and 17,477 students enrolled in Spring, 2016. In particular, Inha has become a flagship engineering-oriented university in Korea, with almost 8,000 undergraduate and graduate students in 21 engineering departments.

Initiating Department: Department of Information & Communication Engineering

About the Implementation: Inha University established its VIP Program in Spring 2014. The program can be considered as a capstone design course having the features of 1) project-based learning, 2) team-based learning, 3) multi-disciplinary learning, and 4) multi-semester learning. In each VIP project, students make teams consisting of multi-disciplinary and multi-year students, and carry out a specific research project guided by the professor. During the class, professor's lectures are minimized; instead, the interactions of students with the professor, graduate mentors, and industrial experts are largely required. The VIP program is designed so that the students can gain 1) both basic and applied knowledge related to the project, 2) problem-solving skills, 3) fellowship and leadership in teamwork, and 4) communication skills. In the 2016 school year, ten VIP classes were opened and served 189 students from 22 departments of 3 colleges out of 15 colleges.

Students participating in the VIP program can earn a maximum of 3 credits of in-major electives and another 3 credits of free electives throughout 6 semesters (Table In-1), and thus the program is approved as a general design course in the engineering departments. In regard to student evaluation, the final grade is determined based on the oral presentations, research diary, peer evaluation in team, and the final demonstration.

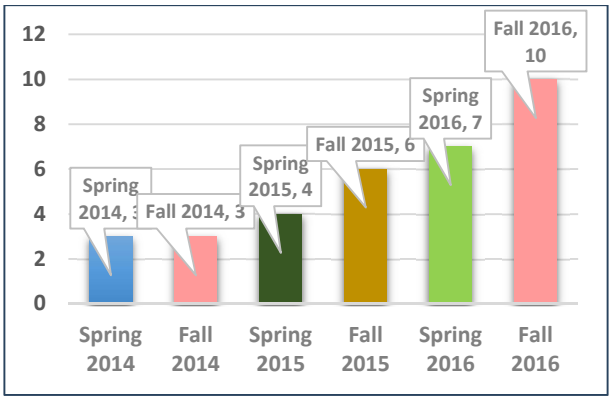


Figure IN-1: Growth in participating professors

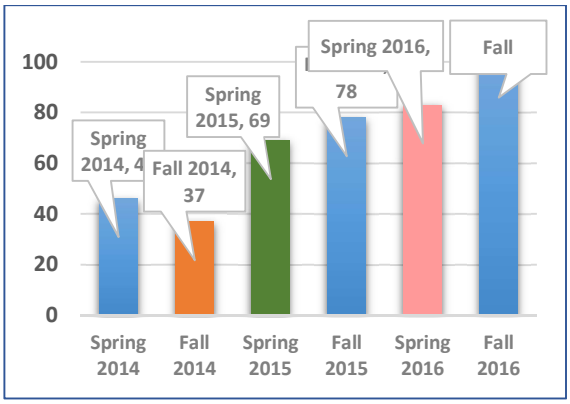


Figure IN-2: Growth in participating students

VIP Program Composition: Inha University established its VIP Program in Spring 2014, with 46 students enrolled in 3 research subjects. With the purpose of improving undergraduates' integrated research ability in diverse engineering disciplines, the VIP program becomes a unique course where all grades (from freshmen to seniors) from multidisciplinary majors not only in

engineering, but also in arts and social studies, work on projects lasting for several semesters. In Fall, 2016, it has grown to 106 students in 10 research subjects (Figures 1 and 2).

Table IN-1 : Course credits and Participating departments

Course name (Course ID)	Credit	Departments
VIP 1 (ACE9501)	In-major elective	Mechanical Engineering Naval architecture & Ocean Engineering Chemical Engineering Polymer Science and Engineering Applied Organic Materials Engineering Civil Engineering Geoinformatic Engineering Architectural Engineering Information and Communication Engineering Visual Communication Design
VIP 2 (ACE9502)	In-major elective	
VIP 3 (ACE9503)	In-major elective	
VIP 4 (ACE9504)	Free elective	
VIP 5 (ACE9505)	Free elective	
VIP 6 (ACE9506)	Free elective	
Total	6 credit	

Unique to this Program: Since 2015, industrial enterprises related to each research subject have participated in the VIP program through mentoring supports and student evaluation. Ten VIP teams opened in Fall, 2016:

· Intelligent automobile technology
· Reconfigurable Share-Use Mobility System (PACE Project)
· Chemical sensitive sensor development
· 3D measurement technology
· Smart Monitoring
· Smart Sensing
· Planning and designing creative products using MCU (Micro Controller Unit)
· Study on the convergence between ceramic product and 3D printing technology
· Development of Minimum Viable Product (MVP) using Lean Startup

In Spring, 2017, two research subjects regarding Deep learning and Big-data analysis will be added to Inha's VIP program, and more students are expected to enroll.

Morehouse College VIP Program

About the Institution: Morehouse College is an independent, fully accredited, historically black liberal arts college for men founded in1867, enrolling approximate 2500 students. The College is a founding member of the Atlanta University Center, a consortium of six independent institutions forming the largest private center of black higher education in the world. Morehouse College is one of only three historically black colleges, and one of only four Georgia colleges with a chapter of Phi Beta Kappa.

Initiating Department: Department of Computer Science

About the Implementation: African Americans constitute 12 percent of the U.S. population and 11 percent of all students beyond high school. In 2009, African Americans received just 7 percent of all STEM bachelor's degrees, 4 percent of master's degrees, and 2 percent of PhDs, according to the National Center for Education Statistics. From community college through PhD level, the percentage of STEM degrees received by blacks in 2009 was 7.5 percent, down from 8.1 percent in 2001. We believe a major reason for this low representation is that African Americans are not exposed to the exciting potentials in STEM fields. Just taking classes in STEM fields is not enough to spark the creativity and desire of students to pursue careers and advance degrees in STEM.

It is our hypotheses that the VIP program, which integrates and engages students at various levels of education in STEM research projects, is a significant key to increasing the number of African Americans graduating with STEM degrees and advancing science and technology in the world. It continues to be our goal through implementing VIP, to increase the number of African Americans in STEM fields. Serving as an undergraduate-serving institution, the VIP program creates opportunities for collaborations with institution that have graduate programs. This also encourages an increase in graduate degrees potentially leading to terminal degrees in STEM.

VIP Program Composition: To date our VIP projects are based on Faculty research interest in Computer Science, Physics, and Chemistry. For example, we have a Robotics Team led by a Professor in the Physics department. This team has been at Morehouse for about 2 years and they placed 4th in Spring 2016 at a national robotics competition at Kenny Space Center in Florida.

Unique to the Program: To expand the breath of projects, Morehouse VIP teams have partnered with Tech companies such as Google and StatRow (a small startup in Atlanta). Both companies provided software engineers to lead a VIP team over a semester. Other companies such as Facebook and Amazon have expressed interest in leading teams. We see these collaborations as promising ways to expand our VIP program.

Purdue University VIP Program

About the Institution: Purdue University, the home of the first Vertically Integrated Projects program, is a large, public, Midwestern land-grant institution. Its Carnegie Classification of Institutions of Higher Education is “Highest Research Activity [22].”

Initiating Department: Electrical and Computer Engineering

About the Implementation: The Purdue VIP Program is curricular, having three different ECE courses which correspond to their academic level (sophomore, junior, and senior) for which students can register. Each of the three courses can be taken for one or two credits. It is the goal of the program directors to expand to course numbers beyond ECE and the College of Engineering, including the creation of campus-wide course numbers. Within ECE, up to six (6) credit hours of VIP courses can be used as EE Electives. In addition, two credits of junior or senior level VIP courses can be used as an upper-level lab. The directors are working to have VIP included as an option for completion of the Senior Design requirement. The program

includes professional development workshops so that students can develop key professional skills such as leadership and communication.

VIP Program Composition: The VIP Program at Purdue University has continued since its conception in 2002, with most activity in the School of Electrical and Computer Engineering (ECE). Participation in the program has increased over the past four semesters as shown in Figure P-1. The program has also become more interdisciplinary as it currently includes teams supervised by faculty advisors from the Schools of Aeronautics and Astronautics; Civil Engineering; Mechanical Engineering; Earth, Atmospheric, and Planetary Sciences; Library Sciences; and Psychological Sciences. The program has dedicated academic space for team meetings and project development.

