University of Massachusetts Lowell NIOSH TPG Final Report
for the period 7/1/2005 – 6/30/2010

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II. List of Abbreviations

ABET	Accreditation Board for Engineering and Technology
DWE	Department of Work Environment
MSD	Musculoskeletal Disorder
NIOSH	National Institute for Occupational Safety and Health
OEH	Occupational and Environmental Hygiene
ScD	Doctor of Science
SHE	School of Health and Environment
TURI	Toxics Use Reduction Institute
UConn	University of Connecticut
UMass	University of Massachusetts
UML	University of Massachusetts Lowell
WE	Work Environment

III. Abstract

The Department of Work Environment (DWE), established in the fall of 1987, offers the Master of Science (MS) and Doctor of Science (ScD) degrees in: a) occupational and environmental hygiene-industrial hygiene, b) occupational safety/ergonomics, c) occupational epidemiology, and d) work environment policy. A fifth graduate program within the DWE, "Cleaner Production/Pollution Prevention," not supported by the NIOSH TPG (to date), educates students in the technical and social aspects of sustainable production.

The name Work Environment was chosen to reflect the Department's commitment to addressing all aspects of the workplace as they contribute to workers' well-being and environmental protection. We take an integrated approach to health and safety as we strive to answer the basic question, "What is the optimal design of the healthy workplace?" It is our belief that specific problems, such as chemical exposures, postural demands, and psychosocial stress are best addressed comprehensively rather than individually. After more than 20 years of teaching, research and service, the feedback we receive from alumni, employers, unions and other partners has consistently stressed the strengths of this integrated approach to all aspects of health and environment at work.

The mission of the DWE is to train work environment professionals and conduct research on the identification and evaluation of health and environmental hazards and the design of safe and efficient alternatives, thereby promoting the development of sustainable systems of production. In carrying out this mission, we are guided by an overarching vision of the Department's role: to design and promote systems of production that are environmentally-sound, safe, healthy and rewarding for workers, communities, and consumers. We accomplish this by:

- Improving and developing new scientific methods to measure health effects and exposures at work and in the environment;
- Contributing to the design of production systems that are non-polluting, healthy and safe, economically and energy efficient, and non-wasteful of natural resources; and
- Closing the gap between occupational and environmental health sciences and politics by developing an understanding of the political, social, economic, and regulatory context of the workplace, work organization, and the general environment, nationally and internationally.

DWE is situated in the School of Health and Environment, along with departments in community health and health education, nursing, exercise physiology and physical therapy, and clinical laboratory science and nutrition. The Department also has strong ties with the UML College of Engineering, where the Department was housed for its first fifteen years. That affiliation provided our program with a firm rationale for incorporating a focus on prevention through design. It was the conviction of the founding members of our Department that the classic public health approach toward the assessment of occupational

exposures needed to be complemented by a strong research and training emphasis on the control of exposures. This orientation has been firmly embedded as the underlying foundation of the entire curriculum and continues to define the character of the department. Despite our move to SHE, there continues to be a strong emphasis on engineering skills in relevant areas of our degree programs and active teaching and research collaboration with UML engineering faculty, much of which involves our students or otherwise impacts their training.

IV. Highlights and Significant Results

In 21 years of the program (1989-2010), there were 219 master's graduates and 114 doctoral graduates, for an average of 16 graduates/year. In the most recent grant period 2006-2010, there were 44 master's graduates and 35 doctoral graduates. In a survey of graduates from the past 10 years, we found that 95% were working in a related field or pursuing an additional related degree.

Almost all of the NIOSH training grant budget was used for direct trainee support. This is possible because the cost of supporting a graduate student at UML continues to be very low and all of the Department faculty are supported 100% by "hard money" from the Commonwealth of Massachusetts. The actual cost for each student varied depending on the residency status (in-state/out of state) and the number of credits taken but averaged about $18,000 for a full-time MS student ($10,000 in stipend plus approximately $8,000 in tuition and fees). In the 2008-09 academic year, about 90% of our direct costs were spent on trainee stipends and tuition and fees, in addition to expenditures that directly benefited students in the form of laboratory supplies and student travel to national meetings.

Until 2007, a total of 45 graduate course credits were required for graduation with a DWE master's degree, which has now been reduced to 36 credits. This resulted from a process begun in 2005 by which the faculty of the department undertook the task of modifying the MS degree core courses. These changes resulted from discussions with alumni and employers about our curriculum, centered on developing a list of new desirable skills and competences needed by MS graduates (practitioners) in the ever-changing workplace.

A research retreat has been organized annually since 1998 and bi-annually for the past 5 years by UMass Lowell and University of Connecticut Health Center faculty, where graduate students from both campuses are encouraged to attend and to present work in progress. These meetings have been important venues for contact between occupational medicine residents and occupational hygiene and ergonomics students, practitioners and faculty. Occupational psychology faculty and graduate students from UConn Storrs have participated since 2004, broadening the scope of discussion even further.

