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ABSTRACT

This report summarizes the activities during the period of 07/01/06 through 06/30/11 for the Occupational Safety and Health (OSH) graduate training program in Industrial and Systems Engineering (ISE). Our aims were to provide a thorough education to trainees, to have them conduct high quality basic and applied research, and to provide service to the OSH profession, to industry, and to society. Our program emphasized three aspects of OSH at the MS and PhD levels: safety engineering, occupational ergonomics / biomechanics, and construction sector OSH. Our program was characterized by a dual emphasis on breadth of trainee experience and the requirement for specialization, the latter emphasized by the need for a formal research project related to OSH. TPG funds helped us to maintain this emphasis, and to attract and retain top students. A broad yet cohesive group of faculty supported the program. Training was achieved through a combination of formal coursework, faculty advising, research, and more general exposure through seminars and interdisciplinary interactions. Candidates for our program were MS or PhD students accepted within the Human Factors Engineering and Ergonomics graduate concentration within the Industrial and Systems Engineering Department. Doctoral-level training was a new addition to the program. Another addition was a focus on construction-relevant OSH training. Prospective trainees were also actively recruited through several means. Our program overall was quite successful during the prior period, based on the number of graduates, the high proportion of graduates continuing in the OSH field, faculty and trainee scholarly output, awards, and the continuing high number of applications received. Program funds were used to support two trainees per year, with five different students supported. Within the program as a whole, 32 trainees completed the program. Of these, the majority were subsequently employed in an OSH field or enrolled in an OSH academic program. Nearly half were women, and there were four trainees self-identifies as under-represented minorities. Many have leading administrative positions or faculty appointments. Program trainees published extensively on OSH topics in the reporting period. Several aspects of the program were modified or expanded, to enhance training opportunities and training experiences.

HIGHLIGHTS / SIGNIFICANT FINDINGS

Significant developments and accomplishments of the program during the reporting period are provided here in terms of trainees, administration, faculty participation, and facilities. Additional details are provided in the subsequent section. Virginia Tech has received funding from NIOSH training grants since 1992, and this funding has served a vital role in maintaining the program, which is the only one of its kind in the state of Virginia. The core goal of the program continues to be the generation of well-trained MS and PhD students specializing in some area of occupational safety and health and with more general exposure to Human Factors and Ergonomics and/or Industrial & Systems Engineering. Primary highlights of the program are: 1) the diversity of faculty expertise participating in student training; 2) the requirements for comprehensive and relevant coursework; 3) a required research experience related to occupational safety and health (OSH), and which contributes towards occupational hazard/risk recognition, avoidance, or control; and 4) professional development through participation in seminars, tours, and conferences. During the reporting period, the program was expanded to include doctoral-level training in OSH. Leveraging recent awards from NIOSH, the program also added a specific emphasis and focus on training relevant to the construction sector.

During the project period, 32 trainees completed the training program (11 MS and 21 PhD). Five different trainees were supported using program funds, and four funded trainees completed the program (2 MS and 2 PhD). The total number of completed graduate trainees represents a 50% increase over the prior five-year period. An increasing proportion of trainees were at the doctoral level, largely as a result of: 1) changes in applicant demand; 2) continuation of MS students in the PhD program; and 3) an increased institutional emphasis on doctoral-level training across all fields.

Our program interfaced closely with several other training activities at Virginia Tech. These were primarily through overlapping participation in several centers, including the Center for Innovation in Construction Safety and Health (led by Kleiner and Smith-

Jackson), the Occupational Safety and Health Research Center (led by Nussbaum), the Center for Gerontology, and the School of Biomedical Engineering and Sciences (Nussbaum and Lockhart are core members). Nearly all of our trainees were also involved with our student chapter of the Human Factors and Ergonomics Society, and many participated in the American Society of Safety Engineers student chapter.