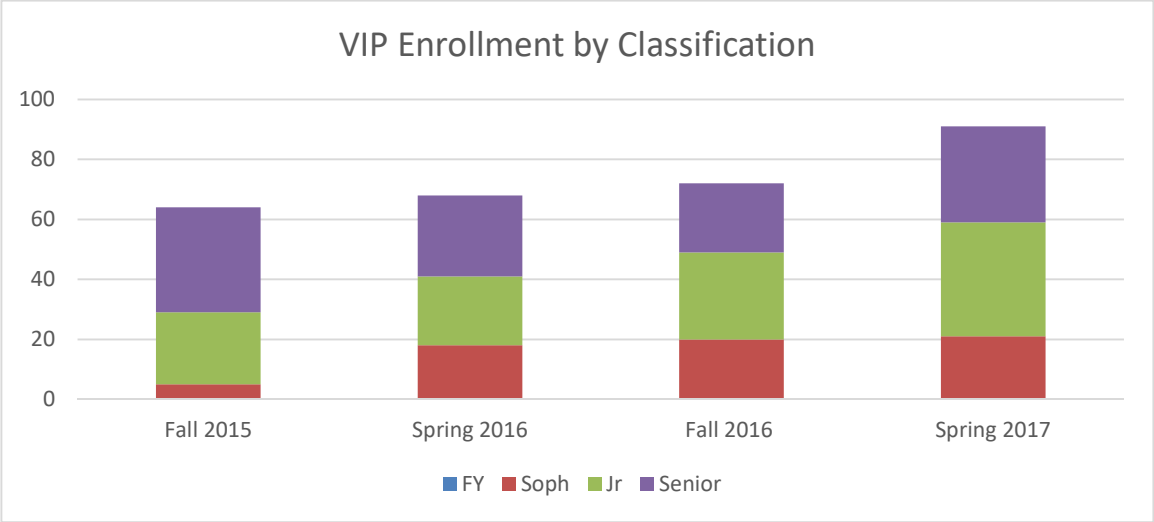


Figure P-1: Purdue University VIP Enrollment by Classification

Several of the teams have close engagement with external partners that are companies or government agencies. The accomplishments of one team has resulted in the award of a large National Science Foundation (NSF) grant to the team advisor and the formation of a start-up company that has been awarded an NSF Small Business Innovative Research (SBIR) grant.

Unique to the Program: The Purdue VIP student assessment process is modeled after performance appraisal systems used in industry and academia. Students submit self-evaluations of their accomplishments and learning periodically during the semester and includes references to where evidence of their accomplishments and learning can be found. Faculty advisors evaluate the students' work and provide formative feedback to improve student learning and success.

Rice University VIP Program

About the Institution: Rice University is a small private university with a strong research focus in science and engineering.

Initiating Department: Electrical and Computer Engineering

About the Implementation: VIP at Rice provides the time and context to learn and practice professional skills, to make substantial contributions, and experience different roles on large multidisciplinary design and discovery teams. The long-term nature of VIP creates an environment of mentorship, with faculty and graduate students mentoring teams, experienced students mentoring new members, and students moving into leadership roles as others graduate.

The Rice VIP Program continues to grow with the fifth through seventh teams beginning in 2017. The projects directly relate to current and developing long-term research projects at Rice. The initial teams were run by faculty in the Department of Electrical and Computer Engineering (ECE) and included graduate and undergraduate students from ECE, Computer Science, and Mechanical Engineering. Recently a VIP team led by a faculty member in Mechanical Engineering has joined the list. Each of the projects is led by a faculty member and typically includes undergraduate, professional masters, and MS/PhD graduate students.

In order to join a team, students interested in VIP projects meet and consult with the faculty lead of that project. Each student must fill out a project application form and include an abstract of their project goals, their role in the project, and planned results for the semester. Undergraduates then enroll in ELEC 491 and graduate students in ELEC 591 while mechanical engineering students may enroll in a section of MECH 490. The courses are comprised of theoretical and experimental investigations under faculty direction and students are graded on their contributions to the team. ECE students participating in VIP projects for 3 or more semesters may be eligible for the Distinction in Research and Creative Works graduation award based on the recommendation from their faculty advisor.

Undergraduate research is greatly encouraged at Rice and the VIP program is promoted through multiple channels including the Rice Research Fair each semester; the IEEE Student Branch advising lunch meetings; in the ECE Department Orientation Week materials; and on the departmental web site. The VIP program also includes a website at the university level (vip.rice.edu). Undergraduate and graduate Rice VIP students earn academic credits, while faculty benefit from the design and discovery efforts of their teams.

VIP Program Composition: Rice VIP students usually begin as sophomores or juniors and then continue their project as seniors in coordination with the Capstone Senior Design sequence. Senior students on VIP teams have the option of working on a subset of the VIP project for their capstone project. This pathway allows for undergraduates to be part of a VIP team and also satisfy their BSEE degree requirements. Participants on VIP teams have generated some research publications as well. In 2016, one of the Rice VIP students received Honorable Mention in the Computer Research Association's Outstanding Undergraduate Researchers program based in part on two conference papers that she wrote related to her VIP project. One of the papers entitled “Decentralized Data Detection for Massive MU-MIMO on a GPU Cluster” was submitted to the 2016 Asilomar conference meeting. The new cardiac team is submitting a paper to the 2017 Asilomar conference, “Real-Time, Nonparametric Algorithm to Learn Parameters for Pacemaker Beat Detection.” *A Digital Cure for Epilepsy* will also enter a paper, “FPGA System for Real Time Seizure Prediction” at that conference.

In addition to garnering external recognition, VIP teams at Rice have won institutional awards. Ictal Inhibitors (*A Digital Cure for Epilepsy)* won the top prize, The Excellence in Engineering Award, in the George R. Brown Engineering Design Showcase held April 13, 2017 (Figure R-1a). At the Rice ECE Corporate Affiliates Day, Teams *DISSECT* and *Digital Gym* won first and second place in the Best Undergraduate Research category while *PHAST* earned second place in the Graduate Demo category.

Unique to this Program: Each Rice VIP team has access to dedicated work and meeting space. In addition, students have access to the EtherNest, a unique space in the ECE department that provides students with space and equipment to use their engineering skills creatively in a self-motivated and unstructured setting. Many undergraduate engineering design projects, including capstone design projects, are largely performed in the Oshman Engineering Design Kitchen (OEDK). The OEDK has a wide range of facilities for supporting design projects, including: machine shop, wood shop, 3D printers, laser cutters, wet lab, poster plotter, electronics assembly and test area, team tables, meeting rooms, classrooms, computer clusters, and test equipment. OEDK teams consistently win numerous national-level awards every year. The OEDK has set up dedicated workspaces for VIP teams that are typically used by VIP capstone teams. Also, the Rice Center for Engineering Leadership (RCEL) is available to all engineering undergraduates and offers a wide variety of courses and programs related to engineering practice that are not discipline-specific. RCEL staff and faculty have identified ENGI 218, Engineering Leadership Lab I, as an ideal leadership course for Rice VIP students.

Four of the Rice VIP teams are well established with three new teams beginning in 2017. The first new team is focusing on wireless cardiac pacemaker research led by Behnaam Aazhang, Aydin Babkhani, and Joseph Cavallaro in ECE in collaboration with the Texas Heart Institute. This new cardiac pacemaker VIP team consists of a senior design project developing new multi-site pacing algorithms running on an FPGA sensor and stimulus platform. A team of juniors has been working with the seniors and next year will integrate wireless sensing and stimulus and develop a pacemaker ASIC. The second new team is in Mechanical Engineering with a focus on semi-autonomous pipeline- and tank- inspection robotics for the energy industry and is led by Fathi Ghorbel. The third new VIP team is developing low-cost medical equipment in collaboration with doctors at Texas Children's Hospital, Baylor College of Medicine, and Shriners Hospital. In the following paragraphs, a brief introduction from the http://vip.rice.edu web site is given on each of the four established teams:

A Digital Cure for Epilepsy (Figure R-1b), Faculty Project Leader: Behnaam Aazhang, ECE; Epilepsy is the 4th most common neurological disease in the United States. Unfortunately, 30% of the patients don't respond well to traditional treatment like drugs. For those patients, the only permanent treatment is resection of the part of the brain whose hyperactivity is the root cause of seizures. This method is invasive and carries high risk. Thus, reliable alternative treatment is needed. By predicting seizure before its onset, doctors could act preventively with actions that include stimulation treatment recently proposed. To facilitate that, scientists at Rice University and the University of Texas Health Science Center work together to develop algorithms that will optimize the development of an implantable device. The device will deliver low-frequency electrical stimulation to the seizure onset zone. Once the prototype is developed, the group would pursue clinical trials. This year's VIP team focused on building an FPGA based seizure

prediction system as the first step to an all CMOS implementation that will be the target next year (see http://dce.rice.edu/).

