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Daniel B. Oerther

Missouri University of Science and Technology, oertherd@mst.edu

Catherine V. Maltbie

Baikun Li

Jin Li

et. al. For a complete list of authors, see https://scholarsmine.mst.edu/civarc_enveng_facwork/483

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2006-91: DISSEMINATING MOLECULAR BIOLOGY FOR ENVIRONMENTAL ENGINEERS WITH NSF CCLI SUPPORT

Daniel Oerther, University of Cincinnati

Associate Professor of Environmental Biotechnology, University of Cincinnati. Dr. Oerther teaches graduate and undergraduate courses in biology and molecular biology as applied to natural and engineered environments. His research focuses upon microorganisms in wastewater treatment plants, drinking water treatment plants, bioremediation field sites, and natural surface watershed.

Cathy Maltbie, University of Cincinnati

Research Associate, Evaluation Services Center, University of Cincinnati. Dr. Maltbie. Dr. Maltbie provides professional evaluation services to clients including administrative and academic units within the University of Cincinnati.

Baikun Li, Pennsylvania State University-Harrisburg

Assistant Professor, Penn State University, Harrisburg. Dr. Li teaches undergraduate and adult education courses in sanitation and environmental engineering. Her research focuses upon biological nutrient removal and sewage treatment.

Jin Li, University of Wisconsin-Milwaukee

Assistant Professor, University of Wisconsin, Milwaukee. Dr. Li teaches graduate and undergraduate courses in water and wastewater treatment. Her research focuses upon microorganisms in natural in engineered aquatic environments.

Amy Pruden, Colorado State University

Assistant Professor, Colorado State University. Dr. Pruden teaches graduate and undergraduate courses in molecular biology and bioprocess engineering. Her research focuses upon applications of molecular microbial ecology to environmental engineering including water quality and bioremediation.

Peter Stroot, University of South Florida

Assistant Professor, University of South Florida. Dr. Stroot teaches graduate and undergraduate courses in microbiology and water quality. His research focuses upon the development of innovative solutions to challenging environmental problems including anaerobic treatment systems and biological nutrient removal.

Disseminating Molecular Biology for Environmental Engineers with NSF CCLI Support

Abstract

For the past five years, more than fifty undergraduate and graduate students at the University of Cincinnati have participated in a term-length course, CEE69 Molecular Biology for Environmental Systems. Using a self-paced approach, teams of students complete laboratory exercises to answer open ended questions about the composition of the microbiological community in an environmental sample. With the financial support of a Adaptation and Implementation (A&I) track grant from the NSF Course, Curriculum, and Laboratory Improvement program the course from Cincinnati is being taught at four partner institutions. This paper highlights the unique challenges of adapting the existing course to other institutions as well as the formation of a meta-assessment program comparing institution-specific student assessment as well as an assessment of the capabilities of the instructors to successfully adapt the materials.

Introduction

Genomic technology is redefining many applied fields including environmental biotechnology. The emerging interdisciplinary area of environmental biotechnology integrates quantitative, analytical tools from the molecular sciences with innovative bioreactor design and operation. Environmental biotechnology has been identified as a corner stone for the future of the field of environmental engineering. In a recent report, “Research Frontiers in Environmental Engineering”, published jointly by the National Science Foundation (NSF) and by the Association of Environmental Engineering Professors (AEEP, September 15, 1998), “Analytical Tools in Molecular Sciences” was identified as one of four critical research needs in the field of Environmental Engineering and Science.¹ In follow-up work, the development of molecular tools to track environmental microorganisms was identified as a research priority by the National Science Foundation² and by the U.S. Environmental Protection Agency.³

Need

In response to the need for environmental biotechnology research and education, academic departments across the country have made a sustained effort to recruit and retain faculty with expertise in environmental biotechnology. In particular, notices seeking faculty candidates often specifically request applications from individuals with expertise in molecular biology (e.g., available job posting of the Association of Environmental Engineering and Science Professors web site at www.aesp.org). Although genomic technology is revolutionizing many of the research programs in environmental engineering, these technologies have not been transferred successfully to the undergraduate and graduate curricula at many institutions.⁴

Approach

The overall objective of this project is adaptation and implementation of a successful NSF CCLI EMD “Proof-of-Concept” project initiated at UC in 2000 introducing environmental engineering

undergraduate and graduate students to molecular biology tools without a requirement for prerequisite courses in biology.^{5,6,7,8} The approach being followed in this project involves sixteen individuals, including: six faculty members at geographically and demographically diverse institutions acting as instructors; three faculty members at institutions serving under-represented student populations acting as advisors; two representatives of business/industry who are members of the National Academy of Engineering acting as advisors; and five faculty members acting as independent assessors (Table 1).