Some administrative and leadership changes occurred. The program was led by Dr. Maury A. Nussbaum (PI/PD) with Drs. Tonya Smith-Jackson and Kari Babski-Reeves as additional core members and co-Directors. Dr. Babski-Reeves left in 2006, and was replaced in 2007 by Dr. Deborah Young-Corbett (who completing program training in the same year). Dr. Michael Agnew joined VT in 2007, and served as an additional supporting faculty. Faculty participation was both high and diverse, covering a wide range of topics within safety engineering, human factors, and ergonomics. Our faculty are somewhat unusual in terms of the breadth and interdisciplinary expertise and research interests they represent.

Training facilities included 12 separate laboratories that were used on a regular basis for safety and occupational health-related research and instruction. Dr. Lockhart created a lab that addresses human visual performance (Visual Controls). Drs. Casali and Kleiner created the Vehicle and Aircraft Simulator lab to facilitate relevant transportation-related research projects. Dr. Winchester created a new lab focusing product and technology design (Laboratory for User-Centric Innovations in Design – LUCID). These and the other laboratories continued to be active in a range of research projects, with support from both government and industrial sponsors.

OUTCOMES / RELEVANCE / IMPACT

Major outcomes of the program are related to the trainees, including their subsequent employment and scholarly output. During the project period, 32 graduate students completed the training program (11 MS and 21 PhD), and five different trainees were supported using program funds. Of the graduates, most (27/32; 9/11 MS and 18/21 PhD) were subsequently employed in an OSH field or enrolled in an OSH academic program. Given the level of under-representation of women and minorities in the fields of OSH, we were successful in training such individuals in the reporting period. Specifically, nearly half of our trainees were women (14/32), and four were under-represented minorities (based on self-identification: 3 African-Americans and 1 Latino). Many have leading administrative positions or faculty appointments. Program trainees generated substantial scholarly output. Specific to OSH research, TPG-supported trainees generated 21 publications (12 in conferences and 9 in archival journals) in the reporting period.

The major outcomes noted above are highly relevant in the context of occupational safety and health in general and in our training program specifically. First, work-related accidents, injuries, and illnesses continue at high levels across many sectors, and much of our training was focused on contributing to a better understanding of the causes and the development and evaluation of methods for alleviating these. Second, we continues to have substantial student interest in these sub-disciplines, not only from within the US, but from around the world. Third, we believe the breadth of experience we emphasized in our program is necessary to adequately prepare students in OSH areas, and to maximize the likelihood of their success after graduation. Fourth, the need for talented graduates in OSH continued, as indicated by the numerous requests from companies and consulting firms that we received for student applications (~ 3-4/month). Fifth, we have graduated well over 100 students from our program, and a majority of these former trainees are currently working in areas related to their training. Sixth, our program is the only one in the Commonwealth of Virginia that provides depth and breadth of training in these fields. We also served a regional need, in that we are not located within close proximity to any current ERCs (the nearest being UNC-Chapel Hill

and Johns Hopkins). In addition, we are located in a rural area and provided expertise and potential employees that can serve in capacities beyond the specific OSH training they receive (e.g., most receive more general training in industrial and systems engineering).

Specific impacts of the program are more difficult to identify and/or quantify. Two items, however, are worth noting. First, as noted above, most of our former trainees (historically, and in the recent reporting period) continue to work in areas of OSH after graduation. Many of these former trainees have leadership positions in industry and several others are conducting OSH research and training in academic positions. Second, the scholarly output generated by our trainees is often cited by others, which indicates that their work is having an impact on others in the OSH field. In large part, the breadth of these impacts is related to our research diversity and our expansion of the program to included doctoral-level OSH training.

TECHNICAL REPORT

Overview

Building on the academic and research strengths at Virginia Tech, our training program emphasized three aspects of occupational safety and health (OSH): safety engineering, occupational ergonomics/biomechanics, and construction OSH. The first is a "core" discipline, the second a "related" discipline, and the third includes both core and related disciplines within the specific industrial sector of construction. The program itself is an academic "track" within the ISE graduate program. A safety engineering emphasis was implemented nearly 35 years ago, and training support as a NIOSH TPG began in 1992. In 2002, the program was expanded to include MS students with training interests in occupational ergonomics and biomechanics. This expansion was done to reflect several changes that had occurred in program faculty, student interests, contemporary needs in research and industry, and ongoing research projects. A more recent expansion included doctoral level training, to address changes in applicant demand and institutional emphasis.