Highlights: Occupational/Environmental Hygiene

The training our students receive prepares them well for today's job market, where OEH professionals typically take on additional duties such as safety, ergonomics, environmental compliance, etc. Unique among occupational and environmental hygiene programs is the highly integrated nature of our curriculum that introduces students to all of these core areas. We take an integrated approach to worker health and safety as we strive to answer the basic question, "What is the optimum design of the healthy workplace?" It is our belief that specific problems, such as chemical exposures, postural demands, and psychosocial stress are best addressed comprehensively rather than individually. For OEH students the existence of the Toxic Use Reduction Institute (TURI) and the cleaner production program within the Department provide the opportunity for unique training in the area of hazard control focused at the source rather than through retrofitting.

The OEH program is accredited by the Accreditation Board for Engineering and Technology (ABET). DWE underwent an ABET recertification beginning in 2005 with submission of our self-study and then a site visit in 2006. As part of the ABET accreditation process we developed general and specific outcomes and competencies under the broad headings of: (1) recognition and evaluation of occupational health and safety hazards; (2) control and prevention of occupational and environmental health and safety hazards and promotion of healthy alternatives; and (3) management of occupational and environmental health and safety programs. Based on our ongoing program assessment process, our Work Environment outcomes/competencies relate closely to ABET general and specific outcomes. These competencies will continue to serve as the basis for ongoing course evaluations.

The Department now offers a Graduate Certificate in Laboratory & Biosafety. The four courses in this certificate are offered entirely online. The program introduces students to the fundamentals of biological safety as well as laboratory health and safety, and serves the biotech, biomedical and pharmaceutical sectors, which continue to show healthy economic growth in the New England region. Each biotech organization must have an environmental health and safety office that covers biosafety, chemical, radiation and animal safety, and it has been difficult for companies to find a biosafety professional with an American Biosafety Association (ABSA) certification since there are currently no graduate or undergraduate programs in biosafety in the United States. We expect that some of those who apply for the certificate program may decide to matriculate into our master's program once they begin their coursework, so we see this as a potential recruitment avenue.

Highlights: Safety/Ergonomics

This program provides the only comprehensive, academic training in occupational safety/ergonomics in the New England region. It is one of the broadest such programs in the nation, with a highly integrated curriculum that

introduces students to all of the core occupational health areas and trains them as real-world problem-solvers. Our program incorporates safety and ergonomics into an integrated treatment of worker health and safety protection, and as a consequence, our students acquire a solid foundation in the public health principles and methods that are necessary for comprehensive risk reduction as well as a full appreciation of their future professional responsibilities and an ability to keep up with advances in their field.

We do not define the field of occupational ergonomics solely with respect to biomechanical risk factors for musculoskeletal disorders (MSDs). While this is an important area, the basic concept of "fitting the task to the person" implies a more comprehensive perspective that applies equally well to safety practice and research. Very few other university training programs in safety/ergonomics have incorporated the study of psychosocial strain and work organization issues to the same extent, especially with expertise as well developed and recognized as at UML.

Research activities in the safety/ergonomics core are diverse, covering work-related musculoskeletal disorder epidemiology, biomechanical modeling, field assessment of ergonomic and safety hazards and psychosocial strain, evaluation of control measure effectiveness, and technical and social factors in the reorganization of work. Many research projects are carried out in collaboration with the UML Psychology Department, the Center for Women and Work, and the Center for Family, Work, and Community. These connections help students to deepen their understanding of psychological strain and behavior outcomes in the area of anxiety, depression, alcohol and substance abuse, as well as the intersection of work experience with family and community burdens of occupational and environmental problems. Collaborations with researchers at UConn and the Liberty Mutual Research Institute for Safety address injury and MSD surveillance and outcomes research.

Highlights: Occupational Epidemiology

Epidemiology taught at UML is tightly linked to the other work environment fields, encouraging a thoroughly integrated perspective from the very first courses. The essential components of epidemiologic method and perspective taught in any master's level program in epidemiology are found in the DWE curriculum, but trainees benefit from learning this material organized around themes of work, environment and health.

While all epidemiologic studies share many common features, the effective application of epidemiologic methods in the occupational setting creates certain opportunities and problems that may be given less emphasis in a generic epidemiology course than is appropriate for the work environment practitioner. For example, occupational epidemiologic studies place heavy emphasis on the quantification of exposure because the control of exposure is very often the first line of defense against workplace hazards. Exposure control strategies – from

the setting of health standards to the choice of personal protection equipment, to the design and evaluation of engineering controls - all require quantitative exposure-response information. The epidemiologic methods for the estimation of such information, and the limitations that arise in application of these methods are a key component of the epidemiologic approach taught at UML. Exposure assessment -- an integral part of occupational epidemiology -- has become an active area of research in and of itself.

The integration of methodology with substantive real-world problems also serves to highlight common work-related conditions that are not always considered of great interest in general epidemiology programs. For example, the epidemiology of musculoskeletal disorders is a strong emphasis in the research and training programs. Students become comfortable from the first course in the master's program with considering ergonomic and chemical exposures in closely parallel ways. This creates an interest in the study of episodic and reversible conditions, something often not covered in standard epidemiology programs except as an advanced elective course.