Table 1. Project Participants.

Name	Project Role	Institution
Daniel B. Oerther, PhD	PI, Project Lead	University of Cincinnati (UC); research extensive Ph.D. granting
Baikun Li, PhD	Co-PI, Instructors	Penn State University, Harrisburg (PSU-H); M.S. granting university
Katherine Baker, Ph.D.		
Jin Li, PhD	Co-PI, Instructor	University of Wisconsin, Milwaukee (UW-M); research extensive Ph.D. granting
Amy Pruden, PhD	Co-PI, Instructor	Colorado State University (CSU); research extensive Ph.D. granting
Peter Stroot, PhD	Co-PI, Instructor	University of South Florida (USF); research extensive Ph.D. granting
Hazel Barton, PhD	Advisor, 4yr	Northern Kentucky U; B.S. granting 4yr university
Ann Gunkel, PhD	Advisor, 2yr	Cincinnati State; A.B. granting 2yr technical college
Kumar Nedunuri, PhD	Advisor, HBCU	Central State U; B.S. granting 4yr minority university (HBCU 89.80)
Glen Daigger, PhD	Advisor, NAE	Sr. Vice President, CH2M Hill; National Academy of Engineering
Mike Kavanaugh, PhD	Advisor, NAE	Vice President, Malcolm Pirnie; National Academy of Engineering
Cathy Maltbie, Ed	Co-PI, Assess. Lead	UC Evaluation Services Center
Judith Zaenglein, Ph.D.	Assessment	PSU-H Department of Education
Anthony Ciccone, Ph.D.	Assessment	UW-M Center for Instructional and Professional Development
Karen Kaminski, Ph.D.	Assessment	CSU School of Education
Melinda Hess, Ph.D.	Assessment	USF Department of Educational Measurement and Research

The “core” content originally developed at UC as part of a prior NSF CCLI EMD “Proof-of-Concept” project is being adapted to meet the needs of individual teaching styles and diverse student learning styles. Each year, for two years, five parallel term-length courses are being taught and local assessment is being conducted as part of our effort to research teaching and learning. The results from each assessment are being used to revise and perfect teaching styles and course content. Parallel efforts at the five partner institutions will be integrated through a project-wide ‘meta assessment’ and fed into the development of a single text book with awareness of special issues for under-represented student populations including women and minorities.

Partnerships

The extensive research team assembled for this project has a number of positive characteristics that were considered requisite for ultimate success of the effort, including: (a) an experienced PI with a track record of working with each faculty-instructor; (b) energetic faculty-instructors with local Department support to develop a novel laboratory course; (c) an advisory board representing 2yr, 4yr, and HBCU (historically black colleges and universities) colleges providing independent critical feedback to make the development of educational materials broadly accessible to diverse student audiences; (d) two members of the National Academy of Engineering as advisors providing independent, objective criticism; (e) local assessors at each participating school using common elements of an evaluation plan originally developed at UC; and (f) a Co-PI as a lead assessor to coordinate the implementation of the evaluation plans at all five participating schools as well as cross-comparing and analyzing the feedback received from each local evaluation in an overall ‘meta-assessment’ plan to research teaching and learning.

As can be observed in Table 2, the five programs where these teaching materials will be adapted and implemented represent a mix of programs with a variety of missions varying from education of undergraduate students and continuing education for adults to research extensive comprehensive doctoral universities. Selecting advisory board members representing 2yr, 4yr, and HBCU institutions ensures that the textbook to be prepared as part of this project is useful to underrepresented student populations. The research team represents a balance between Co-PIs with significant prior experience with the course materials and dedication to the success of the project versus assessors and a distinguished advisory board who provide critical independence to ensure that the success of the project is evaluated objectively.

Table 2. A comparison of critical demographic information for each of the participating schools.