Figure R-1a: Ictal Inhibitors – A Digital Cure for Epilepsy (2017 Senior Design Team)

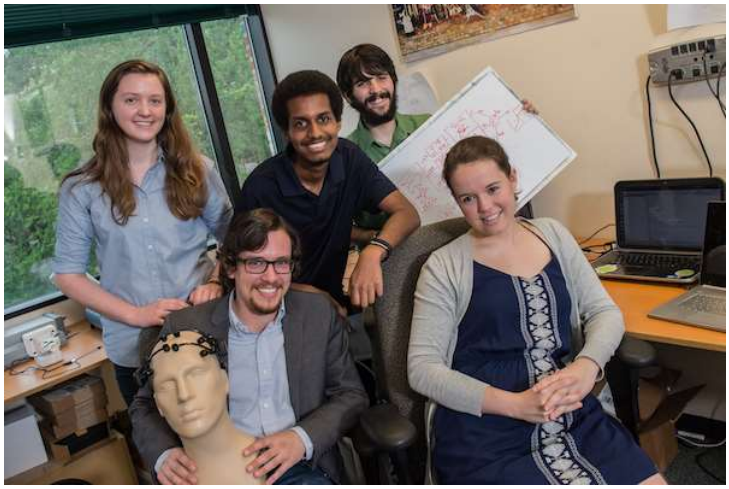


Figure R-2b: A Digital Cure for Epilepsy (2016 Team)

Digital Gym, Faculty Project Leader: Ashutosh Sabharwal, ECE; Imagine a gym that helps you keep track of your exercise, its intensity, its correctness and your vitals while you focus on exercise. The team is developing technologies that will convert any gym into the digital gym of the future. Digital Gym is a project in the world's first Quantified Communities (QC) movement launched by Rice Scalable Health Initiative.

Team DISSECT: DIStributed Sensors, Effectors and Computers Team (Figure R-3), Faculty Project Leader: Ray Simar, ECE; The inspiration for this VIP team came from two efforts of senior teams attacking a problem from the 15th century: how to putt correctly during golf. The requirement that their high-tech putter designs be indistinguishable from a regulation putter

resulted in what was often characterized as “a high-performance computer with a very unusual case.” Team DISSECT was thus born and has been targeting other applications that require a spatially distributed system of sensors and effectors wired to a central computing system. The third effort was an autonomous motorcycle built on a radio-controlled motorcycle platform. Recent work has included a new four-layer PCB to act as the central CPU hub. This project, code named Wrigley, has an 80 MHz ARM floating-point CPU, a USB port, a JTAG test and emulation interface, multiple switches and LEDs, and 100 connections brought to the external world, all in the footprint of a piece of chewing gum. Future work is considering opportunities with Rice 360 for their BreathAlert system (a neonatal monitoring system for under-resourced communities) and the Rice student rocketry club, Eclipse. Team DISSECT is also investigating making their work available through a maker space community portal, such as www.hackster.io.

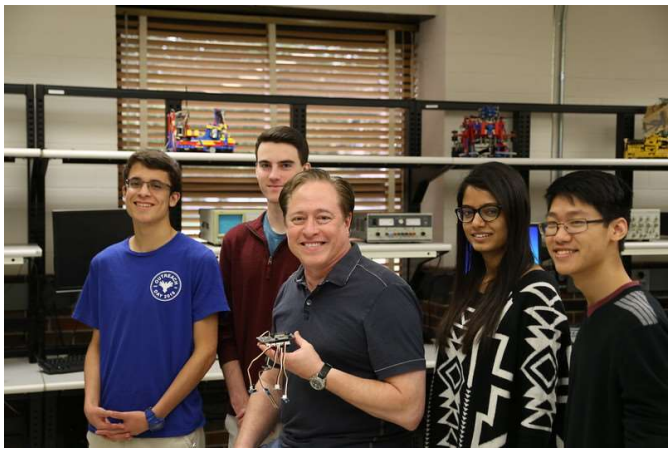


Figure R-4: DISSECT

Parallel Hardware Applications in Science and Technology (PHAST): Faculty Project Leader: Joseph Cavallaro, ECE; Recent advances in VLSI technology are enabling fast computing systems with tens and hundreds of processing units. These range from field programmable gate arrays (FPGA) to graphics processing units (GPU) to multi-core processors, such as the Intel Xeon Phi. These parallel systems can be used to accelerate applications in wireless communications, image processing, and data science. Current projects focus on signal processing algorithms for 5G base stations for large scale or Massive MIMO wireless communications systems. Parallel programming environments and software tools such as CUDA, OpenMP, OpenCL, and MPI are used on systems from mobile GPU system-on-chip devices (SoCs), to high performance desktop GPUs to supercomputers at the Texas Advanced Computing Center.

Texas A&M University VIP Program

About the Institution: Texas A&M University is one of the largest universities in the nation (total enrollment: 64,373; College Station campus: 57,934; total undergraduate enrollment: 49,545; doctoral enrollment: 4,887; total enrollment of underrepresented minority students [Hispanic, African American, and Native American]: 14,766 [22.9% of the entire student population]). Diversity at Texas A&M is an indispensable component of academic excellence,

essential to and integrated with creating a culture of preeminence. Texas A&M's focus on increasing diversity among faculty, students, and staff is demonstrated in many ways. The University Diversity Plan (Texas A&M University, 2016) is designed to enhance accountability, climate, and equity and facilitates steady progress toward greater inclusion and academic excellence. Additionally, diversity is embedded in the strategic plan of each college, including Engineering. The Texas A&M College of Engineering is one of the largest in the nation (total enrollment 15,189; undergraduate enrollment: 11,627) and will continue to grow with the January 2013 announcement of the 25 by 25 initiative to increase the engineering workforce of Texas and the United States [24]. The initiative will increase total engineering enrollment to 25,000 (approximately double the 2012 enrollment) by the year 2025. Targets for the 25 by 25 initiative include: women comprising 35% of the enrollment, Underrepresented Minority (URM) students also comprising 35% of enrollment, and a six-year graduation rate of 75% for first-time-in-college students [24]. Thus, Texas A&M is poised to become a national leader in broadening participation in engineering.

About the Implementation: AggiE_Challenge (the local name for the Texas A&M University VIP program) launched in 2012 with a focus on providing engineering undergraduates, freshmen to senior, an opportunity to join a multidisciplinary team and work on faculty-led research projects investigating aspects of grand engineering challenges. Students are encouraged to participate in the program for two or more semesters and receive course credit that may satisfy degree requirements as set by each major, requirements for the honors program or requirements for the Grand Challenges Scholars Program. Each student team consists of ten or more engineering undergraduates representing and at least three majors. All teams have access to a dedicated graduate student mentor for technical support and project management. Additionally, program participants have access to the Engineering Innovation Center, a 20,000 square foot makerspace with fabrication, 3D printing, and electronics resources offered at zero cost to students. Project topics range and include, among others, topics such as effective oil recovery from oil spills, desalination of water, manufacturing of tissue-mimetic hydrogels, alerts for epileptic seizures, and bio printed cancer models.

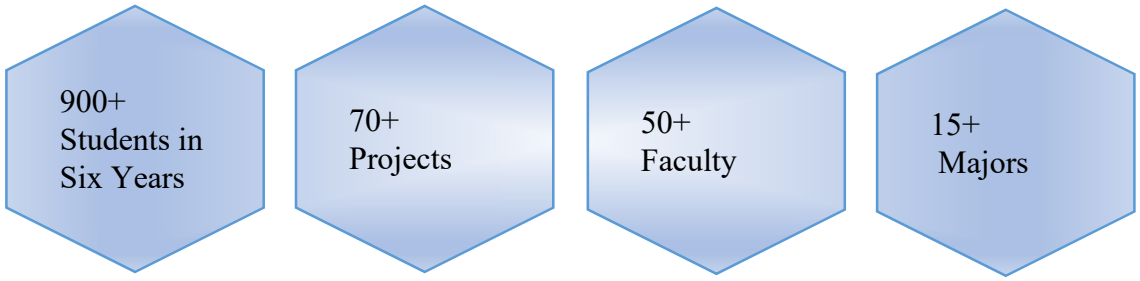


Figure TAMU-1: Texas A&M VIP Program Goals

The program goals include: 1) Increase the number of engineering undergraduates pursuing research, 2) Increase the number of students collaborating in multidisciplinary projects for course credit, and 3) Increase awareness about grand engineering challenges in our society.