Expanding the training program scope to include a focus on construction OSH is another recent development, but a natural outcome of recent research efforts. In the past decade, Virginia Tech has emerged as a leader in the field of construction engineering and management in general, and construction safety and health in particular. With its Vecellio Construction Engineering and Management Program, Department of Building Construction, Myers Lawson School of Construction, and the NIOSH-sponsored Center for Innovation in Construction Safety and Health, Virginia Tech offered significant training opportunities to graduate students interested in occupational safety and health within this important economic sector.

The core rationale for our proposed training project can best be summarized by our department's (Industrial and Systems Engineering–ISE) mission statement, copied below.

1) Provide a high quality education that will prepare our undergraduate and graduate students for a life-long learning experience in this rapidly changing field, and to prepare these students to be future leaders in the industrial engineering profession, in business, in industry, and in academia.
2) Conduct high quality basic and applied research to advance the frontiers of engineering and to support the industrial and economic growth of the Commonwealth of Virginia and the nation as a whole.
3) Provide service to the profession, industry, and society to contribute to the advancement of civilization and the betterment of all.

Several points emphasize and justify the need for training in our program's areas of focus. First, work-related accidents, injuries, and illnesses continue at high levels across many sectors, and much of our training is focused on contributing to a better understanding of the causes and the development and evaluation of methods for alleviating these. Second, we continued to have substantial student interest in these sub-disciplines, not only from within the US, but from around the world. Third, we believe the breadth of experience we emphasized in our program was necessary to adequately prepare students in OSH areas, and to maximize the likelihood of their success after graduation. Fourth, the need for talented graduates in OSH continued, as indicated by the numerous requests from companies and consulting firms that we receives for student applications (roughly 3-4/month). Fifth, we have graduated well over 100 students from our program, and a majority of these former trainees are currently working in areas related to

their training. Sixth, our program is the only one in the Commonwealth of Virginia that provides depth and breadth of training in these fields. We also serve a regional need, in that we are not located within close proximity to any current ERCs (the nearest being UNC-Chapel Hill and Johns Hopkins). In addition, we are located in a rural area and provided expertise and potential employees that can serve in capacities beyond the specific OSH training they receive (e.g., most receive more general training in industrial and systems engineering).

Our program interfaced closely with several other current training activities at Virginia Tech. These are primarily through overlapping participation in several centers, including the Center for Innovation in Construction Safety and Health (sponsored by NIOSH), the Occupational Safety and Health Research Center (led by Kleiner until 2011, and now Nussbaum), the Center for Gerontology, and with the School of Biomedical Engineering and Sciences (Nussbaum and Lockhart are core members). Nearly all of our trainees were also involved with our student chapter of the Human Factors and Ergonomics Society. Membership of students in the American Society of Safety Engineers student chapter continued to grow, and also included students in Civil and Environmental Engineering and Psychology. As a formal relationship, and as noted above, students in the program were part of the HFEE graduate concentration area within ISE, specifically MS (thesis) and PhD students.

Primary purposes and objectives of our TPG were in parallel to those given above as the rationale: to provide a high quality education (at the MS and PhD levels), to conduct high quality research, and to provide service. With respect to TPG funding, this was (and is) used primarily to attract and maintain top students, maintain a critical mass of students, support our curriculum, and facilitate meaningful research that is not otherwise funded. Program funds also allowed us to maintain our program breadth, which in turn also helped attract and support students.

Our training activities occurred in three areas. The first was traditional didactic presentation of instructional material (lecture). Specific curricula requirements were been developed to ensure both breadth and depth of exposure, and are described in the Program Plan. The second was a formal research experience (coaching). All program participants were required to generate either a thesis or dissertation, and most of these led to publications either at a conference or in an archival journal. The third was professional development (seminar/discovery learning), which is described below and was intended to “round out” the trainees’ educational experiences. In addition, more hands-on experience (coaching) will be achieved through an OSH Practicum, which is now being developed.