Investigator Information					
Name	Daniel B. Oerther	Baikun Li	Jin Li	Amy Pruden	Peter Stroot
Education	Ph.D. in Environmental Engineering	Ph.D. in Environmental Engineering	Ph.D. in Environmental Engineering	Ph.D. in Environmental Science	Ph.D. in Environmental Engineering
Rank	Associate Professor	Assistant Professor	Assistant Professor	Assistant Professor	Assistant Professor
Start Date	September 2000	September 2003	September 2001	August 2002	January 2004
Institution Information					
Name	University of Cincinnati (UC)	Penn State University, Harrisburg (PSU-H)	University of Wisconsin, Milwaukee (UW-M)	Colorado State University (CSU)	University of South Florida (USF)
Terms	Quarters	Semesters	Semesters	Semesters	Semesters
# Colleges	13	5	12	8	10
# Faculty	1,657	200	778	1,520	1,611
# Undergrads	24,385	3,000	20,799	21,200	31,203
# Graduates	9,438	400	4,091	3,800	7,162
Highest Degree	Ph.D.	M.S.	Ph.D.	Ph.D.	Ph.D.
% Women	52.5%	54%	56%	52%	59%
% Minorities	15%	11%	14%	12%	23%
Research \$	\$243M	\$10M	\$72M	\$183M	\$250M
Primary Mission	major urban doctoral university	provide excellence in undergraduate, graduate and professional educational programs	major urban doctoral university meet the diverse needs of Wisconsin's largest metropolitan area	land-grant institution and a Carnegie Doctoral/Research University	major urban doctoral university recently founded in 1960

Table 2 (continued). A comparison of critical demographic information for each of the participating schools.

Investigator Information					
Name	Daniel B. Oerther	Baikun Li	Jin Li	Amy Pruden	Peter Stroot
College Information					
Name	Engineering	Science, Engineering and Technology	Engineering and Applied Science	Engineering	Engineering
# Departments	6	7	6	5	7
# Faculty	145	37	57	99	140
# Undergrads	1,839	650	1,621	1,470	2,321
# Graduates	790	130	270	604	805
% Women	16%	15%	13%	17%	18%
% Minorities	5%	13%	10%	9%	18%
Research \$	\$20M	\$2M	\$4M	\$38M	\$25M
Department Information					
Name	Civil and Environmental Engineering	Environmental Engineering	Civil Engineering and Mechanics	Civil Engineering	Civil and Environmental Engineering
# Faculty	21	7	14	36	19
# Undergrads	198	25	234	370	230
# Graduates	105	9 (full time) 20 (part time)	45	180	150
% Women	19%	12%	18%	21%	25%
% Minorities	4%	11%	9%	7%	16%
Highest Degree	Ph.D.	M.S.	Ph.D.	Ph.D.	Ph.D.
Research \$	\$6M	\$1M	\$1M	\$7M	\$3.3M
Course Information					
Name	Molecular Biology for Environmental Engineers	Application of Molecular Biology in Environmental Engineering	Molecular Tools for Engineers	Molecular Tools for Engineers	Molecular Biology for Environmental Engineers
Undergrads	5	7 (expected) 20-30 workshop participants (expected)	5 (expected)	5 (expected)	20
Graduates	10	7 (expected)	8 (expected)	10	10
Description	Term-long (10wks) courses devoted to lectures and labs	Semester-long (15 weeks) lecture, literature review, class presentation, discussions and labs.	Semester-long (15 weeks) lecture, discussion and labs.	Semester-long (15 weeks) lecture, readings, discussions and labs.	8-week course comprised of lectures and labs

University of Cincinnati, Daniel B. Oerther

UC is a comprehensive, research-extensive institution offering doctoral degrees from thirteen colleges. The program of Environmental Engineering and Science (EE&S) within the Department of Civil and Environmental Engineering is one of the strongest programs at UC with a compliment of twelve faculty and research expenditures above \$4M per year. Because of the tremendous strength of the EE&S program, the PI was afforded the opportunity to develop a new and highly experimental course introducing engineers to Molecular Biology. To his knowledge, this is the first course of its kind offered in any EE&S program in the United States.

The course materials originally developed at UC beginning in 2000 (Oerther, 2002a; 2002b; 2003a; 2003b) were continually improved over the past five years and have been distributed freely at four partner institutions. Dr. Oerther continues to teach CEE619, “Molecular Biology for Environmental Engineers,” at UC, and he is serving as an advisor to provide feedback for each Co-PI as they adapt the course materials to their own institution.