Field epidemiology experience is provided through collaborations with the Massachusetts Department of Public Health, student-initiated course and capstone projects, and student participation in faculty research. Occupational epidemiology in the program is taught as a fundamentally interdisciplinary science, and students come to see the importance to epidemiology of the full range of other offerings in the work environment sciences, including physiology, toxicology, biostatistics, industrial hygiene, and biomechanics, psychology, sociology and public policy.

Highlights: Work Environment Policy

The key area of policy research that distinguishes our program is the investigation of social factors in occupational safety and health. The training required for practical work in policy development and analysis is interdisciplinary, including economics and other social sciences. Our program also utilizes social history and cross-national studies as ways of analyzing problems and developing new approaches to preventing workplace injury and disease.

The goal of the policy program is to prepare professionals with the ability to function effectively in the internal and external-contextual domains of occupational health. Our students are proficient in scientifically evaluating the hazards of workplace exposures as well as the effectiveness of engineering or administrative control measures. These skills prepare them to function effectively within the internal domain of the scientific study of the effects of employment conditions in human health.

Simultaneously, our students are educated in the external-contextual domain of occupational health. Occupational health issues exist within a social context external to the narrow exposure-effect relationship and the traditional

scientific research enterprise. The multi-disciplinary character of our curriculum allows students to probe the socio-economic context of occupational health on themes such as economics, regulation, public administration and policy. To this end the policy educational program has been designed to prepare graduates with dual skills: First, to conduct sophisticated investigations of problems so that the best information is available when developing or designing new engineering or other controls along with appropriate secondary prevention activity –i.e., the internal domain of occupational health; and Second, to examine and understand the socio-political context of occupational health impacts in society – i.e., its external contextual domain.

The WE Policy program also has the broader objective of promoting sustainable production: environmentally sound systems of production, healthy work environments, and productive work organizations. The overarching principle is to design production that is non-polluting; conserving of energy and natural resources; economically efficient; safe and healthful for workers, neighbors, and consumers; and rewarding for employees. The WE Policy program was instrumental in the founding of both the Toxics Use Reduction Institute (TURI) and the Lowell Center for Sustainable Production (LCSP), both within DWE. Through the Toxics Use Reduction Institute and other funding sources, we have an active research agenda concerning the ways that new generation environmental technology policies affect the work environment. We have active research on the economics of health and safety, including research on workers' compensation issues and the cost-effectiveness of preventing musculoskeletal disorders.

V. Outcomes-Relevance-Impact

In 21 years of the program (1989-2010), there were 219 master's graduates and 114 doctoral graduates, for an average of 16 graduates/year. In the most recent grant period 2006-2010, there were 44 master's graduates and 35 doctoral graduates. Almost all of these alumni are currently working in the fields of health, safety and environment.

Trainees from the most recent grant period 2006-2010 have published at least 32 papers in the peer-reviewed literature during or subsequent to their training. Nearly all graduates of the training program are currently working in occupational or environmental health and safety or a closely related field.

Almost the entire budget in the most recent grant period was used for direct trainee support. This is possible because the cost of supporting a graduate student at UML continues to be very low and all of the Department faculty are supported 100% by "hard money" from the Commonwealth of Massachusetts. The actual cost for each student varied depending on the residency status (in-state/out of state) and the number of credits taken but averaged about $18,000 for a full-time MS student ($10,000 in stipend plus

approximately $8,000 in tuition and fees). In the 2008-09 academic year, about 90% of our direct costs were spent on trainee stipends and tuition and fees, in addition to expenditures that directly benefited students in the form of laboratory supplies and student travel to national meetings.

Technical Report

VI. Background

A. NIOSH-TPG Funding History.

For the period 2005 to 2010, the NIOSH-TPG Training grant has provided continued program support for four training programs: a) Occupational and Environmental Hygiene-Industrial Hygiene (OEH-IH), b) Occupational Safety/Ergonomics, c) Occupational Epidemiology, and d) Work Environment Policy/Cleaner Production. The four programs together constitute the Department of Work Environment (DWE) at the University of Massachusetts Lowell. These programs have been funded by NIOSH since 1995, with support at the master's and doctoral level for each program.

B. Program Administration.

The Department is located in the School of Health and Environment (SHE) which was founded in 2003. The mission of SHE is to promote human health and development that enables people to live in safe and productive communities and environmentally sustainable economies. The DWE graduate programs join with other nine undergraduate and graduate degree programs: Environmental Health, Nursing, Clinical Laboratory Sciences, Community Health Education, Exercise Physiology, Physical Therapy, Medical Technology, Health Services Administration, and degree programs, the School prepares future professionals to practice with knowledge, competence and respect for the interdependence of human and global well being. SHE promotes human health and development that enables people to live in safe and productive communities and environmentally sustainable economies.