Program Leadership and Faculty

Dr. Maury A. Nussbaum, Professor in ISE, was PI and directed the grant and Training Program, served as the NIOSH liaison, and managed budgetary issues. Dr. Nussbaum assumed the director’s role in 1999, after being an active participant and serving as co-director for several prior years. Drs. Smith-Jackson and Young-Corbett (who replaced Dr. Babski-Reeves) were additional members of the “core” program administration, and each was involved in substantive decision making regarding the program. As a group, Drs. Nussbaum, Smith-Jackson, and Young-Corbett provided relevant expertise in the primary training areas (safety engineering, occupational ergonomics, and construction OSH).

This core administration also received input from two sources (internal and external advisory committees and feedback from past trainees). An *Internal Advisory Committee* consisted of all

faculty in the ISE HFEE area and Dr. Young-Corbett. The Internal Advisory Committee discussed the status of the program at least once per year, to review the program performance and address any substantial operational issues. Smaller-scale issues were discussed by email, moderated by the program director. Continuing feedback regarding the program operations and opportunities for improvement was obtained early in the reporting period from an *External Advisory Committee*, but this is being reorganized to enhance interdisciplinary strengths. Trainees completing the program, as well as prior trainees, provided informal feedback to the core administration.

The individuals listed below each contributed to the training program during the prior reporting period. All were full-time, on-campus faculty. Except for Dr. Young-Corbett, who is in the School of Construction (tenure department = Civil & Environmental Engineering), each was a full-time, on-campus faculty member in the HFEE concentration area within ISE. This faculty represented a diverse combination of expertise in the areas of safety engineering, occupational ergonomics, occupational biomechanics, and industrial hygiene.

Core Faculty	**Areas of Primary Expertise Relevant to the Program**
Dr. Maury A. Nussbaum	Occupational Biomechanics; Physical Ergonomics
Dr. Tonya L. Smith-Jackson	Risk Perception; Cognitive Ergonomics; Cultural Ergonomics and Safety
Dr. Deborah E. Young-Corbett	Construction Hazard Control; Industrial Hygiene; Construction OSH; Indoor Environmental Quality; Prevention through Design

Supporting Faculty	**Areas of Expertise**
Dr. Michael J. Agnew	Occupational Biomechanics; Physical Ergonomics; Work Physiology
Dr. John G. Casali	Hearing Conservation & Protection Technology; Acoustics
Dr. Brian M. Kleiner	Macroergonomics; Construction Safety
Dr. Thurmon E. Lockhart	Biomechanics of Slip and Fall Accidents; Aging
Dr. Woodrow W. Winchester	Product and Systems Design; Affective Engineering; Usability

Mentoring of trainees occurred through both formal and informal mechanisms. Formal mentoring occurred primarily through advising of student research at both the MS and PhD levels. A research project was required at both levels, and program faculty served as major advisors and committee members for trainees. Informal mentoring occurred through several mechanisms. Organized by our student HFES chapter, there were several “brown bag” seminars led by faculty and students each semester, with recent examples including “How to write a proposal”, “How to write a thesis/dissertation”, “How to choose a research topic and advisor”, and several presentations by senior and former graduate students on their own research and real-world experiences and opportunities. As free lunch was provided by the student chapter, these events are generally very well attended! In addition, the core program faculty provided mentoring as needed, pro-actively based on our tracking of student progress, and at a trainee’s request.

Collaboration among our faculty and among trainees was extensive. Faculty also served mutually as members of trainee MS and PhD committees, which was enforced by our own requirements of no fewer than two and three HFEE faculty on MS and PhD student committees, respectively. Program faculty were active in a diverse set of research areas and funded

projects. This research support, in turn, provided increased exposure to trainees on a variety of contemporary topics, and much of this funding allowed for student support in addition to that provided by the TPG.

