Inter-Institutional Partnerships Propel A Successful Collaborative Undergraduate Degree Program In Chemistry

Malcolm J. D'Souza, Ph.D., Wesley College, Dover, Delaware, USA
Qiquan Wang, Ph.D., Delaware State University, Dover, Delaware, USA

ABSTRACT

Small private liberal arts colleges are increasingly tuition-dependent and mainly attract students by creating student-centered learning communities. On the other hand, larger universities tend to be trendsetters where its faculty tend to seek intellectual independence and are involved in career focused cutting-edge research. The Institutional Development Awards (IDeA) and Experimental Program to Stimulate Competitive Research (EPSCoR) are federal-state-university partnerships that builds basic research infrastructure and coax the state-wide higher education institutions to collaborate with each other in order to enhance their competitiveness. As a result in Delaware, Wesley College instituted curricular and operational changes to launch an undergraduate program in biological chemistry where its students take three upper division chemistry courses and can choose to participate in annual summer undergraduate internships at nearby Delaware State University.

Keywords: INBRE; EPSCoR; Undergraduate Research; Inter-institutional Partners; STEM; Biological Chemistry; Wesley College; Delaware State University; HBCU

INTRODUCTION

Wesley College (Wesley; www.wesley.edu) is located in the historic district of Dover Delaware. This private, baccalaureate, residential liberal arts college is fully accredited through the Middle States Commission on Higher Education. Wesley was founded in 1873 and is affiliated with the United Methodist Church. Its Fall 2011 student population of 1,892 has minorities comprising 52% of its total enrollment (45% Caucasian, 42% African-American, 10% Hispanic, 1% Asian, and 2% other). More than 40% of students are the first in their family to attend college. Wesley offers 30 undergraduate programs leading to a Bachelor of Science (B.S.) degree or a Bachelor of Arts (B.A.) degree, and 4 Master's degree programs. The typical tuition and fees for a full-time Wesley undergraduate student is currently approaching $21,000 for the academic year.

There are 138 undergraduate students in the Science, Technology, Engineering, and Mathematics (STEM) related fields of biological chemistry, biology, environmental studies, mathematics, and medical technology. In the Wesley STEM disciplines there are 13 full-time STEM faculty members including two in chemistry, and environmental studies offers a Master of Science (M.S.) degree program.

Delaware State University (DSU; www.desu.edu) is a historically black college/university (HBCU) with its main campus situated adjacent to U.S. Highway 13 in Dover, Delaware. DSU was established in 1891 as an 1890 land-grant institution for the agriculture and mechanical arts. It has evolved into a fully accredited, comprehensive university with 6 academic colleges that offer 52 undergraduate degrees, 25 graduate degrees and 5 doctoral degree programs. DSU enrolls a diverse population of about 4,000 students, of which nearly 80% of students are members of racial and ethnic minority groups.

In 2008, DSU's College of Mathematics, Natural Sciences & Technology (CMNST) launched a Ph.D. Program in Applied Chemistry and the Chemistry Department became the third department at DSU to offer a doctoral degree. The department currently enrolls 54 undergraduate chemistry majors and has 8 full-time faculty members.

The State of Delaware's flagship public institution of higher education is the University of Delaware (UD; www.udel.edu). UD is a land grant, sea grant, and space grant institution that is located in the city of Newark. UD is a research-intensive, doctoral-granting institution with more than 20,000 undergraduate and graduate students.

In 2001, UD's leadership secured an IDeA Networks of Biomedical Research Excellence (INBRE) grant funded by the National Center for Research Resources at the National Institutes of Health (NIH-NCRR), which brought together six Delaware institutions to build biomedical research capability statewide, and to provide access to biomedical research resources for promising undergraduates (DE-INBRE; www.inbre.udel.edu). The partners in this project include the University of Delaware (UD), Delaware State University (DSU), Delaware Technical & Community College (DTCC), Wesley College (Wesley), Christiana Care Health System (Christiana), and the Nemours/A.I. DuPont Hospital for Children (Nemours).