Penn State University, Harrisburg, Baikun Li and Katherine Baker

The primary mission of PSU-H is to provide excellence in undergraduate, graduate and professional educational programs. The main features of the Environmental Engineering Program (EEP) at PSU-H include: (i) instruction for undergraduate and M.S. candidates with a strong focus on ‘real-world’/applied research; (ii) local employment of graduates; and (iii) hosting the U.S. EPA and PA Department of Environmental Protection (DEP) training center for water and wastewater treatment plant operators and managers.

Two faculty members, Drs. Baikun Li and Katherine Baker, teach and conduct research in the area of Environmental Microbiology and biological wastewater treatment processes. In addition, several other Departments at PSH provide courses involving Molecular Biology including human genomic justice, sustainable environmental development, and the Penn State College of Medicine (located just 7 miles from Harrisburg) offers an Environmental Elevation program. Therefore, Drs. Li and Baker have faculty peers for support in their teaching efforts as well as a large student pool from which to draw to populate their new course entitled, “ENVE 497, Application of Molecular Biology in Environmental Engineering.” At PSU-H, the course materials originally developed at UC have been significantly modified to adapt to the unique student population. The three major adaptations include:

1. Expanding a fundamental discussion of molecular biology skills. Most students in the EEP at PSU-H lack formal training in Biology and do not have exposure to molecular biology skills. Therefore, the ‘introductory’ materials are being expanded to represent thirty percent of the total course (5 of 15 lectures). The belief is that this adaptation will allow students to become familiar with molecular biology terminology and skills necessary for the laboratory.

2. Emphasizing case studies discussing the application of molecular biology tools to address engineering problems. Because the teaching perspective at PSU-H focuses on the practical application of knowledge, it is critical to include engineering case studies to demonstrate to students the value of using molecular biology tools to address water and wastewater treatment. Including a discussion of practical applications is being used as an adaptation of the UC materials to bridge the students’ engineering experience (especially for part-time students) with Molecular Biology. The belief is that this adaptation will allow students to learn that Molecular Biology is more than a fancy tool; instead, this technology can be used to solve ‘real’ engineering problems.

3. Team-teaching by combining the expertise of two instructors. At PSU-H, this course will be team-taught by two instructors with complementary expertise (Dr. Li, Environmental Engineering; and Dr. Baker, Environmental Microbiology). With rich experience in each field, students will benefit from two different perspectives of the application of Molecular Biology in Environmental Engineering. Moreover, two instructors are co-directing the laboratory component. The lab procedures and videos developed at UC are being used in the first year of the course. Based upon student assessment and feedback, adjustments will be made to the course content to adapt the materials as appropriate for the students’ learning level at PSU-H. Drs. Li and Baker expect the team approach to provide students with a strong demonstration of the

fundamental and practical perspective of Molecular Biology applied to Environmental Engineering.

University of Wisconsin, Milwaukee, Jin Li

The mission of UW-M is to become an outstanding urban research and educational institution by offering quality instruction and research opportunities to traditional full-time students as well as adult professionals returning to school to retrain or to update their skills. The Department of Civil Engineering and Mechanics (CE&M) is particularly sensitive to the needs of non-traditional students as they constitute a significant percentage of the enrollment. As a result, CE&M actively encourages faculty to relate course material to practical applications. Currently, four faculty members work in the area of Water Resources/Environmental Engineering, and Dr. Li is primarily responsible for biological systems.

A new three-credit hour course entitled “Molecular Tools for Engineers” is being developed at UW-M by adapting the course originally developed at UC to meet student needs at UWM, including:

1. Expanding the lectures to help students master the vocabulary and key concepts in Molecular Biology. Based on personal experience with current students, Dr. Li expects that more than fifty percent of the enrolled students will be adult professionals returning to the classroom after many years of employment. A thorough review of Microbiology and Molecular Biology will help refresh students’ memories because many of these students are expected to have poor recall of their prior formal coursework in Biology and Chemistry.
2. Including a literature review and case studies. It is believed that modern technologies are best introduced to adult professionals through case studies combined with hands on, inquiry-based experiences. Student teams will perform a literature search and present case studies to the entire class demonstrating engineering applications of molecular tools, especially the combination of molecular tools with other analytical methods such as microelectrodes and microautoradiography.
3. Collaborating with the Great Lakes WATER Institute. The Great Lakes WATER Institute is a University of Wisconsin System research facility administered by the Graduate School of the UW-M. Many researchers at WATER are enthusiastic about perusing collaborative research focused on environmental issues and establishing new educational programs in the area of environmental biotechnology. Dr. Li has included peer faculty to provide guest lectures for her course introducing students to the use of molecular biology tools throughout the University of Wisconsin System.