Program Description

Our program was designed to provide training in three aspects of OSH: safety engineering, occupational ergonomics, and construction OSH. Here, occupational ergonomics includes WMSD prevention, occupational biomechanics, and work physiology. Training was offered at both the MS (thesis) and PhD levels. Trainees in the program formed a subset of ISE graduate students, within the Human Factors Engineering and Ergonomics (HFEE) graduate concentration. This was done using separate curricular requirements ("tracks") within the department. We used TPG funds to support (typically) two full-time students per semester. The program as a whole, however, had annual enrollments of ~5 MS and ~10 PhD students.

Separate coursework and training requirements existed for MS and PhD students, which were implemented and administered as "tracks" as indicated earlier. (Note that the ISE graduate program as a whole is organized into several tracks, including general IE, human factors & ergonomics, manufacturing systems, operations research, and management systems.) While graduate students can obtain a non-thesis MS degree, only thesis students were considered part of the training program. Trainees typically completed their training in ~2-2.5 years for the MS and 4-5 years for the PhD. Many MS students required the second summer or a fifth semester to complete the program. Most PhD students were able to complete their training in three years, post MS (increasing numbers of PhD students, though, were directly admitted post-BS to be competitive with other programs). During their training period, student progress was monitored and evaluated primarily by the advisor and the trainee's committee. In addition, the program director (Nussbaum) communicated at least once per semester with each trainee, and the ISE department completed a formal review process for each trainee at the end of each academic year.

MS Training

MS trainees completed a formal research project (thesis option) and 31 credit hours beyond the baccalaureate. Of these, at least 25 credit hours (eight courses) were formal coursework. All program MS trainees completed a set of four "core" courses and a required ISE department seminar (0 credit hours). These core courses provided a fundamental exposure to major aspects of human factors / ergonomics and experimental design / statistics, as well as more detailed exposure to human mental and physical abilities and limitations. MS trainees also completed a minimum of four elective courses. Sets of "pre-approved" electives were provided, though trainees could deviate (with advisor and committee approval) from these as warranted by their current and future interests as well as to accommodate new or irregular course offerings. Our intent with these electives was to build expertise (on top of the foundational coursework), and to allow students the flexibility to develop specialization within a sub-discipline.

PhD Training

PhD trainees had the same "core" coursework requirements as for MS trainees. In addition, each needed to broaden their expertise in experimental design and statistics, by completing additional coursework on these topics (e.g., multivariate, non-parametrics). They also completed a set of elective courses, such that the total credit hours post-BS was ≥45 (consistent with ISE requirements). Pre-approved electives (and deviations from these) were the same as

for MS trainees. An individualized, hands-on approach was taken with each trainee in terms of selecting coursework, led by the advisor and committee and with support of the TPG director. Overall, the intent was to ensure adequate breadth in OSH through coursework while also supporting the development of specific expertise in the trainee's research domain(s).

Common Requirements for MS and PhD Training

Beyond the didactic course requirements indicated above, both MS and PhD trainees had several requirements set by the ISE department. Each had to complete a plan of study (within their first year of graduate school), in which the set of courses intended to meet the requirements was listed, and which was approved by the student's advisor, committee, and ISE graduate program director. Both advisors and committee members were selected by the student, with input as needed from any program member. A formal research proposal was required, with a written version distributed to the student's committee followed by a formal oral presentation (proposal defense). For trainees in our program, the research had to be focused on OSH or have clear OSH relevance. Upon committee approval of the proposal, students commenced their research, with a department-required progress meeting occurring at least once before the final defense. The research was presented in written form (thesis/dissertation) to the committee, again followed by an oral presentation (final defense). All students were required to show evidence of prior or intended publication of their research at the final defense. In addition to these requirements, PhD students took a preliminary exam prior to generating their research proposal. This is a two-week written exam, with questions submitted by the advising committee, followed by a two-hour oral exam. Consistent with graduate school requirements, all trainees had to maintain a GPA ≥ 3.0 (B); if this was not achieved, trainees were placed on academic probation and had one semester to reach compliance. No trainees dropped or were removed from the program.

