

Development of a Bachelor of Science in Toxicology Program at a Liberal Arts College

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Abstract

Nazareth College, an independent, primarily undergraduate institution serving approximately 2,900 students, has recently developed a bachelor of science in toxicology program designed to prepare students for entry into careers in industry, government, or academia or for further study in graduate or health professional programs. The strong life sciences foundation courses and the variety of upper-level biology and chemistry electives already in existence at the College necessitated the development of only three new courses for the major – Principles of Toxicology, Ecotoxicology, and Cellular Toxicology. The program, including curriculum development, course design, and approval by both the College and New York State, took two years to develop. In its first year in existence, the program has attracted nine majors and the first course in the toxicology sequence, Principles of Toxicology, has become one of the most popular life sciences electives at the College.

Keywords

Toxicology program; undergraduate; liberal arts college

Program Development

The lack of toxicology education at the undergraduate level has been noted by those in the field for decades^{1,2}. The Toxicology Educational Summit, recently convened by the Society of Toxicology (SOT) to discuss toxicology education, identified a need for increased toxicology education as well as new educational paradigms at all levels³. To meet the demand for toxicologists, a handful of undergraduate toxicology programs have come into existence over the past few decades; however, the majority of these programs are located at large research-intensive institutions or highly specialized health sciences schools. Nazareth College has recently developed a bachelor of science in toxicology program that builds upon its existing strengths in the life sciences and offers toxicology education in the liberal arts college environment (characterized by small class sizes, personal attention from faculty, innovative pedagogical approaches, and a core curriculum that fosters development of critical thinking and communication skills) that appeals to so many students. The toxicology program is designed to train students for employment in industry, government, or academia, and to provide a foundation for students planning to pursue advanced degrees in the life sciences or professional degrees in medical, veterinary, dental, pharmacy, or other health-related programs. By utilizing the science and math foundation courses and the diverse array of advanced electives already offered within the Biology and Chemistry and Biochemistry Departments at the College, only three new courses were developed for the toxicology program, all of which also serve as advanced electives for other life sciences majors.

Nazareth College is an independent, coeducational, primarily undergraduate institution located in suburban Rochester, New York. The College employs approximately 175 full-time faculty members and serves approximately 2,100 undergraduates and 800 graduate students with an average class size of 18 students and a student-to-faculty ratio of 10:1. The College offers 58 undergraduate majors. The toxicology program at Nazareth College is administered by the Biology Department which is comprised of six full-time tenured or tenure-track faculty members, one of whom was hired in part to develop and direct the program. In addition to the toxicology major, the Biology Department offers majors in biology (option with childhood or adolescent education certification) and environmental science and sustainability and minors in biology, environmental science, environmental studies, bioethics, horticultural therapy, pre-medical, pre-veterinary, and pre-dental. Together with the major, a minor in toxicology was also developed. Other life sciences majors offered by the College include chemistry (option with childhood or adolescent education certification) and biochemistry.

A number of factors contributed to the decision to develop a bachelor of science in toxicology program at Nazareth College. Although The Bureau of Labor Statistics Occupational Outlook Handbook does not provide data for the field of toxicology specifically, a 21% growth rate in employment opportunities for biological scientists in general is predicted during the 2008-2018 decade⁴. As the field of toxicology, specifically, continues to grow, the need for toxicologists has outpaced the supply⁵. Further, data from the Society of Toxicology's Seventh Triennial Toxicology Salary Survey indicate that nearly one-third of scientists employed in the

field of toxicology work in the Northeast region of the United States, where Nazareth College is located⁶. The College sought to build upon its existing strengths in the life sciences (including its innovative introductory courses, a variety of advanced elective offerings, and a strong tradition of undergraduate student involvement in research) by developing a number of new majors in the life sciences, of which toxicology was the first. Part of this plan involved construction of a new math and science building which includes state-of-the-art teaching laboratories as well as designated laboratory space for faculty-student research (outfitted with equipment including mammalian and plant tissue culture facilities and a confocal microscope). The opening of the new building coincided with the launch of the toxicology program in 2012. Additionally, increased enrollment in the Biology Department necessitated the creation of a new tenure-track line, positioning the Department to hire a toxicologist who could develop and direct the fledging program.

Development of the toxicology program began with the hiring of a toxicologist faculty member (2009-2010). While teaching approximately nine credits per semester of introductory biology and microbiology courses, the faculty member received between one and three credits of course release time per semester over the next two years (2010-2011, 2011-2012) for curriculum design, course development, and preparation and presentation of new program proposals for both College and New York State approval. Input on program development was sought from a regional panel of science professionals and from area members of the Society of Toxicology who provided recommendations regarding regional employment needs as well as course content suggestions. In total, three new courses were developed for the program (Table 1). Principles of Toxicology (the prerequisite for the other two toxicology courses) is currently offered every fall semester, while Ecotoxicology and Cellular Toxicology will be offered in alternating spring semesters. The program welcomed its first class in the 2012-2013 academic year.