Approach: Each spring semester, the college invites interested faculty to submit proposals to the AggiE_Challenge program for the following academic year. Successful proposals include a suitable research project for undergraduate teams, connect the project to grand engineering

challenges and the faculty's respective area of research, prove the availability of graduate mentors, and include any external connections which will enrich the experience for the students. A faculty committee then reviews and makes recommendations to the college. Funded projects fall into two categories: Option 1 – faculty mentors a team of ten or more engineering undergraduates representing at least three majors, Option 2 – faculty mentors a team of five or more students who represent two or more majors. Faculty receive stipend support for graduate mentors and also project supply funds.

VIP Program Composition: The program is on its sixth year and has had more than 900 students participate in the program for one or more semesters. The program attracts a high percentage of females (25% to 30%) and surpasses the percentage of females in the college. Figure TAMU-2 shows enrollment data since program inception while Figure TAMU-3 includes participant majors for Fall 2016.

Student Testimonials:

> "Collaborating with different people from different technical backgrounds is the biggest advantage of the program in giving students the ability to learn from people with different perspectives and gain a wider view of engineering."
>
> "This program has inspired me to create; I have now begun my own microcontroller project thanks to the things I learned in this class. The senior mentors were very useful thanks to their large pools of knowledge and experience. I would be interested in pursuing a STEM degree in graduate school. This program helped me rediscover the beauty in engineering."

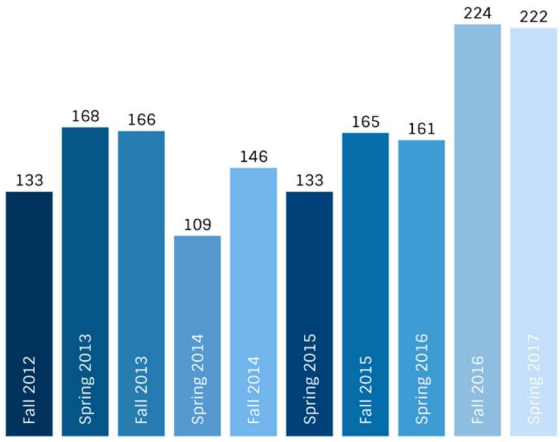


Figure TAMU-2: Enrollment Data.

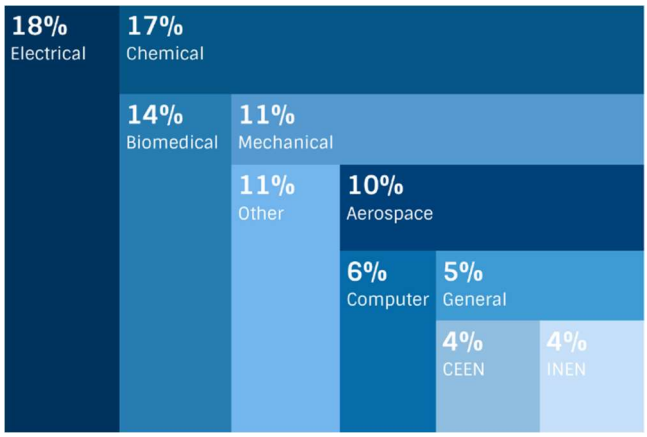
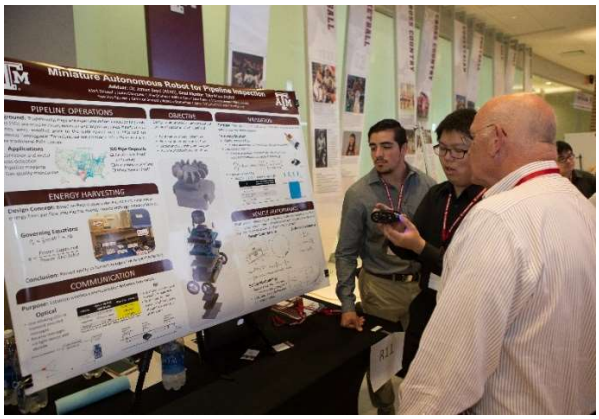


Figure TAMU-3. Major Demographics (2016 Fall)

Unique to this Program:

Lean Launch Program – In summer 2016, the college offered a pilot program called the Lean Launch Program in which select undergraduate program participants and graduate mentors explored the commercial potential of their projects through extensive customer research. Five teams successfully completed the program and provided a strong impact on the faculty projects. The college has just been awarded a National Science Foundation I-Corps Sites award ($500K) which will support select teams in the next five years.

Engineering Project Showcase – Program participants have an opportunity to present their project work at the annual Engineering Project Showcase (Figure TAMU-4 and Figure TAMU-5) and compete for awards.



Figures TAMU- 4 & 5 - Program participants presenting their work to industry at the annual showcase.

University of California – Davis VIP Program

About the Institution: The University of California Davis (UC Davis) enrolled in Fall 2016 its most culturally and geographically diverse body of undergraduate and graduate students in the history of the campus to engage with faculty and research staff in STEM, social sciences, agriculture, veterinary, and human medicine programs.

Initiating Departments:

Department of Molecular and Cellular Biology, College of Biology
Department of Physics, College of Letters and Science
Department of Plant Pathology, College of Agriculture and Environmental Sciences

About the Implementation: The UC Davis VIP program engages undergraduate students in a research-based learning environment grounded in a collaborative, inter- and multi-disciplinary framework throughout their sophomore, junior, and senior years. The VIP program is already providing mentoring and teaching opportunities for graduate students, postdoctoral associates, and research personnel; it has been well received and will grow into an integral component of research and teaching. The significant aspects of VIP program at UC Davis are provided here. The UC Davis VIP program can be accessed at http://vip.ucdavis.edu/.

VIP program management: UC Davis has a strong tradition of shared governance. The VIP program is co-directed by three faculty members, Subra Muralidharan (Department of Molecular and Cellular Biology, College of Biology), Daniel Cox (Department of Physics, College of Letters and Science) and David Rizzo (Department of Plant Pathology, College of Agriculture and Environmental Sciences). The co-directors provide leadership and direction in a consultative manner.

VIP course credits: Students in the VIP program are earning graded credits through the Science and Society (SAS) program [http://ucanr.edu/sites/sas]. Sophomores earn SAS 98 credits, and juniors and seniors earn SAS 198 credits. Unique course registration numbers (CRNs) are generated for each team and the PIs award grades each quarter using the criteria of documentation and records (33%), personal accomplishments and contribution to the team's goals (34%), and teamwork and interaction (33%). VIP teams have weekly group meetings to discuss research progress, research plan, and literature discussion to facilitate a stimulating learning environment in which students can develop their research, problem solving, critical thinking, and communication skills.

VIP student recruitment: Recruitment of undergraduate students to the VIP teams is accomplished through multiple mechanisms:

1. The VIP website provides information about the teams and an application tab. Students can identify one team to apply by providing information on their major, year of study, GPA, and most importantly a 200-word description of their motivation to join the team. The applications are centrally received and distributed weekly to the team PIs who accept students that best fit their program. Students who do not get into their groups of choice can then apply to another group. We find this process to work well for the students and PIs. The average placement rate is 80% for Fall 2016 quarter. Teams typically have 4-8 students.
2. Two half day symposiums on September 23 and 30, 2016 provided information to students and faculty about the VIP program which helped in recruitment.
3. The Undergraduate Research Center (URC) provides information to students about the VIP program.
4. The participation of VIP students in the 28th Annual Undergraduate Research, Scholarship & Creative Activities Conference, April 28 and 29, 2017 will provide further visibility to the program.
5. We are working with CAMP (California Association for Minority Participation), MURPPS (Mentorship for Undergraduate Research Participants in the Physical and Mathematical Sciences), BUSP (Biology Undergraduate Scholars Program), and UHP (University Honors Program) to target URM students for the VIP program.
6. We are planning to work with the transfer opportunity program (TOP) and transfer admissions guarantee (TAG) programs supported by the state of California to recruit URMs for STEM early in their education for the VIP program. We are actively formulating plans to set up VIP incubators at community colleges in collaboration with UC Davis VIP groups to recruit the TOP and TAG students in their freshman year and provide them an opportunity to spend part of the summer at UC Davis performing research. Those who transfer to UC Davis will be able to continue in the VIP program.
7. Starting an M.S program in molecular biosciences is in active discussion to provide a M.S. degree with thesis a year after baccalaureate for those students who have been enrolled in the VIP program from their sophomore year. This would be attractive to students contemplating a break year to explore their career options.