In 2005, UD, DSU, Wesley, and DTCC were partners on the Experimental Program to Stimulate Competitive Research (EPSCoR) grant program led by the National Science Foundation (NSF). The main goals of this program are to broaden the participation of Delaware's diverse student population in science and technology career pathways; and to bridge the gap between discovery research and application to help solve Delaware's environmental problems and create jobs (DE-EPSCoR; www.epscor.udel.edu).

WESLEY'S PROGRESSION TOWARDS BUILDING UNDERGRADUATE RESEARCH CAPACITY IN STEM FIELDS

Prior to 2002, relatively few Wesley undergraduates and faculty participated in research due to a lack of core research faculty, resources, administrative support, and infrastructure. As a result, there may have lacked an environment that encouraged Wesley STEM students to choose graduate or professional programs to further their education.

Now at Wesley the DE-INBRE and DE-EPSCoR funds have provided for some expanded modernized research spaces, cyber infrastructure improvements, laboratory upgrades and equipment, a certified chemical safety officer (CSO), undergraduate research stipends and paid annual 10-week undergraduate summer research internships, remote on-line library access, and access to advanced chemical instrumentation at partner institutions. Additionally, all of the classrooms and laboratories in Cannon Hall, the Science and Math building named for aluma/scientist Annie Jump Cannon, are equipped with interactive StarBoard™ technology.

In 2003 with DE-INBRE support Wesley launched a Directed Research Program (D'Souza et al., 2011; http://www.wesley.edu/academics/grants/inbre.html) for some of its STEM related areas. In this program students can begin participating in research during the second semester of the freshman year. After successful completion of a semester in Directed Research at Wesley the undergraduate is afforded an opportunity to participate in an intensive 10-week summer internship program at any partner institution, thus broadening their undergraduate research experience (URE). Students can participate in such research intensive programs as long as they maintain a cumulative grade point average (GPA) of 3.0, although some internships have been made to involve promising candidates with a GPA > 2.5.

We have found that this early URE typically launches research activity throughout the four years of the students' undergraduate stay at Wesley. May and Chubin (2003) citing earlier work further showed that minority student participation in a fruitful URE strongly motivated the participants to pursue advanced degrees and research careers in science and engineering. Crowe and Brakke (2008) surveyed the literature to evaluate appropriate assessment instruments of the various available UREs.

Every rising Wesley STEM senior is required to complete a two-semester capstone-research project under the guidance of a faculty mentor that culminates in an oral presentation to a small audience of their peers and other interested listeners. In the fourth year, those majoring in Medical Technology have to complete a senior year clinical experience at a medical facility. The Wesley STEM faculty are currently in the process of developing and testing appropriate assessment models to demonstrate that every STEM graduate has learned a variety of inquiry and analysis, critical and integrative thinking, and teamwork skills.

The main objectives of the Wesley College mentored Directed Research Program in Chemistry are to prepare its undergraduate participants to train in advanced science programs by teaching them the process (1) to participate in authentic and vibrant undergraduate research projects; (2) to develop creative ideas; (3) to formulate and execute solutions to problems; (4) to motivate and encourage these Wesley STEM undergraduates to attend graduate school in Delaware; (5) to provide a mechanism for the student to interact more closely with other faculty mentors and undergraduate researchers within the partnership networks; and (6) to develop an ability to discuss/present outcomes of their individual research projects at regional and national conferences.

During the past ten years this directed research program in chemistry has achieved outstanding results. There are 41 Wesley STEM undergraduate co-authors on 40 peer-reviewed publications, 45 students have earned national awards/recognitions, 2 pharmaceutical drug databases have been created with one being commercially available, and there have been more than 225 undergraduate poster presentations at various regional and national scientific conferences. Additionally, over 80% of the undergraduate researchers now move on to graduate or professional programs on graduation.