Our location in SHE allows our students to have access to clinical data on work-related disease and opportunities to see occupational health from a health care delivery perspective. The success of DWE in interdisciplinary research has increased understanding in the new school of prevention and causes of occupational and environmental health morbidity and mortality, as well as their social and physical determinants. There are a number of active areas of teaching and research collaboration between DWE and other SHE departments. These include DWE faculty contributions to a course on environmental health; a graduate certificate in disability studies with the Department of Physical Therapy; enrollment in our epidemiology courses by students from several SHE departments; guest lectures by DWE personnel on occupational health topics in a variety of courses; nursing, exercise physiology, and health education students

serving as Research Assistants on DWE projects; and cross-department faculty service on doctoral research committees.

DWE also has strong ties with the UML College of Engineering, where the Department was housed for its first fifteen years. That affiliation provided our program with a firm rationale for incorporating a focus on prevention through design. It was the conviction of the founding members of our Department that the classic public health approach toward the assessment of occupational exposures needed to be complemented by a strong research and training emphasis on the control of exposures. This orientation has been firmly embedded as the underlying foundation of the entire curriculum and continues to define the character of the department. As described above despite our move to SHE, there continues to be a strong emphasis on engineering skills in relevant areas of our degree programs and active teaching and research collaboration with UML engineering faculty, much of which involves our students or otherwise impacts their training.

C. Internal Departmental Administration

The DWE is organized under an elected Chair presiding over the faculty, with a general faculty meeting once a month conducted by the department chair and having input from all department members. The current Chair is Professor David Kriebel. Research faculty members are also invited to attend. Key departmental activities are carried out by three independent committees that also meet at least once per month: a) Recruitment and Outreach (Dr. M. Quinn, Coordinator); b) Administration and Finance (Dr. K. Geiser, Coordinator); and Academic Affairs (Dr. Woskie, Coordinator). Decisions within the committees and the full faculty meeting are reached by consensus.

The department is organized academically into program areas (concentrations), each one directed by a faculty member. Four of these correspond to the four training grants funded by NIOSH: Occupational and Environmental Hygiene, Safety/Ergonomics, Occupational Epidemiology, and Work Environment Policy. A fifth concentration, Cleaner Production/Pollution Prevention, is being merged into Work Environment Policy. There are also four research centers and institutes affiliated with the department. Because the four NIOSH-funding training programs cover nearly all DWE academic programs, the administration of the Department and of the training programs are closely linked and operated as a single entity.

VII. Specific Objectives

The Mission of the DWE is to train work environment professionals and conduct research on the identification and evaluation of health and environmental hazards and the design of safe and efficient alternatives, thereby promoting the development of sustainable systems of production. In carrying out this mission, we are guided by an overarching vision of the Department's role: to design and

promote systems of production that are environmentally-sound, safe, healthy and rewarding for workers, communities, and consumers. We accomplish this by:

a. Improving and developing new scientific methods to measure health effects and exposures at work and in the environment;
b. Contributing to the design of production systems that are non-polluting, healthy and safe, economically and energy efficient, and non-wasteful of natural resources; and
c. Closing the gap between occupational and environmental health sciences and politics by developing an understanding of the political, social, economic, and regulatory context of the workplace, work organization, and the general environment, nationally and internationally.

The program's academic objective is to educate students at the graduate level by awarding Master of Science and Doctor of Science degrees on Work Environment on four core programs: a) Occupational and Environmental Hygiene-Industrial Hygiene (OEH-IH), b) Occupational Safety/Ergonomics, c) Occupational Epidemiology, and d) Work Environment Policy/Cleaner Production.

Our academic objectives have been represented by three broad educational outcomes: (1) recognition and evaluation of occupational health and safety hazards; (2) control and prevention of occupational and environmental health and safety hazards and promotion of healthy alternatives; and (3) management of occupational and environmental health and safety programs.

VIII. Results and Discussion

A. Department of Work Environment History and Mission

The Department of Work Environment (DWE), established in the fall of 1987, offers the Master of Science (MS) and Doctor of Science (ScD) degrees in: a) occupational and environmental hygiene-industrial hygiene, b) occupational safety/ergonomics, c) occupational epidemiology, and d) work environment policy. A fifth graduate program within the DWE, "Cleaner Production/Pollution Prevention," not supported by the NIOSH TPG (to date), educates students in the technical and social aspects of sustainable production.

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In light of the departmental consensual management approach, most administrative issues are addressed and resolved by the faculty of the Department meeting as a committee of the whole. Issues that are narrowly defined and appropriately reserved to one program alone are managed by a committee of the faculty members identified with that program and chaired by the program director. As a result, the department Chair receives continuing advice from the faculty through the regular monthly department meetings and the separate core program meetings. Input is also sought from the graduate student leaders, in particular the Work Environment Student Association (WESA). Through this group and the student chapters of the professional societies, the students provide input on the academic program and bring student issues to the attention of the program directors and department chair. The students organize an election for an annual teaching award, and organize seminars, outings and informal activities which greatly improve the academic experience for students.

C. Training Objectives

The Department of Work Environment's degree programs provide training and research on the identification, characterization and control of chemical, physical, psychosocial, and biological risks associated with work environments as well as in understanding and developing respect for the complex social, political and economic context in which environmental and occupational health problems must be studied and addressed. Our model of research and education integrates a rigorous scientific methodology with practical collaboration with the region's industry, labor, communities and governments to design safer and cleaner systems of production. The goal of the graduate program is to prepare professionals with the ability to scientifically evaluate the hazards of production as well as to design efficient alternatives to hazardous exposures.