VIP activities: Significant activities related to the VIP program so far are:

1. A VIP symposium was held for half day on September 23 and 30, 2016.

2. Students in the VIP program will be presenting posters and talks at the 28th Annual Undergraduate Research, Scholarship & Creative Activities Conference, April 28 and 29, 2017.
3. VIP program is working with Seed Central (http://www.seedcentral.org/) to identify research opportunities for VIP teams to collaborate, and to provide internship and employment opportunities for VIP students in agriculture and related fields.
4. VIP program is developing close relationships with Davis-Sacramento area biotechnology companies to develop research projects with VIP teams and provide internship and employment opportunities for VIP students. The Seed Central and biotechnology industrial relationships will be critical to the implementation of the M.S. program.

VIP Program Composition: A diversity of students from the Colleges of Biological Sciences; Letters and Science; Engineering; Agricultural and Environmental Sciences; and Veterinary Medicine are currently enrolled in the VIP program. This includes students majoring in biochemistry, microbiology, neuroscience, chemistry, physics, chemical engineering, mechanical engineering, biomedical engineering, plant science, veterinary medicine, and medical school are enrolled in the VIP program.

VIP research: The current VIP team research consist of the following areas:
1. Structure-guided vaccine designs.
2. Amyloids for Nanoparticle Synthesis, Wiring, Energy, and Remediation (ANSWER).
3. Real-Time Data Analytics for the Assessment of Pathologic Patient-Ventilator Interactions.
4. Bacterial isolation and genome sequencing in the modern age.
5. Multi-scale understanding of microbial systems and their application to facilitate sustainable and healthy solutions.
6. Design, fabrication, and characterization of addressable biomembrane arrays for nanomedicine.
7. Practical learning analytics for undergraduate education.
8. Design and evaluation of nanoscale drugs for glioblastoma.
9. Searching for broad spectrum anti-virals among membrane-active molecules.
10. Sudden oak death and phytophthora ramorum.
11. Rice plant infection resistance.
12. Predicting stem cell potency and effectiveness.
13. Course-based undergraduate research experiences (CUREs).

Unique to the Program: Unlike most VIP Programs that originate in Engineering, the UC Davis VIP Program is based in the sciences. Co-management of the Program by faculty from three colleges (College of Biology, College of Letters and Science, and the College of Agriculture and Environmental Sciences) allows for more rapid dissemination through the institution and adoption by faculty and academic units.

University of Hawaii VIP Program

About the Institution: The University of Hawaii is partnered with the highly successful *Native Hawaiian Science & Engineering Mentorship Program*, which has attracted and retained a large

number of Native Hawaiian and Pacific Islander students, an underrepresented group in STEM fields.

Initiating Department: Electrical Engineering

About the Implementation: The VIP program is housed at the University of Hawaii's main campus, Manoa. However, the University of Hawaii System consists of ten campuses, including two-year community colleges. A VIP partnership has recently been created between the main Manoa campus and five other University of Hawaii campuses (Kapiolani Community College, Honolulu Community College, Leeward Community College, Windward Community College, and Maui College). Students in their last semester at the partner campuses will take a VIP course and work with existing VIP teams at the Manoa campus. Then, these students will transfer to the Manoa campus and will continue work on their VIP team. This will help to create seamless pathways for these transfer students, and should help with the retention of these students, as they will already belong to a cohort of students on the Manoa campus (their VIP team).

VIP Program Composition
Since the VIP program started in January 2015, the number of VIP students has grown from 70 to over 200, and the number of VIP teams has grown from 3 to 12. The VIP teams are organized around the following themes:

- The College of Engineering has a strong *robotics* program spanning microrobotics to marine (submersible and surface) robotics to aerospace (drones and small satellites) and surgical robotics.
- The University of Hawaii has a strong astronomy program with access to real telescope time for developing astronomical instruments, ideal for a VIP focus area in *space and astronomy*.
- The University of Hawaii System has made it a priority for its students to be part of the "Maker Movement," supporting a VIP focus area in *rapid prototyping and re-manufacturing.*
- The fourth focus area is in *sustainability*. As the most isolated land mass in the world, Hawaii has a vested interest in sustainability in many areas: architecture, energy, food, water, and transportation. This focus allows rich multidisciplinary VIP opportunities across many academic disciplines.

Microrobotics VIP: This project involves the design and implementation of various control systems for microrobots, which are sub-millimeter-sized micro-actuators. This team uses optically controlled microrobots, in which light generates thermal gradients that create actuation forces. The microrobots can be used to assemble cells in specific locations, which can enable studies on cell-to-cell communications, give insight into treating various diseases, and help to grow functional tissues in the laboratory. Members of this VIP team have also participated in the annual Mobile Microrobotics Challenge, and won first place in the Mobility Challenge in 2015.

Liquid-Metal Electronics VIP: This project seeks to develop various reconfigurable electronic devices using liquid metal. Liquid metal can reflow to form conductive elements of varying shapes and sizes, resulting in the tuning of circuits. The aim is to make the tuning of electronic devices as straightforward as drawing patterns on an Etch-A-Sketch toy. Liquid metals have been used to implement frequency-tunable antennas and filters, and tunable matching networks that

can used to efficiently couple RF components. A junior-level VIP student on this team has authored and presented a paper on this research at an IEEE conference.

Space and Aerial Robotics VIP: This project focuses on space and aerial robotic platforms taking the form of nanosatellites and unmanned aerial systems (drones). Our lab has developed several generations of nanosatellites, ranging in size from a loaf of bread to a golf ball. The reduced development time and launch cost of these small satellites have made them attractive for applications ranging from technology demonstrations to biological experiments to space weather research. Our VIP team is also developing unmanned aerial systems using autonomous surveillance and image detection to aid in search-and-rescue relief efforts. In 2016, the team went to national competition and is anticipated to participate again in 2017.

UXS Kanaloa VIP: The Unmanned X Systems (UXS) development group is aimed towards the advancement of Unmanned Systems technologies. The need for robust software and hardware robot platforms, often equipped with expensive sensors and instrumentation, creates a high barrier of entry to the field of robotics and unmanned systems. By following the VIP academic framework, this group aims to engineer robust unmanned aerial, surface, and underwater platforms for practical applications. Success in development tasks was defined by culminating participation in the AUVSI RobotX competition in December 2016.

Manoa Astronomical Technologies VIP: This team develops new or improved astronomical instruments. In its first year, a 12.5" primary mirror, Newtonian-style telescope dubbed Pioneer 01-A was designed and manufactured. Currently the team is working on a novel counter-balanced primary mirror constraint system which improves collimation and stability throughout all viewing vectors. The team intends to transition these technologies to larger mirror systems starting with a 24" mirror polish in Summer 2017.

Rapid Prototyping VIP: As a part of the Makeschools initiative, this project focuses on building novel devices that make use of 3D printing, laser cutting, printed-circuit-board milling, and nanotechnology including 2D materials. One subgroup is closing the loop on 3D printing by creating realtime feedback to ensure quality printing and enable new printing methods. One subgroup is using the technology to make a 3D wind harvester. The graphene subgroup has published results in *IEEE Transactions on Electron Devices* and will present at *Graphene 2017* in Barcelona, Spain. Many students go on to actively pursuing entrepreneurship through the campus-wide Breakthrough Challenge and the Business Plan competition.

Smart Campus Energy Lab VIP: Students work on projects associated with energy and sustainability, involving hardware, software, and systems. Our major project involves building low-cost self-powered weather boxes that gather environmental data (solar irradiation, temperature, humidity, wind speed, and direction). Other projects involve low-cost acoustic and ultrasonic wind sensors, and forecasting solar irradiation. Work in the SCEL has been presented at the *Clean Technology Conference and Expo* and in the journal *Sensors and Transducers*.