DSU's PROGRESSION IN CHEMISTRY ON DE-EPSCoR

The DE-EPSCoR Program in DSU (http://www.desu.edu/epscor) is located in the College of Agricultural and Related Sciences (CARS). Funds are made available to faculty members in STEM disciplines across the whole campus through seed grants that support preliminary research activities that show potential to win further external support. Year-long undergraduate research opportunities are provided to students from the STEM disciplines by the DSU EPSCoR Office.

The Chemistry Department at DSU was one of the major collaborators with CARS in the DE-EPSCoR Phase I (2005-2007) project. In 2006, a faculty member with expertise in environmental chemistry was hired with EPSCoR salary-support and start-up funds. Since 2006 there are three chemistry faculty that have won ESPCoR seed grants; seven or eight undergraduate students were supported for research in the faculty research labs, and four graduate students were awarded support for thesis research.

It is the DE-EPSCoR funds that stimulated the DSU faculty members in chemistry to become more collaborative with faculty in other departments at DSU and the partner institutions in order to further seek competitive external research grants. So far, the EPSCoR Seed Grant supported preliminary research projects in chemistry at DSU have fully or partially resulted in three external research grants and more than five research papers have been published in peer-reviewed journals.

Additionally under the leadership of the new chemistry chair, the DSU chemistry department is placing a greater emphasis on research mentorship to undergraduate students majoring in chemistry and is striving to improve its existing graduate programs. The department has also chosen Sustainable Chemistry to be its core discipline for future development and its faculty members are working closely with the DE-EPSCoR Program to gain greater support for research and education in this new direction. It is anticipated that with the support from the college and the university three to four more faculty lines will be added to the department faculty team to enhance the research in renewable energy and sustainable chemistry.

THE WESLEY AND DSU COLLABORATIVE PARTNERSHIPS IN CHEMISTRY

The driving distance between the campuses of Wesley and DSU is less than three miles so faculty collaboration on research and teaching projects should, in theory, be a viable option. Furthermore, participation in

the DE-INBRE and DE-EPSCoR grants requires strong inter-institutional relationships. In the current competitive higher education environment meaningful inter-institutional alliances that are founded on the principles already in place in successful "interdisciplinary strategies" (Sá, 2008) at major research universities, can become sustainable. Brown (2008) provided her experiences with inter-college consortiums at the Kentucky Appalachian College Association, and Kiley (2012) recently showed evidence of a shared remedial math program amongst five colleges within a 300-mile radius in West Virginia.

In 2005, the chemistry departments of Wesley and DSU were successful in a collaborative proposal to the NSF-Major Research Instrumentation (NSF-MRI) program for a 300 MHz nuclear magnetic resonance (NMR) spectrometer. This instrument is housed at DSU and is used for teaching and research by faculty and students of DSU and Wesley.

During the 2007-2008 academic year as a result of a developing robust partnership developed between some members of the two chemistry departments, Wesley College established a B.S. in Biological Chemistry program (Table 1) where its students take three upper division chemistry courses; Physical Chemistry I & II, and Instrumental Analysis, at DSU. In exchange, DSU students are allowed to enroll in up to three Wesley College science courses. This arrangement created a possibility of combining DSU and Wesley College students in low-enrollment, upper-division chemistry courses offered during a particular term at either campus. To be eligible to enroll in courses on the partner campus, a student is required to be a full-time student, have a cumulative GPA of 2.5 or higher, and continue to maintain this grade point average during the student's progress through the program. Because of the DE-INBRE and DE-EPSCoR consortium arrangements involving both institutions, no additional tuition costs are charged to Wesley students enrolling in the three specified DSU courses, nor are additional tuition charges be applied to DSU students, who may enroll in as many as three Wesley science courses during the completion of their program. Students are responsible for paying to the host institution any laboratory fees designated for the course(s) they take and students are not subject to any technology, student government, or other similar fees at the host institution.