Colorado State University, Amy Pruden

CSU is an 1860 land grant University with the primary mission of serving the community through research and education. The CED (Civil Engineering Department) is the home to the largest graduate program (both Masters and Ph.D.) on campus, and has recently been honored with the prestigious CSU designation as a “Program for Research and Scholarly Excellence.”

Environmental Engineering is housed within the CED and is an ABET accredited program at the undergraduate level. During the Spring Semester of 2004, the CED provided financial support and access to the newly renovated Environmental Teaching Laboratory for Dr. Pruden to teach an experimental course, CE 581 “Biomolecular Tools for Engineers”. The Colorado Institute of Technology (CIT) also has recently provided one-year of seed funding to assist in further developing CE 581. This course was inspired by the “Pilot-course” taught at UC, and will continue to build on it in several ways, including:

1. Adapting to a semester term and including additional topics from Molecular Biology:

Adjusting from a 10 week quarter to a 15 week semester will allow for new topics to be covered in the course. New lecture topics in CE 581 are focused primarily upon complementing the “full-cycle 16S rRNA approach” with functional gene analysis and proteomics, which currently represent the cutting-edge in biomolecular analysis. Dr. Kenneth Reardon is leading the proteomics lectures from the Chemical Engineering Department at CSU. In addition, another adaptation of the UC materials is the addition of denaturing gradient gel electrophoresis (DGGE), real time polymerase chain reaction (qPCR), and high throughput genomic analysis by capillary electrophoresis.

2. Integrating readings of primary literature, discussions, journals, and class presentations:

While the course is meeting once per week for a 100 min. lecture, a major adaptation from the format developed at UC is the review and discussion of primary literature implementing biomolecular tools for Engineering applications. With the assistance of the instructor, students are selecting one article from the peer reviewed literature for an oral presentation in class. To facilitate learning, each article presentation is followed by a group discussion and students are required to maintain a journal of their thoughts and reflections on the articles.

3. Targeting a broader base of Engineering majors: At CSU, the course materials originally developed at UC have been significantly expanded to target a broader base of Engineering disciplines. While all Engineering majors have been welcomed to enroll in the course, it has been specifically advertised to Civil, Environmental, Chemical, and Biomedical Engineering majors. The intention is to modify the nature of the journal article presentations to reflect the diverse interest of a broad student enrollment.

University of South Florida, Peter Stroot

The Environmental Engineering Program (EEP) at USF is growing to meet the demands of its recent designation as a Carnegie Research Extensive University. Traditionally, half of the graduate students are adult professionals attending USF on a part-time basis. With the recent transition in status, EEP is actively recruiting full-time students with an emphasis on retaining B.S. graduates for the M.S. program. The faculty within EEP currently participates in a NSF Research Experience for Undergraduates (REU) site and a Research Experiences for Teachers (RET) site to improve outreach to undergraduate engineering students and local high school students in the Tampa area. In addition, the USF has above average representation of minorities (23%) and female (59%) undergraduate students providing a unique audience for testing new teaching materials. Cognizant of the unique features of the EEP and recent training to improve teaching effectiveness, Dr. Stroot has adapted the course materials from UC, including:

1. Adopting an evening course format. In order to provide a course to undergraduates, traditional graduate students, and a large numbers of non-traditional students, the course is being offered in the evening. By offering the course in the evening, non-traditional students have the opportunity to spread the knowledge they gain in the course throughout their network of adult professionals in the Tampa area. In addition, undergraduate students are being exposed to working professionals. It is believed that this interaction may spur undergraduate interest to pursue graduate studies in Environmental Engineering.

2. Emphasizing inquiry-based Learning. The material for the “Molecular Biology for Environmental Engineers” course that was originally developed at UC has been adapted to enhance inquiry-based Learning. The original course format encouraged student teams to select their own environmental sample for investigation. Since the course at USF is focused on undergraduates, their exposure to Environmental Engineering is limited, and therefore their ability to select an appropriate sample for analysis is also limited. Allowing student to choose a sample is important to instill a sense of ownership. Therefore student teams are selecting a sample from a selection provided by the instructor (e.g., primary solids, activated sludge, anaerobic sludge). The student teams are conducting a literature review and designing an experimental approach using molecular biology tools to investigate their samples. Each student team provides a final written report and presentation of their findings to the class.