Open Power Quality VIP: This project involves the design and implementation of open source hardware, software, and data for low cost, crowd-sourced power quality monitoring, storage, and analysis. In Hawaii, increased use of renewable energy sources such as rooftop solar is hampered

by a lack of understanding of the local impact of distributed intermittent power generation on voltage, frequency, THD, and other power quality measures. Members of the VIP OPQ team won second place in the student division at the 2016 Booz Allen Ideas Festival in Honolulu, HI.

Unique to the Program: The University of Hawaii Manoa's partnership with five community colleges increases the program's reach, with the intention of increasing transfer student retention. Through this partnership, students from the community colleges can join VIP teams before transferring to the Manoa campus, after which they will continue with their teams. This will help to create seamless pathways for these transfer students, with their ties to their VIP teams providing both connections and support at the new campus.

University of Michigan VIP Program

About the Institution: The University of Michigan is a large public Research University, located in Ann Arbor, enrolling approximately 43,000 students.

Initiating Department: Multidisciplinary Design Program

About the Implementation: *Institutional Support:* The unique learning environment created by the teams of the VIP program aligns and supports greater university-wide initiative for "Engaged Learning." This has allowed the VIP program to integrate well with the College of Engineering, and has led to institutional recognition. One program which is complimented well by the VIP program is the Undergraduate Research Opportunity Program (UROP); UROP creates one-on-one research experiences for first- and second-year students. First year students can participate in UROP as a member of a VIP team. This program synergy allows students to join a continuous, multifaceted research experience that can last their entire undergraduate career.

New Team Formation & Growth: VIP teams at the University of Michigan begin with informal discussions about the program and its relationship to a faculty research agenda. Formal organization begins with a series of meetings between faculty PI and the program manager, part of the staff of the Multidisciplinary Design Program within the College of Engineering, discussing: short and long term goals of the PI, timing, etc. An organizational plan is created for both the nascent organization, termed a "seed team" (first 1 or 2 semesters) and a "steady state" organization. Initial student/subteam roles and reporting structures are defined. "Seed" teams are often staffed by students currently working with faculty. The "Seed" team members become the first leaders within the research group as it starts to expand. Seed teams are typically 4-6 students often growing to a steady-state size of 15-20 by the 3rd semester. Teams are supported in recruiting by annual recruitment events and online solicitation, as well as a matching process for linking new students with appropriate teams based on skills and preference.

Day-to-Day Team Management: Each VIP team at the University of Michigan is organized around weekly or bi-weekly meetings, which may take place at multiple times and locations in the case of large VIP teams that tend to incorporate multiple subteams. Students are encouraged to prepare some sort of presentation or report (the exact format of which is up to faculty discretion), wherein they discuss what they accomplished in their individual work time, what issues they may have encountered that hindered progress, and proposed courses of action for the

next work period. Meetings serve as a chance for each student to seek guidance from the faculty and other team members, and the sharing of progress serves as an accountability mechanism that documents individual effort.

The Student Experience: Students joining a VIP team must enroll for credit and participate for a minimum of two semesters. While students are only required to enroll for two semesters, they are highly encouraged to remain with the team to develop a deeper understanding of the domain and take on leadership (technical or organizational) positions. The ideal is that students participate for 5-7 semesters. Each semester students participate via a 2 credit course, which translates into approximately 6-8 hours per week of total work time, some of which is spent in team meetings. Should the efforts of a VIP team result in publishable or patentable work, students are included as authors and student inventors (respectively), allowing them to cultivate tangible accomplishments beyond grades and experience alone.

Program Composition: As of January 2017, the VIP program at the University of Michigan consists of 172 students distributed among 12 unique teams (2 new in 2017), ranging in size from 6 to 37 students. Approximately 25% of students are female vs. 21% in the College of Engineering, 3% are from underrepresented minority groups, and 40% are non-citizens or permanent residents. A large percentage of Masters-level graduate students (26%) are also included in the program.

A total of 34 majors from across the university are represented. The majority of the students (80%) are from the College of Engineering, and 20% come from the rest of the University including Business; Literature, Science & Art; Medicine; Art & Design; Public Health; and Social Work.

Unique to the Program: *Central Support to Teams:* The VIP teams at the University of Michigan are supported by academic advising from Multidisciplinary Design Program staff, as well as a dedicated program manager. Aside from these, there are also two rather unique support mechanisms that enhance the successful implementation of the program: active management and a best practices guide. Teams that are deemed to be struggling with project management and/or student participation, which may arise naturally due to faculty lack of experience in managing large groups, are visited regularly by the program manager (who has an engineering background) at each of their team meetings and subject to "active management." The program manager first observes a team, and then participates in assigning weekly/semesterly goals and facilitating the technical discussions of the group. In meetings with both faculty and students, the program manager is able to find any disconnects between them and help ensure the team operates as a unified whole. Along with direct supervision, a "Best Practices Guide" is also shared with each faculty member at the beginning of each year. This guide, updated annually, is a compilation of observations from each of the VIP teams and showcases both the breadth of implementations employed as well as what has (and has not) worked in the majority of cases.

University of Strathclyde VIP Program

About the Institution: The University of Strathclyde is a large public institution in Scotland with over 21,000 students (14,500 Undergraduate and 5.500 postgraduate) studying across four

schools: Engineering; Science; Business; and Humanities, Arts and Social Science. There is a strong technological theme with a high level of industrial engagement.

Initiating Department: Launched Institute Wide

About the Implementation: The University of Strathclyde established its VIP program in 2012 and now has over 230 students on 8 projects spanning all four schools. The seeds of VIP were sown at University of Strathclyde in August 2010 when a visit was made by Ed Coyle who happened to be at a conference nearby. Ed has known the Academic Lead of Strathclyde VIP, Steve Marshall for many years through their common research interests. Ed delivered a talk about VIP which was well received by Teaching and Learning staff. At a Strategic Meeting of Senate some months later, the University Leadership had set the task of identifying new ideas for *Innovation in Teaching* and VIP was selected as the most exciting and innovative.

Having decided to establish a VIP Program we invited Ed to visit for an extended period and identified a series of academic staff that we felt were good candidates for leading a VIP. We brought them up to speed and asked them to identify slots in their curriculum where VIP could be accommodated. In 2012 we launched with 4 VIPs and have since doubled this.

VIP Program Composition: The VIP program has students from 22 Departments over 35 Majors from across the University. As described above these are very diverse.

Faculty have many reasons for participation in VIP. In some cases this can be enlightened self-interest by the Faculty. For example, it is now important that Life Science students gain experience of computer based tools, which can be achieved through VIP. In one project a Performance and Drama VIP can be used to generate interest in STEM subjects with the support of Science staff and students. In another project school children were encouraged to come to the University to build remote vehicles. This project was specially designed to get more girls, especially from underserved backgrounds, to become engaged in Engineering to address our targets on Gender equality and Widening access.

In the case of students, many see VIP as increasing their employability by giving them a broad set of skills from computing to project management. This is even more important in courses which are not directly vocational.

Unique to the Program: The VIP program is very diverse including the first ever projects in Humanities, Entrepreneurship, and Life sciences. All projects are multidisciplinary and some are highly cross disciplinary combining English Literature with Computer Science, Biology with Maths, and Engineering with Business.

Most of the projects have an outreach aspect engaging with local businesses, high schools, and in the field of international development. As well as having a number of VIPs in Entrepreneurship there are also Business students allocated to other VIPs to identify value and explore fundraising, licensing, and marketing. In other VIPs Business students have worked with leading research groups to identify market opportunities for emerging technologies.

With the recent increase in emphasis on Global Challenges (United Nations' Sustainable Development Goals) the VIP program is seen as an ideal vehicle to address these challenges and to bring together both the Faculty and students to learn to work together in a cross disciplinary way. As such, VIP projects are now asked to align with one or more of the seventeen Sustainable Development Goals that were launched in 2016 by the United Nations. Through VIP, Strathclyde intends to inspire our undergraduate students to make their own contribution to the overall aims of sustainable global development. The experience of co-mentoring a cross disciplinary Vertically Integrated Project can bring Faculty together and lay the foundations of joint research proposals.