This Wesley biological chemistry program was launched to provide its graduates the necessary skills that are essential in the Northeast region to be competitive in the growing biotechnology, pharmaceutical, agricultural, and chemical industries; medical programs; and in the various research and government agencies. This major involves an interdisciplinary curriculum featuring a broad range of advanced coursework in chemistry, biology, and mathematics, and is designed to evaluate and understand the fundamental principles that underline the complex molecular mechanisms of life. This dynamic and focused program strongly encourages hands-on undergraduate research participation, training in advanced instrumentation techniques, and provides an educational experience that will prepare any participant to enter a variety of interdisciplinary biomedical, chemical, biochemical, biological, and biophysical fields.

In the curriculum shown in Table 1, all Wesley students in biological chemistry, biology, environmental studies, and medical technology, begin the year-long organic chemistry sequence during the second semester of their freshman year. The main advantage of such a curriculum is that it allows for additional time for some students to catch up on their math requirements. On the other hand for the biological chemistry majors who typically place into first-semester calculus, this curriculum sequence not only allows them to begin undergraduate research in organic chemistry in the second semester of their first year, but it also allows them to quickly begin coursework in the necessary social and behavioral sciences (core electives) stipulated under the new guidelines proposed by the American Association of Medical Colleges (Alpern et al., 2011).

At Wesley, research projects in physical organic chemistry focus on methods used to understand chemical reactivity and the reaction mechanisms of molecules containing carbon, oxygen, phosphorus, sulfur, selenium, and nitrogen, all essential to biological systems. A second track features chemometrics, where the undergraduate participants are exposed to modern emerging information technology tools and instrumentation. By the end of the sophomore year, these students show competency in small molecule synthesis and formulation, chemical kinetics and analysis, and knowledge of instrumentation techniques such as gas chromatography (GC), NMR, ultraviolet (UV), and Fourier transform infrared spectroscopy (FTIR).

Table 1. Biological Chemistry: Major in the Wesley College Science Department

Description of Program

First year		**Credits**
Fall:		
BI140	Scientific Process	1
CH150	Chemistry I	4
EN100	College Writing	3
MA211	Calculus I	4
Core Elective		3
Spring:		
BI150	Biology I	4
CH200	Organic Chemistry I	4
EN101	Lit for Composition	3
MA212	Calculus II	4
Physical Education		1
Second year		
Fall:		
BI155	Biology II	4
CH210	Organic Chemistry II	4
PS240	Physics I	4
Core Elective		3
Spring:		
CH160	Chemistry II	4
PS250	Physics II	4
MA205	Statistics	3
Physical Education		1
BI215	Anatomy &Physiology II	4

Third year		**Credits**
Fall:		
BI310	Microbiology	4
2 Core Electives		6
DSU's	Physical Chem. I	4
Free Elective		3
Spring:		
BI322	Cell Biology	4
CH326	Bio Chemistry	3
DSU's	Physical Chem. II	4
CH310	Analytical Chem.	4
Fourth year		
Fall:		
BI406	Research Methods	2
3 Core Electives		9
BI3XX Zoology or Botany course		4
Spring:		
Core Elective		3
CH407	Senior Research	1
DSU's	Instrumental Analysis	4
BI34	Genetics	4
Free Elective		3
	Total Credits	**124**

As rising juniors some students choose to continue their URE during the summer months in the chemistry or biology departments at DSU, or in research groups at the other partner institutions.

The DE-EPSCoR supported environmental chemistry research lab in the Chemistry Department at DSU has been successfully collaborating with Wesley in undergraduate research. These research projects are closely related to the environmental problems seen in Delaware where concentrated poultry farming is the major agricultural income of the first state. For the purposes of health protection and therapeutical treatment, veterinary antibiotics are routinely administered to chickens. Up to 90% of the fed antibiotics are excreted shortly after treatment and enter into the environment with chicken manure. The presence of antibiotics in the environment may lead to the development of antibiotic genes among microbes, which can be transferred to pathogens, resulting in antibiotic treatment failure on human and animal inflammation. There is a need to investigate how these antibiotics can be degraded rapidly in manure and soil. High performance liquid chromatography (HPLC) is commonly used as a reliable instrumental method to analyze the concentration of the target antibiotic in manure/soil samples.