Trainee Research and Interdisciplinary Experiences

All MS and PhD trainees within the program participated directly with research activities. In large part this was related to the formal research requirements, but such participation was almost always broader for several reasons. First, students became members of laboratories directed by their advisors, and hence were exposed to other work being undertaken there. Second, defenses were open, providing exposure to work throughout the HFEE area. Third, students often volunteered to either serve as experimental participants or to assist with data collection. Specific student research projects were chosen at the discretion of the student and their advisor. These were typically either new topics developed by the student, or extensions of existing work being done by the faculty advisor. Each student was expected to make a new intellectual contribution (e.g., simply performing work that had been proposed by a faculty advisor in detail would not be considered acceptable).

Students were also expected to broaden their educational experience by attending seminars within and outside the university, department, and option. As noted above, there were several offered by faculty and students within HFEE. In addition, our student HFES chapter was quite active, and hosted 2-3 speakers on basic and applied topics each semester. We have not formally enforced any requirements to attend seminars, as we have found that students attend these voluntarily (many are standing room only). Most of our students attended the annual HFES conference, either supported by their advisors or using travel supplements provided by our TPG, the university, or the student HFES chapter.

Our program sought to ensure that graduates were equipped to recognize, evaluate, and control occupational hazards. They received special knowledge in diverse areas, such as: system safety analysis, industrial fire control, ergonomics, toxicology, acoustics and hearing protection,

industrial hygiene, injury epidemiology, accident analysis, occupational biomechanics, low-back pain and WMSDs more generally, radiation protection, machine guarding, electrical hazards, experimental design, and statistical analysis. It is this combination and breadth of interdisciplinary material that we believe keeps our program in demand. The combined program faculty are unusual in ergonomics and human factors programs because of the breadth and interdisciplinary backgrounds they bring.

Our program also fostered interdisciplinary interactions. We cooperated in particular with Civil Engineering, Engineering Science and Mechanics, The School of Construction, The School of Biomedical Engineering and Sciences, Computer Science, Statistics, and Psychology. This cooperation took place through exchange of students, encouraging students to take classes in other areas, cross-discipline research, and committee work. For example, safety engineering students and faculty have shared recently with civil engineering in transportation safety, crane safety, and construction safety. Dr. Nussbaum has affiliated status with Mechanical Engineering. Dr. Smith-Jackson has a joint appointment in Psychology. Dr. Young-Corbett has appointments in Civil and Environmental Engineering, the School of Construction, Building Construction, and Industrial and Systems Engineering. Her laboratory is also fully equipped for industrial hygiene sampling and analysis of particulate and chemical air contaminants. Several faculty are affiliates with the VT Center for Gerontology (Lockhart, Nussbaum, and Smith-Jackson) and are core faculty of the School of Biomedical Engineering and Sciences (Lockhart and Nussbaum). Many students took Dr. Scott Geller's course on safety management principles in the Department of Psychology, and students have also attended local seminars taught by health professionals. Allowing students to freely select several of their required three committee members has also promoted a good level of interdisciplinary interaction.

Virginia Tech has very active student chapters of the American Society of Safety Engineers (ASSE) and Human Factors and Ergonomics Society (HFES). The ASSE chapter was the National Student Section of the Year in 1999, and the HFES chapter is the largest in the nation (and consistently receives "Gold Level" recognition). These chapters regularly conducted site visits to local industries and engineering laboratories, and hosted formal seminars and "brown-bag" lunches by safety researchers and professionals. These interdisciplinary exchanges occurred on a continuing basis and were a vital part of both faculty and student experience.

Students in the core and allied programs frequently interacted through the mechanisms described above (meetings, gatherings, etc.) and through coursework. While students in the program took elective courses specific to their interests, there was overlap among students in these, and along with the core course requirements the curriculum ensured that all program trainees interacted with each other and with students in other disciplines. Interaction among trainees was further facilitated through performance of project requirements associated with classes. In these cases, projects were often student selected and usually student groups were selected to combine student expertise across multiple areas.