The master's program prepares graduates to be prevention practitioners who have a solid grasp of the fundamental skills necessary for recognition, evaluation, and control of hazards in the work environment. Graduates find employment as leaders and professional practitioners of occupational and environmental health and safety within a company, a government agency, a consulting firm or insurance agency, or a labor or community organization. Many master's courses have either a field or a laboratory component, so that the trainee obtains hands-on experience; the training also includes experience working in small groups and making professional presentations.

The doctoral program is designed to prepare research scientists with a strong orientation towards prevention and applied research. Graduates become research scientists and policy specialists with the background and skills needed to produce new knowledge in their chosen field of specialization, in academia, governmental or private research organizations and industry. The student participates in the design and data collection and is responsible for statistical analysis of the data. The completion of a dissertation demonstrates that the student has integrated the necessary academic skills and has the ability to identify problems in work environments and to work together with co investigators in the necessary disciplines to carry out a successful study. The doctoral degree provides the background and the skills needed for work in academic faculty positions, as well as careers in governmental or private research organizations.

D. The Master's Degree

The Master's of Science program requires 36 credits and usually takes two years of full-time study. Part-time students take one or two courses (3 or 6 credits) per semester, completing the degree in 3 to 6 years. An interdisciplinary program core of 15 credits is required of all students in any of the DWE master's degree programs. An additional 21 credits are taken within one of the core programs ("concentrations"). The variety of standard program options and their requirements are detailed in each of the program descriptions below.

The Program Core: The program core courses are common to all four programs. The core is designed as an introduction to the field of work environment and to the essential disciplines upon which it is based. The courses have been designed to be integrated so that the interactions of the various elements are emphasized. Most students take the first four core courses during their first two semesters after matriculation. The core brings together students from all the programs, and consists of the following five courses.

Core Courses for the MS degree in Work Environment

Course No.	Title	Credits
19.500 (or 19.651)	Analytical Context of the Work Environment (or Work Environment Policy and Practice)	3
19.503	Toxicology and Health	3
19.525	Introduction to Industrial Hygiene and Ergonomics	3
19.575	Introduction to Occupational Epidemiology and Biostatistics	3
19.600 19.601	Work Environment Capstone Preparation Work Environment Capstone	0 3
Total Graduate Credits for DWE Core Courses		15

The introductory course (19.500) is designed to provide the contextual and information base needed for any student regardless of background or planned concentration. It also provides an integrated view of the disciplines that define work environment issues. This is accomplished using a course structure that is built around case studies and interdisciplinary group problem-solving. The course is presented in two major parts; the first introduces students to the ways in which hazards can be identified and characterized whether physical, chemical, biological or psychosocial. The second part explores the methods of prevention of these hazards and integrates representative aspects of the Department's concentrations. Care is taken to develop the interconnections between exposures and illness/accident development at three levels: the individual, the work organization and the society. This course brings issues of science and policy together in an effective exploration of the origin of and solutions for work environment problems. (This course was re-named in 2007, from Introduction to Work Environment to Analytical Context of the Work Environment.)

The survey course that combines industrial hygiene and ergonomics (19.525) is designed to educate all students to an understanding that work settings are always a combination of chemical, physical, biomechanical and psychosocial hazards. This approach responded to our observation that graduates were invariably faced with problems that were not "simply" either a

chemical exposure needing only industrial hygiene expertise or repetitive trauma that needed only ergonomics expertise. Thus the emphasis is on learning the basic aspects of assessing and controlling all types of hazards in an integrated manner, so that the foundation for learning integrated practice skills is laid down at the beginning of the educational program.

The course in toxicology and human health effects (19.503) provides a sound introductory understanding of the health impacts of the principal types of hazards encountered in the work environment. The course is organized into three complementary components. The first covers the pathophysiologic mechanisms of workplace exposures with an emphasis on toxicologic mechanisms such as carcinogenesis and allergy, and also including the effects of physical agents. The second portion reviews the anatomy, physiology and important occupational diseases of each human body system. In the final portion of the course, the important classes of work environment toxins and their health effects are discussed. The course is designed to provide a comprehensive pathophysiologic and toxicologic foundation for advanced courses, such as Evaluation of Work Environment Hazards (19.614), Measurement of Airborne Chemical Exposures (19.617), and Occupational Biomechanics (19.531). Students are required to complete a final project for this class. Students are also provided the opportunity, if desired, to prepare a final project based on a clinical case of occupational disease seen at an occupational medicine clinic.

The introduction to epidemiology and statistics (19.575) is designed to provide an introduction to the principal quantitative methods for assessments of the work environment. Basic epidemiology study designs are introduced along with consideration of causal inference in epidemiology, bias, and confounding. The fundamentals of biostatistics are taught in the context of epidemiology with attention to probability theory, the normal distribution, Gaussian statistics, and an introduction to linear regression.