Besides veterinary antibiotics, trace amount of steroidal estrogenic hormones naturally produced by chickens may be also excreted by animals and thus present in poultry manure. Since human beings and vertebrates share the same or quite similar hormones, the occurrence of estrogenic hormones in the environment, even at trace level, may cause observable adverse effect on animals immediately exposes to that environment. Students involved in this environmental chemistry research lab are very interested in analyzing selected estrogenic hormones in various environmental samples related to poultry farming, aiming to eliminate human exposure to hormone contamination

resulted from chicken houses. Derivatized gas chromatography-mass spectrometry (GC-MS) is normally used for this analysis.

Each summer the director of the DE-EPSCoR supported Ethics Resource Site at DSU (http://www.desu.edu/ethics-resource-site) conducts an ethics program for all of our DE-INBRE or DE-EPSCoR supported undergraduates at Wesley. This program includes insightful lectures, an evaluation of current ethical case studies, and guided discussion to promote the ethical behavior in research and the critical thinking about ethical solutions.

Also every summer a daylong retreat is organized by the statewide DE-INBRE and DE-EPSCoR undergraduate research summer internship programs (typically at UD or at the DuPont Environmental Education Center in Wilmington) where the students are provided with a series of peer-networking opportunities and workshops that deal with academic success, career growth, and personal enrichment. Additionally for these annual summer internship participants a culminating poster session is held at UD at the end of the 10-week summer internship. Here these URE participants are given the opportunity to showcase and explain their independent projects to a very large audience comprised of members and stakeholders from all of the partner institutions. This enables students to gain experience in communicating their results.

The advanced coursework in chemistry and biology in the junior and senior years of the Wesley biological chemistry program includes exposure to advanced instrumentation techniques and chemical analysis, bioinformatics, macromolecular structure and function, and cellular metabolism. Hence these majors accumulate the necessary convertible chemical and communication skills and special details in the various STEM domains that are needed to be successful in future advanced graduate or professional programs.

Formative evaluation to validate that the goals of this Wesley baccalaureate program are being achieved is conducted by evaluating student academic performance levels and degree of satisfaction, program retention, student performance and proficiencies on poster presentations, participant's acceptance to professional programs and graduate school, and job placements on graduation. Annual summative evaluations are conducted by outside evaluators as part of the overall DE-EPSCoR and DE-INBRE evaluation process.

CONCLUSIONS

Interaction between the faculty of the two chemistry departments has greatly increased. There have been additional collaborative joint grant proposal submissions to federal agencies. Students from Wesley continue to complete undergraduate research projects in the chemistry department at DSU, and DSU has had one M.S. degree student complete part of his chemistry thesis work at Wesley.

Three students have graduated from the biological chemistry program at Wesley. One was quickly absorbed by a Delaware biochemical company on graduation; one received a full-ride merit scholarship to medical school, and one first received an internship at a major pharmaceutical company and will now enter a medical Ph.D. program in biochemistry and molecular biology in 2012.

In Table 2, we list the 2009-2011 enrollment data for the closely related fields of biology, biological chemistry, and medical technology, obtained from the Office of Admissions at Wesley College. It is our strong belief and hope that as the Wesley College STEM programs builds upon its successes and distinctions we will eventually become visible in the higher education landscape, as potential applicants will set us apart from other institutions of similar size and character.