In 2016 a VIP Conference was held at Strathclyde, inviting all Strathclyde VIP projects to submit a short abstract describing their research and all VIP teams were invited to deliver poster presentations at the event. A shortlist was also selected to give an oral presentation to an audience of fellow VIP students and University research staff and students (approx. 100 attended). The students' presentations and posters were judged by representatives from industry, and modest prizes were awarded. It is also worth noting that – in the true spirit of VIP involving students in 'real-world,' for-credit experiences – the VIP conference was organized by a team of students from a Hospitality Management course within the Strathclyde Business School. In 2017, an additional event modeled after Dragon's Den was introduced at the second Strathclyde VIP conference. Six VIP teams applied to participate, and four successful VIP project teams delivered a pitch at the conference for investment of up to £3000 in their VIP research. The pitches were made to a panel comprised of high-profile individuals from industry and government funding bodies. The winning team was awarded £2500 to support their research in using image processing to create new tools for drug discovery. Two other teams won £1500 each, which will support one team with their research in sustainable energy for 3rd world countries and another with their engagement with local schools. Funding for this activity was obtained via a successful application made to Strathclyde's Alumni and Development fund and was topped up by a philanthropic £500 cash contribution from a member of the judging panel.

University of Washington VIP Program

About the Institution: The University of Washington (UW) is a large public research university and is one of the oldest public institutions on the west coast. The UW has a total enrollment of 45 k students, including 29 k undergraduate and 14 k graduate and professional students. Approximately 72% of undergraduates are Washington residents. The UW is well known for its School of Medicine, College of Engineering, Michael G. Foster School of Business, and other programs.

Initiating Department: College of Engineering

About the Implementation: The UW VIP Program was established in the Spring of 2015 and is led out of the College of Engineering. The UW has taken an organic approach to its VIP implementation. It identifies burgeoning and established projects with high undergraduate participation that fit the tenets and goals of VIP and brings the framework and resources of VIP to the selected projects.

The VIP framework includes the use of graded courses, emphasis on design documentation, and encouragement of long-term student participation. VIP courses are primarily administered through departmental independent study courses and VIP-specific courses within College of Engineering. ENGR 297/497 were created in the Spring of 2015 and are 1-2 credit VIP courses for underclassmen (ENGR 297) and upperclassman (ENGR 497). The syllabi of these courses are inspired by the Georgia Tech model, as they relate to course description, learning objectives, expectations, and grading. The structure of these courses allows faculty to require student participation for at least two quarters, in order to receive graded credit. The UW VIP Program is working with departments in the College of Engineering to integrate these VIP courses into departmental curricula.

The VIP resources include project funding and student recruitment. VIP projects are funded through project-specific sponsors, the original VIP grant from the Leona M. and Harry B. Helmsley Charitable Trust, and departmental and college sources. The UW VIP Program actively recruits new students for all of the VIP projects, and prospective students can apply through the UW VIP website. Review of student applications and team membership is handled by individual projects.

Program Composition: The UW VIP Program includes seven teams involved in a range of research and design activities, including:

- AccessMap: developing navigational tool to assist individuals with mobility impairments
- DAWGMA: building new strains of microorganisms to perform new, useful tasks
- EcoCAR: redesigning a stock Camaro to create a hybrid electric vehicle
- Engineering Innovations in Medicine: working with local clinical partners to develop healthcare solutions
- OSRead: creating educational platform focused on literacy learning in populations with learning disabilities
- UW Solar: developing solar facilities on campus and with regional partners
- Engineering a Mammoth: creating procedures and technology to 3D scan and print a Mammoth skeleton

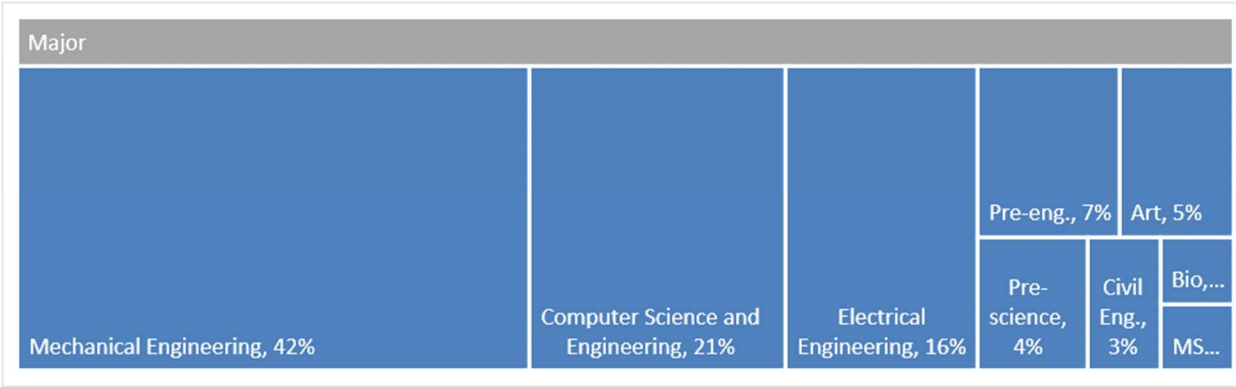


Figure UW-1: Block diagram showing breakdown of UW VIP Program students by major (MS stands for Material Science and Engineering, and Bio stands for Biology).

Figure UW-1 presents a breakdown of VIP student majors. A majority of the program's students come from the Mechanical Engineering, Computer Science and Engineering, and Electrical

Engineering Departments; however, other departments within and outside the College of Engineering are represented. The UW VIP Program includes a team (UW Solar) led out of the Department of Urban Design & Planning within the College of Built Environments. Three of the teams are led by female faculty and one is led by a URM, and UW VIP is actively recruiting additional underrepresented faculty to lead new teams.

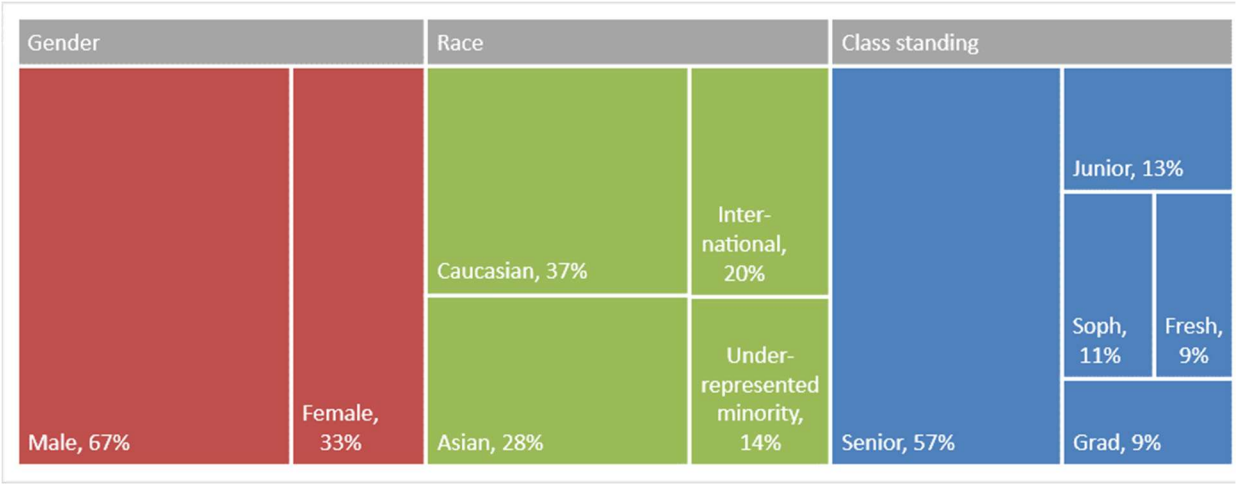


Figure UW-2: Block diagram showing a breakdown of the UW VIP Program students by gender, race, and class standing.

Figure UW-2 presents a breakdown of the demographics of the VIP students, including gender, race, and class standing. The representation of women within the UW VIP Program is higher than within the College of Engineering (33% in VIP vs. 28% in College). The representation of underrepresented minorities within the UW VIP Program is also higher than within the College of Engineering (14% in VIP vs. 8% in College).