All master's students are required to complete a capstone experience (19.600/19.601). The capstone is designed to complete the experience started in the first course of the master's program, Analytic Context of the Work Environment, by further developing and integrating the major themes of that course in application to a real-world problem. In this final project, the student addresses a specific work environment issue by defining the problem, characterizing the risk, and developing solutions in an interdisciplinary fashion. In addition to developing an integrated approach to occupational and environmental problem-solving, two explicit goals of the capstone are: 1) to develop students' skills in report writing and oral presentation; and 2) to educate them in the responsible conduct of research (the latter discussed further in section 5. below). Many students need help in improving their written and oral communications skills, and the capstone course is the principle opportunity for this support. Draft written reports and practice final presentations are critiqued and discussed in class before each final product is submitted. Students may

work in pairs, but the weekly meetings provide all students the chance the share their experience and to benefit from each other's areas of concentration. Students produce a final report and make a public presentation of the proposed approach, with formal judging by a jury of all DWE faculty members.

E. The Doctoral Degree

Doctoral degree requirements generally include 24 to 30 credits (minimum of 18) post-master's degree with 18 credit hours of courses beyond those required for the master's degree and 12 credits of dissertation research. A student with a master's degree from another institution will need to show knowledge in all subject areas required for the equivalent Work Environment master's degree (see above) from the University of Massachusetts Lowell. Typically from two to five years will be needed post master's to complete the program.

Course Requirements for the Doctoral Degree: Courses will be selected to prepare each student in one major and two minor fields. The major field must include, at a minimum, six full courses (18 credits), and the minor fields, three courses (9 credits) each. Courses taken for the master's degree may be used to meet these requirements. There is no language requirement. Each doctoral student will be assigned a doctoral program advisor based on review of their application by the faculty and agreement as to who is the best match for the students interests along with which faculty member may have research funds to support the student. The advisor works with the student to propose a set of courses to meet the major and minor requirements and prepare them for with the breadth and depth needed for their dissertation work. The student will then file a program approval request with the DWE Department Graduate Committee, made up of faculty representatives from each program, who then approve or request revisions in the courses listed for majors and minors.

Following approval of this course program, the student will be eligible to take a written qualifying examination. The exam will be designed to test the knowledge in the major field. Upon meeting the course and written exam requirements, the student must identify a dissertation topic and select a thesis committee. In addition to the chair, the thesis committee must have 2-3 faculty that represent other disciplines relevant to the thesis. The student must then prepare a thesis proposal in the format of a NIH R01 grant application and pass an oral qualifying examination based on the proposal.
The doctoral dissertation is based on a substantial body of original research carried out by the candidate. The selection of the research topic will be the responsibility of the student in consultation with the academic advisor. When the doctoral student has completed all course requirements for the doctoral degree, the student and advisor together will propose a Dissertation Research Committee to the Department Graduate Committee. Once approved, the Research Committee will meet at least as frequently as every six months to review the student's progress. The Research Committee will assess whether the student is

making adequate progress toward completing the dissertation in the required years of study and will approve the dissertation. The dissertation will, in general, be in the form of three publishable manuscripts and will include an appropriate literature review and overview of the dissertation research. The student is required to give an oral defense of the dissertation before the Research Committee and other faculty members. The defense is open to the public.

F. Interdisciplinary Training Experiences

Students in each of the core programs frequently take courses in the other programs as electives, providing numerous opportunities for interdisciplinary discussions both in and outside the classroom. For example, many students in safety/ergonomics take courses offered by industrial hygiene faculty in exposure assessment and exposure data analysis, which has led to increased interaction between industrial hygiene and ergonomics faculty members about course material pertinent to both fields. Analogous cross-fertilization occurs with other departments within UML. For example, graduate students in both Mechanical Engineering (ME) and Physical Therapy (PT) may select Work Environment options in their degree programs, leading them to take three and four safety/ergonomics courses, respectively. In turn, Ergonomics students may take courses in the PT Department.

Doctoral students in any DWE program take advanced anatomy and physiology courses in order to broaden their knowledge in those areas. Nursing doctoral students take several DWE epidemiology and biostatistics courses.

DWE students have significant interactions with the Department of Psychology and the Department of Regional Economic and Social Development (RESD), taking courses in the socioeconomic and psychological aspects of work, family, and community, while students in those departments also take courses of ours such as Work Environment Policy, Introduction to Industrial Hygiene and Ergonomics, Healthy Work Organization, and Intervention Research.

A number of DWE faculty actively participate in the intercampus Biomedical Engineering and Biotechnology (BMEBT) program. Dr. Buchholz serves as the program director and he and other faculty are lead advisors on BMEBT doctoral research projects.

Other student opportunities for interdisciplinary work have developed over time through our multifaceted collaboration with the University of Connecticut. Students from UML have carried out job analyses at sites in Connecticut, in collaboration with personnel at the UConn Ergonomics Technology Center, leading to course projects and at least once to a master's research project.