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COURSE	DESCRIPTION
Principles of Toxicology (3 cr)	A comprehensive overview of the effects of chemicals (pollutants, pharmaceutical agents, etc.) on biological systems at the organismal level with emphasis on the effects of chemical exposure on human health. Topics include general principles of toxicology and pharmacology; the dose-response relationship; absorption, distribution, metabolism, and excretion; non-organ directed toxicity; target organ toxicity; risk assessment.
Principles of Toxicology Seminar (1 cr)	An introduction to toxicological research in which specific environmental issues serve as the basis for the study of the effects of chemical exposure on human health as explored through primary literature analysis.
Cellular Toxicology (3 cr)	An in-depth study of the molecular mechanisms by which chemicals exert their effects on biological systems. Topics include molecular- and cellular-level study of chemical absorption, distribution, metabolism, and excretion; toxication versus detoxication reactions; and biochemical mechanisms of toxicity.
Cellular Toxicology Lab (1 cr)	An investigation of the effects of toxicant exposure at the molecular level. Students will use current toxicological methods to assess the effects of toxicant exposure on molecular and cellular structure and function. Methodologies include analysis of DNA integrity and measurement of levels and activities of enzymes important in toxication and detoxication.
Ecotoxicology (3 cr)	An exploration of toxicology at the ecosystem level. Topics include the fates of chemicals in ecosystems; effects of toxicant exposure on individual organisms, populations, communities, and ecosystems; biomarkers; biological monitoring; and the evolution of resistance to pollutants.
Ecotoxicology Lab (1 cr)	A collection of experiments employing a variety of toxicological methods to investigate levels of toxicants in various environments and their effects on biological systems at the whole organism level.

Table 1. Course descriptions for the three new courses developed for the program.

Program Structure

The toxicology major curriculum includes introductory biology, general chemistry, organic chemistry, physics, calculus, statistics and three cornerstone toxicology courses – Principles of Toxicology, Ecotoxicology, and Cellular Toxicology (Table 2). Because Principles of Toxicology requires one semester of introductory biology for majors as a pre-requisite, the majority of students take Principles of Toxicology in the fall semester of their sophomore or junior years. Principles of Toxicology serves as the pre-requisite for both Ecotoxicology and Cellular Toxicology, thus students generally take these courses in the spring semester of either their junior or senior years. Students also select one of three tracks (Cellular, Organismal, or Environmental) within the program in which to specialize, taking two advanced biology and/or chemistry electives within their selected track (Table 3). In addition to the College Core curriculum requirements, students are required to take either Environmental Sociology or Water and Society as well as six liberal arts electives (Table 4).

The toxicology degree culminates in a three-semester capstone seminar sequence in which students work with a faculty mentor to carry out an independent research project in an area of toxicology, present their findings in both oral and written format, and pass a comprehensive exam. Faculty members in the Biology Department are engaged in research in an array of areas including cell and molecular biology, microbiology, developmental biology, physiology, plant biology, and ecology, so students may carry out a research project that addresses a toxicological question in any of these areas. Additionally, students may work with faculty members in the Chemistry and Biochemistry Department or choose to do their research at an off-campus site, such as a larger research university, private company, or government laboratory.

The toxicology minor curriculum is comprised of 18 credits and includes the three-semester introductory biology sequence (Biological Systems I, II, and III), Principles of Toxicology, and Environmental Sociology or Water and Society.

An array of instructional delivery methods are employed throughout the program. Classroom instruction for the three toxicology courses relies heavily on case study analysis. Two of the courses (Ecotoxicology and Cellular Toxicology) have co-requisite laboratories with inquiry-based components. In lieu of a laboratory, the first course in the sequence (Principles of Toxicology) includes a co-requisite seminar in which students develop critical thinking skills by evaluating current issues in toxicology through primary literature analysis and communicate their findings in both oral and written format, skills identified as essential to a successful career in toxicology by participants in SOT's Toxicology Educational Summit³.

A variety of assessment modalities will be utilized to evaluate the success of the toxicology program. Students will take a comprehensive examination at the end of their senior year to assess their mastery of concepts. Achievement of learning outcomes related to written communication will be assessed by comparing students' writing in a first-year course (such as Biological Systems I) and a fourth-year course (such as Capstone Seminar III). Exit interviews will be conducted to assess students' satisfaction with the program and graduates will be tracked

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to determine employment and graduate/professional school placement statistics. The toxicology curriculum will be regularly reviewed and compared to similar programs and Society of Toxicology recommendations to ensure that the program remains current and competitive.