Unique to the Program: The UW VIP Program is working to recruit underrepresented and underserved student populations and is developing processes for student recruitment and enrollment in collaboration with the Consortium to Promote Reflection in Engineering Education (CPREE). Similar to VIP, CPREE is funded by the Leona M. and Harry B. Helmsley Charitable Trust. This collaboration with CPREE helped identify barriers faced by underrepresented and underserved student populations related to involvement in activities like VIP. This collaboration shaped our recruitment efforts and messaging.

The UW VIP Program actively recruits underrepresented and underserved student populations through email and in-person outreach to engineering affinity groups, including the Society of Women Engineers, National Society of Black Engineers, American Indian Science and Engineering Society, Society of Hispanic Professional Engineers, and Phi Sigma Rho (social sorority for women in engineering). Additionally, the UW VIP Program holds poster sessions, where current VIP students present their work in a relatively casual setting, where prospective students can learn about the VIP program, as well as the work and culture of specific teams.

In our recruitment materials and presentations, we stress that prospective VIP students do not need to be experts, rather they just need to be interested and able to commit their time and

energy. Additionally, we provide team-specific expectations, including weekly time commitment, in order to help prospective students make commitments that are consistent with their other obligations (academic, familial, etc.).

Virginia Commonwealth University VIP Program

About the Institution: The Virginia Commonwealth University (VCU) is an urban, public research university in Richmond, the capitol of the Commonwealth of Virginia. VCU currently enrolls over 31,200 students making it the 2nd largest university in the state. VCU has a large active medical center that is ranked in the top 100 in the nation. In FY 2016, VCU's funded research exceeded $270 million.

VCU's School of Engineering was created in 1996. It currently enrolls over 1500 students in five engineering majors including Electrical and Computer Engineering, Mechanical and Nuclear Engineering, Chemical and Life Sciences Engineering, Biomedical Engineering, and Computer Science.

Initiating Department: Electrical and Computer Engineering

About the Implementation: The VCU School of Engineering began its VIP program in 2014 and now has over 75 students on 8 projects. The teams are comprised of students from all 5 engineering majors as well as students in biology, nursing, nurse anesthesia, and medicine.

Institutional Support: The VCU School of Engineering has created the position of "Director" of the VIP program at VCU. This position is funded with a salary supplement to provide summer salary for the Director. This support allows the Director to focus on the administration, support, and growth of the VIP program. The School also provides support for a Graduate Research Assistant. This GRA, nominally a Ph.D. candidate, helps students in the VIP program to utilize the computing resources supplied to the VIP teams described below.

The VIP program at VCU provides a dedicated computer server to execute several dedicated software packages used by the VIP teams. Principal among these is a commercial version of Wiki software called Confluence. Each team has a home space in Confluence that they use to organize their teams and document their developments. This server is behind the VCU firewall and cannot be accessed from outside the university network. This allows teams to use their Confluence pages to house intellectual property that they are developing within their projects.

The VCU School of Engineering has secured an endowment of approximately $1,000,000 to support the VIP program and the VIP teams. This endowment is primarily used to provide each new VIP team with an initial budget of $10,000. These funds are to be used to purchase equipment and supplies needed by the VIP students for their projects. It is also used to support team-building activities that each team is encouraged to conduct each semester.

The VCU School of Engineering maintains a VIP@VCU webpage (www.vip.vcu.edu). This webpage contains descriptions of all of the VIP teams, what their current projects involve, and who the faculty mentors for the teams are. The webpage also includes information on how

students can apply for the VIP teams and when accepted, how they can request permission to register for the correct VIP course section in order to earn academic credit for their participation.

The teams and their main objectives are described below:

Collaborative UAVs: This team works to state-of-the-art hardware and efficient, modular software for autopilots for small UAVs. These autopilots support the development of techniques and algorithms for multi-UAV collaborative teams. The team validates the systems developed with accurate simulations and real-world flight testing.

Engineering Critical Patient Care: This team works to identify and characterize issues related to patient safety, personnel safety, ergonomics, efficiency, and cost in the operating room, recovery room and critical care unit, with particular emphasis on areas populated by Anesthesiology. Based on these issues, the teams prioritize the findings and conceive, characterize, design, prototype and implement improvements and remedies representing positive step changes in the standard of patient care.

'Skintronics' Electronic System on the Skin: The team is working to develop conformal electronics systems that help identify, treat, and assist patients in dealing with health issues. One such project is the development of a soft, conformal, skin patch with polymer microneedles in an array fashion, which enables pain-less injection, skin-friendly biocompatibility, and gradual transport of drugs to blood vessel with controllable flow rate.

Medical Device Development and Prototyping: This teams concentrates its efforts on the development electronic medical devices. One such project involves the design and development of 3D printed antennas and antenna systems to be used in collateral therapy protocols for chemotherapy treatments. The designs will be individualized to the patient's unique shape and needs.

Nanoinformatics: This team is using natural language processing techniques to automatically aggregate studies on the development, use, and health effects of new engineered nanomaterials (ENMs). The goal is to semi-automate the cataloging of ENMs and their unique physico-chemical properties.

Aerosol-Enabled Nanomaterials: The team is working to develop novel aerosol processes to synthesize various nanoparticles, perform online and offline characterization, toxicity evaluation, and apply them for different applications, such as air purification, water treatment, and medical imaging and therapy.

MechanoUrology: The team is working on the development of improved clinical biomechanical diagnostics for Overactive bladder OAB and other bladder disorder and to understand the complex biomechanical and biochemical mechanisms responsible for dynamic elasticity in humans and animal models of OAB.

SustainLab: The initial focus of this team is to develop collaborations between engineering, art, and biology to design and implement a Green Wall on the VCU campus as an urban solution for

carbon sequestration. In addition to the design and implementation of Green Walls, this team will investigate various aspects of urban ecology including interactions and impact of humans on natural environments.

Unique to the Program: In addition to the institutional support described above, the VIP@VCU program has several unique features that are worth noting.

Each semester, the faculty mentors, VIP Director, and VIP Graduate Assistant hold a "VIP mentoring lunch." During this meeting, the Director presents VIP policies and resources, as well as current initiatives for the VIP program. In addition, each VIP mentor presents the current accomplishments of their teams over the past semester as well as issues that they have encountered. These issues are discussed in the group to help faculty mentors to develop solutions for them and improve the operation of their teams.

In addition to the institutional VIP@VCU webpage and the team Confluence Wiki pages described above, each VIP team receives a "team webpage" for their own use. These webpages are outside the VCU firewall and thus are publically viewable. As such, the team can use them to advertise the work that their team is accomplishing on their projects. Students on the team can use this to show their friends and family as well as potential employers what they are working on. In addition, the faculty mentor can use the webpage to show potential team sponsors what the team is working on in order to help solicit external support for their team.

Conclusion

As discussed in the introductory sections, VIP integrates rich student learning experiences with faculty research, transforming the contexts for undergraduate learning and faculty research. It provides a rich, cost-effective, scalable, and sustainable model for multidisciplinary project-based learning. It is rich because students participate for multiple years as they progress through their curriculum. It is cost-effective because students earn academic credit instead of stipends, and faculty lead teams outside of their standard course teaching loads. It is scalable because faculty can work with teams of students instead of individual undergraduate research fellows, and typical teams consist of fifteen or more students from different disciplines. It is sustainable because faculty benefit from the research and design efforts of their teams, with teams becoming integral parts of their research group. This paper presented profiles of sixteen VIP programs at a variety of institutions, illustrating the adaptability of the VIP model to varied academic settings. With the potential to scale-up to serve entire institutions, and with the increasing adoption of the model by different types of institutions, the VIP model has the potential to transform undergraduate education, offering rich multidisciplinary learning experiences to all students.

Acknowledgements

This material is based upon work supported by:

1. A grant from the Leona M. and Harry B. Helmsley Charitable Trust.

2. The Korean Ministry of Trade, Industry & Energy and the Korea Institute for Advancement of Technology through the fostering project of the Innovation for Engineering Education.
3. The National Science Foundation under Grant Nos.
    a. CNS MRI-1429345
    b. CNS MRI-1532061
    c. CNS RAPID-1507611
    d. ECCS COMMS, CIRCUITS & SENS SYS-1408370
    e. EFMA EFRI-1629659
    f. HRD ENG DIVERSITY ACTIVITIES, ALLIANCES-MINORITY PARTICIPAT-1642028
    g. IIP I/UCRC-1338922
    h. IIS III-1213026
4. U.S. DOT Grant ARI73.

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