Interactions were also fostered through several hands-on experiences that occurred during course-based training, particularly in the safety courses. Consistent with the Paideia method, Dr. Smith-Jackson used safety cases and seminar-type discussions to allow students to use problem-based approaches to apply their knowledge and skills. Students were assigned projects that were either self-selected by exploring common issues related to hazards in Industry or projects that are provided by our Industry partners. These projects allowed students to create meaning based upon their own past experiences, knowledge, and skills, with support from scientific theory and practical industry knowledge. Student teams explored, at all levels, the causes, antecedents, and implications of different hazardous contexts. For example, in

2008, one student team explored the link between sleep, hours-of-service, citations, and accidents for Advance Auto. These students interacted with long-haul truckers to identify barriers and incentives for safer driving practices. Teams not only collected data, but also provided administrative and training recommendations and models for the corporation to implement at the levels of policy and practice.

Instruction in the Responsible Conduct of Research

Formal instruction on scientific integrity and ethnical principles has been part of our graduate training for several years, and continued throughout the reporting period. Ethical principles guiding the use of human subjects in research were discussed in three courses offered in the program: ISE 5615 Human Factors Research Design (taught by Nussbaum or Agnew), ISE 5674 Systems Safety (taught by Smith-Jackson), and ISE 5694 MacroErgonomics (taught by Kleiner). In ISE 5615 and 5674 there are units wherein the information was presented in lecture format complemented by handouts and source identification for additional information. Topical content areas covered included conflict of interest (5615, 5674, 5694), data management and sharing (5615), human subject use (5615, 5674, 5694), relationship between the institution and graduate students (5694), and professionalism and ethics in human factors and ergonomics intervention (5694). ISE 4644 (Occupational Safety and Hazard Control Course) also addressed scientific integrity, research and professional ethics, and ethical practices in general by covering the fundamental canons of industrial engineering and professional ethics requirements for Industrial Engineers. Research ethics was also extensively covered in a new elective course (ISE 6624) on “Proposing IE Research”. This course is offered every other year (by Nussbaum), and was taken by many program doctoral trainees.

All trainees performed research using human subjects (or data obtained from human subjects). As such, they were required (by the VT IRB) to complete an on-line web-based training module and successfully pass the module, or complete alternative comparable training (e.g., from the NIH website). Documentation of such training was required before an IRB application is approved.

Training Candidates

Trainees in our program were candidates for the Master of Science and Doctor of Philosophy within the Human Factors Engineering and Ergonomics (HFEE) concentration area in the Department of Industrial and Systems Engineering. Trainees all held baccalaureate degrees in engineering, science, or cognate area from an accredited college or university. They were admitted competitively based on grade point average, letters of recommendation, personal statements, work experience, and standardized test scores. Admissions were handled centrally in the Department, though primarily based on individual faculty input. Admission standards were as follows: GPA (3.0), TOEFL (550 paper; 213 computer, 80 iBT), GRE (400 verbal, 650 quantitative, 3.5 analytical).

Once accepted, there was an open competition between the students for NIOSH training grants. Awardees were selected each year based on current GPA, program experience, and their stated goals for their participation in the program. Students who were in their second year in the program and were ready to conduct a research project were given priority, as were trainees funded previously and who had made good progress through their program. Funding was limited to those who meet citizenship requirements. Students who did not receive TPG funding usually received other support from the Department in the form of Graduate Research Assistantships, Graduate Teaching Assistantships, and Graduate Fellowships.

Prospective trainees were also actively recruited through our web page, from program brochure mailings, and from active participation of both faculty and students in conferences. We drew students from around the US, and with major sources of international applicants from China, Korea, and India. Approximately 30-50 applications were received each year for the entire program (HFEE area within ISE). Of these, roughly 50-60% were accepted and ~10-15 enrolled. Of the HFEE students who matriculated, roughly half pursued research is some aspect of OSH. Over the last several years, we have had 4-6 candidates per year for our two NIOSH traineeships.