BIOLOGY COURSES	CR	COLLEGE CORE COURSES	CR
Biological Systems I*	3	Academic Skills	1
Biological Systems I Lab*	1	College Writing I	3
Biological Systems II	3	College Writing II	3
Biological Systems II Lab	1	Physical Education	0
Biological Systems III	3	Visual/Performing Arts course	3
OTHER SCIENCE COURSES		History course	3
General Chemistry	3	Literature course	3
General Chemistry Lab	1	Mathematics course	4
Analytical Chemistry	3	Philosophy course	3
Analytical Chemistry Lab	1	Religious Studies course	3
Organic Chemistry I	3	Natural Science w/ Lab course	4
Organic Chemistry I Lab	1	Social Science course	3
Organic Chemistry II	3	Integrated Studies course	3
Organic Chemistry II Lab	1	Integrated Studies course	3
Introductory Physics I	3	Integrated Studies course	3
General Physics Lab I	1	Core Milestone Experience	0
Introductory Physics II	3	LIBERAL ARTS COURSES	
General Physics Lab II	1	Environmental Sociology or Water and Society	3
Calculus I*	4	Liberal Arts electives (6)	18
Statistics for Scientists	3	CAPSTONE COURSES	
TOXICOLOGY COURSES		Introduction to Scientific Research	1
Principles of Toxicology	3	Capstone Seminar I	1
Principles of Toxicology Seminar	1	Capstone Seminar II	1
Ecotoxicology	3	Capstone Seminar III	1
Ecotoxicology Lab	1	Comprehensive Exam	0
Cellular Toxicology	3		
Cellular Toxicology Lab	1		
TRACK COURSES			
Biology or Chemistry elective	3		
Biology or Chemistry Lab elective	1		
Biology or Chemistry elective	3		
Biology or Chemistry Lab elective	1		
		Program	58
		Core and Liberal Arts	63
		TOTAL CREDITS	121

Table 2. Toxicology program requirements. *Denotes a course that also fulfills a Core requirement.

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CELLULAR TRACK	ORGANISMAL TRACK	ENVIRONMENTAL TRACK
Cancer Biology Genetics General Microbiology Clinical Microbiology Immunology Bioinformatics Cell Biology Advanced Genetics Biochemistry I Biochemistry II	Comparative Chordate Anatomy Plant Biology Animal Physiology Introduction to Animal Behavior Reproduction and Development General Microbiology Clinical Microbiology	Comparative Chordate Anatomy Plant Biology Introduction to Animal Behavior Reproduction and Development General Microbiology Ecology Conservation Biology Environmental Chemistry Chemical Instrumentation

Table 3. Electives within the toxicology program tracks.

SAMPLE LIBERAL ARTS ELECTIVES
Environmental Economics Natural Resource Economics Environmental Law Social History of Medicine and Disease Natural Disasters in American Society Introduction to Public Health Public Administration Nutrition Concepts Interpersonal Communication Public Speaking Biomedical Ethics

Table 4. Sample liberal arts electives.

Discussion

Since its inception one year ago (2012-2013), the toxicology program has drawn nine majors (for comparison, the Biology Department normally serves approximately twenty-five majors per year). The Principles of Toxicology course (the first course in the toxicology sequence to be developed) has been offered for two semesters as a life sciences elective, attracting six students in the first semester and nine in the second. For the fall 2013 semester (the first semester in which toxicology majors are in the course), fourteen students enrolled. In addition to toxicology majors, the course has thus far served biology, environmental science and sustainability, biochemistry, and anthropology majors and has become one of the most popular life sciences electives at the College.

Currently the toxicologist faculty member who was hired to develop and direct the program teaches all three courses in the toxicology sequence. However, as the program

continues to grow, it is anticipated that additional adjunct faculty members will be hired to teach both existing courses and new courses in the program. Significant increases in enrollment will necessitate the hiring of another full-time toxicologist faculty member.

Future plans for the program include the addition of an internship option as well as the development of articulation agreements with nearby two-year colleges. Additional electives for the program are being considered. A summer toxicology camp program for middle school and high school students is planned as a way to expose students to the new program. It is expected that as more students learn about the program, and current majors enter the field, the program will continue to grow and provide a pipeline of liberally-educated, technically-skilled graduates who will become part of the next generation of toxicologists.

Notes

The author declares no competing financial interest.

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