A research retreat has been organized annually since 1998 by the UML and UConn faculty, where graduate students from both campuses are particularly

encouraged to attend and to present work in progress. These meetings are important venues for contact between occupational medicine residents and DWE students, practitioners and faculty. Occupational psychology faculty and graduate students from UConn Storrs have participated since 2004, broadening the scope of discussion even further.

Program faculty members collaborate on research with occupational medicine physicians not only at UConn Health Center but also Harvard Medical School, the Harvard and Boston University Schools of Public Health, UMass Medical Center (Worcester), Yale University, and Washington University (St. Louis MO). These collaborations have also involved graduate students in various ways, ranging from single-semester course projects to doctoral research. In turn, UML faculty members have served on degree committees at the Harvard School of Public Health and other institutions.

G. Training Facilities

Laboratories: Department laboratory facilities include two industrial hygiene labs, a toxics use reduction lab and a safety/ergonomics lab. The industrial hygiene labs are dedicated to general industrial hygiene and to aerosol science, and are used both for research and for instruction. All laboratory equipment is housed on-campus and students have access to all.

Occupational & Environmental Hygiene Chemistry/Field Laboratories: one field/analytical teaching lab (368 feet^2); one analytical prep lab (480 ft^2); one analytical analysis lab (768 ft^2) and one field equipment lab (210 ft^2). Current work in these instructional and research laboratories is focused on exposure assessment, sampling and analysis of air contaminants. Extensive air sampling equipment including personal sampling pumps, direct reading particulate, gas and vapor monitors, and microbial air samplers are housed in this laboratory. In addition, an atomic absorption spectrometer, gas chromatograph, UV/Vis spectrophotometer, High pressure liquid chromatograph,and a HPLC/MS/MS; two gas chromatograph/MS instruments, an FTIR and environmental chamber with microbalance are used in the chemical analyses done in this lab. A comprehensive computer system linked to the autosamplers of the analytical equipment also supports the instrumentation in this laboratory.

Industrial Hygiene/Aerosol Science Laboratory (240 feet^2): The Department of Work Environment has established an Aerosol Science laboratory in support of the Department's teaching and research programs. The laboratory is equipped with a sophisticated aerosol generation system, where various test aerosols can be generated and subsequently employed to test aerosol measurement and control equipment. The ventilation evaluation equipment of the Department is housed here and the lab is used to teach ventilation design and evaluation methods. In addition, the laboratory is equipped with various aerosol measurement and generation instruments, including a Zeiss phase contrast

microscope, a laser particle spectrophotometer, a Wright dust feeder, and a fibrous aerosol generator.

Toxic Use Reduction Institute Surface Cleaning Laboratory(1,000 feet^2): The Toxics Use Reduction Institute has developed a research and testing laboratory specializing in cleaning methods and chemistries. The surface cleaning laboratory evaluates the effectiveness of different cleaners and the laboratory is equipped both with cleaning equipment and with analytical equipment to measure surface cleanliness. Currently, the major focus of the laboratory is the evaluation of aqueous-based cleaning systems being developed as alternatives to chlorinated solvents.

Occupational Biomechanics Laboratory (600 feet^2): is used extensively in several courses, i.e., Occupational Biomechanics Laboratory, Advanced Biomechanics, and Methods of Work Analysis. It is also an important resource for many master's and doctoral level research projects. The lab contains standard biomechanical measurement instrumentation such as inclinometers, goniometers and lumbar motion monitors. Also available are digital still and video cameras, 4-channel EMG systems, as well as a variety of ergonomic analysis programs such as Mannequin Pro (HumanCAD anthropometric modeling software), ErgoEASER (USDOE checklists for upper extremity risk factors, lifting analysis, and VDT workstations), and The University of Michigan 3-dimensional static strength modeling and energy expenditure prediction programs.

Computer and Telecommunications Resources: The Department of Work Environment has a Sun Sparcstation 20 which is networked to faculty and doctoral student computers and serves as host to a UNIX version of SAS that is dedicated to research projects that require increased computational capabilities. The department has a student computer laboratory with six desktop computers. The Occupational Biomechanics Laboratory has a desktop capable of analog-to-digital data collection and storage and the Industrial Hygiene Laboratories also have a number of PCs for use in laboratory courses. There are additional personal computers for use by Research Assistants on research projects, including a number of laptops for fieldwork.

The University has been supporting distance learning and training via video for over 10 years. Connections for video are primarily using ISDN technology. Video connectivity exists between all UMass campuses as well as other institutions in the area. Video streaming is also a supported service on the UML campus.

Classroom Space: The department has a large classroom with permanent LCD projector equipment and computer with internet high speed connection capabilities. It also has a department seminar room with similar projection capabilities. The department has additional portable video, PowerPoint

projector, overhead projector equipment and laptop computers that faculty can use for classes elsewhere.