Assessment Plan

Conventional local assessment is being conducted at each of the five participating institutions. Common data that is being collected includes:

- student demographics
- pre- and post-testing of student knowledge to assess preconceptions and preparation of material as well as retention of material from previous lectures
- teaching performance observed directly in the classroom by a third party
- mid-term interview with students by a third party evaluator in the absence of the instructor
- written student evaluations at the end of the term.

In addition to this conventional local assessment, the Evaluation Services Center (UCESC) of UC’s College of Education, Criminal Justice and Human Services, is conducting a comprehensive meta-evaluation of this project. The complex and unique structure of this innovative program requires an evaluation methodology with multiple complementary techniques. The overall goal of the meta-evaluation is focusing upon answering the following question: Is this an effective program for introducing environmental engineering undergraduate students to molecular biology tools without a requirement for prerequisite courses in biology?

To address this overall question, the evaluation considers:

- How well do project activities address project goals?
- Do the questions and design have the potential to provide scientific evidence?
- Are the activities conducted consistent with the design?
- What issues/ problems/ concerns have arisen during the course of the project and how effective are the proposed solutions?, and

- Are the project team's decisions for developing the Molecular Methods in Environmental Engineering course consistent with the project's overall goals?

Evaluation activities are being guided by the following questions:

1. How effective is the Molecular Methods in Environmental Engineering course as related to the adaptation, delivery, and assessment of the lecture and laboratory content as implemented at five universities participating in this project?
2. How effective is the fusion of the five partner universities' parallel efforts in developing a textbook and laboratory manual that serve as an authoritative, stand-alone course on Molecular Biology in Environmental Engineering and a supplement to a course of biological principles or biological processes?
3. How effective is the research team, in conjunction with the appointed advisory committee, in disseminating the results of this project?

The project team has identified specific activities that will be assessed individually (formative evaluation) leading to an overall evaluation of the progress made toward accomplishing the stated goals (summative evaluation). The formative evaluations are being presented to the project team on an ongoing basis to track performance and to guide course modifications for improvement. The summative evaluations will be given to the project team on an annual basis and will be used to assess accountability, impact and sustainability.

The identified project activity strands are: 1) Adaptation of lecture and laboratory course content; 2) Implementation of lecture and laboratory course content; 3). Assessment of lecture and laboratory course content; 4) Fusion of the parallel efforts of the five partner universities in developing a single, authoritative text; and 5) Dissemination. The instructors, students, and local assessors as well as the advisory board will all be targeted as part of the 'meta-evaluation' activities.

During the 2005-2006 academic year, evaluation activities are focused primarily upon formative assessments as each faculty-instructor adapts the materials originally developed at UC to meet their perceived needs of their individual student populations.

The evaluation team is lead by Dr. Cathy Maltbie with assistance from the UCESC staff. Dr. Maltbie is responsible for ensuring that program evaluation is integrated into all project activities, and she is responsible for conducting the meta-evaluation. At PSU-H, Dr. Judi Zaeglein is working with Drs. Baikun Li and Baker to conduct assessment including an emphasis on the feedback received from adult professionals participating in ENVE497. At Milwaukee, Professor Anthony Ciccone, director of the UW-M Center for Instructional and Professional Development is working with Dr. Jin Li to use the results of the assessment to improve and redirect course delivery in the future. At CSU, the local evaluation plan is being coordinated with Dr. Karen Kaminski from the School of Education. At USF, Dr. Stroot is working with Dr. Melinda Hess, Director of the Center for Research, Evaluation, Assessment and Measurements within the College of Education.

Conclusions

Extensively described in previous publications, the Molecular Biology for Environmental Engineers course developed at the University of Cincinnati is being adapted and implemented at four partner institutions during a three year period (2005-6; 2006-7; and 2007-8, academic years). To date, the project team has identified necessary changes to the course materials to adapt the NSF CCLI Proof-of-Concept to four diverse institutions. The changes have been incorporated into ongoing courses that are being completed during the 2005-6 academic year. It is expected that the results of the assessment plan will provide quantitative data to support the or refute the effectiveness of the team's approach to the NSF CCLI Adaptation and Implementation program.

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