Table 2. Interest in the Wesley College biology, biological chemistry, and medical technology programs (2009-2011)

		2009	2010	2011
Biology	Inquires	337	313	367
	Applications	107	138	135
	Accepts	62	86	68
	Deposits	14	20	18
Biological Chemistry	Inquires	25	65	68
	Applications	20	36	29
	Accepts	8	20	17
	Deposits	0	4	6
Medical Technology	Inquires	67	89	80
	Applications	37	44	36
	Accepts	15	15	15
	Deposits	6	5	4

ACKNOWLEDGEMENTS

The undergraduate research is supported by - grants (DE- INBRE and DE-EPSCoR programs) from the National Center for Research Resources - NCRR (5P20RR016472-12) and the National Institute of General Medical Sciences - NIGMS (8 P20 GM103446-12) from the National Institutes of Health (NIH); a National Science Foundation (NSF) Delaware EPSCoR grant EPS-0814251; an NSF MRI grant 0520492; and an NSF ARI-R2 grant 0960503. The authors also sincerely acknowledge the efforts of the numerous faculty, staff, and administrators at Wesley, DSU, UD and the other partner institutions who are strongly committed to making these inter-institutional commitments succeed in Delaware.

AUTHOR INFORMATION

Malcolm J. D'Souza is professor of chemistry at Wesley College, in Dover, Delaware. He has published seventy-two peer-reviewed journal articles and more than 250 abstracts in conference proceedings. Fifty undergraduate coauthors appear on his list of peer-reviewed publications, and forty-five undergraduates from his laboratory have earned national awards and recognitions. In 2009, he was nominated and identified by a selection committee for the 2009 Northern Illinois University (NIU) Golden Anniversary Alumni Award. Recently, he was awarded the American Chemical Society's (ACS) 2012 E. Emmett Reid Award, which recognizes high-quality teaching in chemistry at small colleges in the ACS Mid-Atlantic region. In addition to his research in physical organic chemistry, he also has projects, presentations, and publications in the area of chemometrics, developing commercial databases that assist in the development of new pharmaceutical and agricultural products. E-mail: dsouzama@wesley.edu (Corresponding author)

Qiquan Wang is an associate professor of environmental chemistry in the Chemistry Department, at Delaware State University. He has mentored 3 graduate students and 12 undergraduate students in research. So far he has published 50+ research papers in peer-reviewed journals. His research interests lie in the occurrence of organic contaminants in the environment and in strategies for accelerating the degradation of them in the environment.

REFERENCES

1. Alpern, R.J., Belitsky, R., and Long, S. (2011). Competencies in Premedical and Medical Education: The AAMC-HHMI Report. *Perspectives in Biology and Medicine*, 54(1), 30 - 35.
2. Brown, A. (2008). Collaboration Among Colleges: Impossible Mission? *Inside Higher Ed*, August 19.
3. Crowe, M. and Brakke, D. (2008). Assessing the Impact of Undergraduate-Research Experiences on Students: An Overview of Current Literature. *Council of Undergraduate Research Quarterly*, 28 (4), 43-50.
4. D'Souza, M.J., Dwyer, P., Allison, B.E., Miller and J.M., Drohan, J. (2011). Wesley College Ignites Potential with Undergraduate Student Research Program. *Council of Undergraduate Research Quarterly*, 32 (2), 41-45.

5. Kiley, K. (2012). Welcome to the Party. *Inside Higher Ed*, April 19.
6. May, G.S. and Chubin, D.E. (2003). A Retrospective on Undergraduate Engineering Success for Underrepresented Minority Students. *Journal of Engineering Education*, 92 (1), 27- 40.
7. Sá, C.M. (2008). 'Interdisciplinary Strategies' in U.S. Research Universities. *Higher Education*, 55, 537-552.
8. The Ethics Resource Site at Delaware State University: http://www.desu.edu/ethics-resource-site
9. The Delaware-EPSCoR website: www.epscor.udel.edu
10. The Delaware-INBRE website: www.inbre.udel.edu
11. The Delaware State University website: www.desu.edu
12. The Delaware State University EPSCoR website: http://www.desu.edu/epscor
13. The University of Delaware website: www.udel.edu
14. The Wesley College website: www.wesley.edu
15. The Wesley College INBRE website: http://www.wesley.edu/academics/grants/inbre.html