Library Resources: The campus system includes three separate libraries. Together, these libraries cover more than 203,000 square feet of floor space, include more than 1200 seats, and hold approximately 357,000 volumes. UMass Lowell's "electronic library" offers access to over 300 databases, full-text access to over 1 1,000 journals, 200 newspapers and reference works such as the Gale Business Resources. Professional library staff members have produced local content databases that are available through the library's web site as well. Voyager, a multi-tiered, client/server, fully integrated on-line system is our Web-based catalogue that showcases the "Electronic Library" and provides a single point of access to all Library materials, in all formats. The journal collection includes 717 print subscriptions and access to more than 11,000 titles in full-text through various database subscriptions.

Distance learners have equal access to on-line materials through the Library's Remote Access services. Instructions are available on Library's Web page for proxy access to all information available through the library web page including subscribed databases. The Library Web page offers "Live Help," which offers on-line assistance via the main menu on the Library Web page. The services allow users to chat on-line with a reference librarian.

The DWE also has its own library, with current journals, reports, monographs and textbooks in relevant fields, which is maintained jointly with the Toxic Use Reduction Institute.

H. Admission Requirements

Admission to MS Program: Prospective students must apply to the Graduate School and meet the requirements of both the University and the Department before admission. To be admitted, applicants must have a BA or BS with an overall GPA of at least 3.0. Applicants must have a grade of C or better in required, prerequisite technical courses. Specific pre-requisites are listed separately for each core program.
GRE's are required unless the student has completed a previous relevant graduate degree. There are specific admission requirements for each of the four core programs that are described below in each Program Plan. For students who graduated from a university in a country where English is not the official language, TOEFL scores should be at least 550 (paper-based), 213 (computer-based), or 79 (internet-based).
Excellent written communication skills are important in graduate school, as well as in professional careers. For this reason, the Department places special emphasis on documentation of writing ability. The applicant's statement required as part of the graduate application is one such document, but applicants may also submit other writing samples.

Successful applicants must also have demonstrated the ability and motivation necessary for independent creative work and an interest in issues of the work environment. Preference is given to candidates with both a quantitative academic background and work experience in industry, government or health care. At the same time, the faculty of the Department of Work Environment believes that the program (and the profession) is strengthened by admitting students from a wide diversity of backgrounds, and therefore students with non-traditional educational or work backgrounds will be considered carefully.

A faculty committee evaluates each applicant's complete packet of application materials including GPA, GRE, TOEFL, experience, recommendations and essay. Meeting minimum requirements does not guarantee acceptance. In some cases, applicants who do not meet one of our entry requirements may be admitted if other parts of their application outweigh the deficiency. In addition, applicants who do not meet one of our entry requirements may be admitted if they have completed 9 credits of Work Environment Department courses, all with a B+ or better as a non-matriculated student.

Admission to ScD Program: In addition to the requirements above for master's admission, doctoral students require a more extensive review process. In any of the core programs, successful applicants must demonstrate the potential for independent research, excellent writing skills, and a substantive area of interest that is compatible with faculty expertise within that program. The faculty members of the core program where the candidate wishes to matriculate will carefully evaluate the candidate in terms of his/her potential ability to conduct research, often with a personal (face-to-face or telephone) interview. If the core program faculty members are in consensus and at least one appropriate advisor can be identified from these faculty, the candidate is presented to a DWE faculty meeting.

Doctoral training is built on the didactic training gained in the master's degree program. Candidates who enter with a master's degree in a related area from another university often have gaps in coursework. These gaps will be made up upon admission to attain the equivalent of our master's degree in the designated major field.

I. Graduating MS and ScD Students in Grant Period.

Table 1 identifies the graduates that received NIOSH-TPG funding in the last grant period by core program. Tables 2 and 3 show the total number of graduates in the same period.

Table 1. UML Work Environment Graduates Recipients of NIOSH-TPG Support, 2005-2010					
Year	Safety/Ergo	OEH-IH	Epidemiology	Policy	Totals
2005		1	2	3	6
2006	2	1		1	4
2007		4	1	3	8
2008	2	1	2	1	6
2009	1			1	2
2010		2	1	2	5
Totals	5	9	6	11	**31**

Table 2. Department of Work Environment Doctoral Degrees, 1989-2010					
	1989-2005	**2006-10**		**Totals**	**%**
EPI	**11**	**11**		**22**	**20**
SAFETY-ERGO	**12**	**5**		**17**	**15**
OEH-IH	**21**	**7**		**28**	**24**
POL /CPPP	**35**	**12**		**47**	**41**
TOTAL	**79**	**35**		**114**	**100**

Table 3 Department of Work Environment Master of Science Degrees, 1989-2010						
		2000-05		**2006-10**	**Totals**	**%**
EPI		**7**		**2**	**9**	**4**
SAFETY-ERGO		**58**		**7**	**65**	**30**
OEH-IH		**91**		**20**	**111**	**51**
POL /CPPP		**19**		**15**	**34**	**15**
TOTAL		**175**		**44**	**219**	**100**

IX. Conclusions

The four training programs in the Department of Work Environment have been highly successful at their mission of preparing practitioners and researchers for the rapidly changing fields of occupational and environmental health and safety. The faculty, students and alumni of the programs are recognized for their innovative work in disease and injury prevention, and the design of sustainable systems of production.

X. Financial Report

The Financial report has been sent separately to NIOSH.