Consistent with recent college and departmental changes in focus, specifically increasing their emphasis on doctoral-level training, we had more applications and more enrolled students at this level in our program. To address this in the future, we will increase our recruiting efforts on MS trainees. Our program, however, continued to contribute to the role of TPGs in ensuring "an adequate supply of qualified professional occupational safety and health practitioners and researchers." While year-to-year we had a changing balance between practitioner- and researcher-focused trainees, our overall goal in recruiting and training were to achieve both products to the extent possible. We will continue to work with the Multicultural Academic Opportunities Program and the Office of Diversity and Inclusion to enhance diversity of under-represented minorities and women in the program.

Training Facilities and Resources

Our training facilities included a number of laboratories that were used on a regular basis for OSH-relevant research and instruction:

- Assessment and Cognitive Ergonomics
- Auditory Systems Laboratory
- Displays and Controls Laboratory
- Environmental and Safety Laboratory
- Human-Computer Interaction Laboratory
- Industrial Ergonomics and Biomechanics Laboratory
- Laboratory for User-Centric Innovation and Design
- Locomotion Research Laboratory
- Macroergonomic and Group Decision Systems Laboratory
- Safety Engineering Laboratory
- Vehicle Simulation Laboratory
- Visual Controls Laboratory

Other facilities included those normally found at a major University and include dedicated, multimedia classroom space, computer laboratories, and faculty and student office space. Additional research support was provided by the Industrial and Systems Engineering Department in the form of office space for all graduate students (each office containing a networked computer with software), supplemental funds for subject fees and travel, and a fully equipped machine and electronics shop with four full-time staff members.

Program Outcomes and Accomplishments

The Virginia Tech TPG was a component of the graduate program in the Department of Industrial and Systems Engineering (ISE). During the reporting period, the program consisted of MS (thesis) students with specific concentrations (Safety Engineering, Physical Ergonomics, and Occupational Biomechanics) and PhD students conducting research in occupational safety and health. Our program was very active over the past project period. This activity included several sponsored projects, numerous research publications, and awards to the faculty and trainees. The program also generated several program graduates (see below), who have been productive in research and gone on to careers in occupational safety and health.

Our program has been quite successful at recruiting and retaining students overall, and especially in enhancing program diversity. With respect to recruiting, we had applications from around the country and the world, from individuals with diverse backgrounds (engineering, psychology, math, physical therapy, etc.). In the prior reporting period, no trainees left the program, and the vast majority completed the program in a reasonable time period (i.e., 2.5 years for the MS and 4-5 years for the PhD); exceptions to these have mainly been students who worked full or part time during their training. Roughly half of our prior and current trainees are females, and a substantial number are from minority and/or underrepresented groups.

We supported five different trainees during the reporting period using TPG funds. Of these, one completed PhD training and two completed MS training. In total, there were 32 students who completed training, 11 MS and 21 PhD. This total represents a 50% increase over the prior 5-year period. There was also an increasing proportion of trainees at the doctoral level, largely as a result of: 1) changes in applicant demand; 2) continuation of MS students in the PhD program; and 3) an increased institutional emphasis on doctoral-level training across all fields.

Of all program graduates, the vast majority (27/32) had subsequent employment in an OSH field or in an OSH academic program. This included 9/11 MS trainees, and 18/21 PhD trainees. Trainee employment was diverse, and included consulting, research, government, and academia. Of note, 10 PhD trainees obtained (and continue in) academic positions in which a main focus is OSH teaching and research. Others are currently in leading research, administrative, or applied/consulting positions.

Given the level of under-representation of women and minorities in the fields of OSH, we were successful in training such individuals in the reporting period. Specifically, nearly half of our trainees were women (14/32), and four were under-represented minorities (based on self-identification: 3 African-Americans and 1 Latino).

Diverse research products were generated by the program in the reporting period. Trainees supported by the program generated 9 and 12 papers in journals and at conferences, respectively. For the program as a whole, there were (approximately) an additional >70 journal papers, and >80 conference presentations/papers.

Conclusions

Our program occupied a niche that is somewhat unique, given both it's breadth and depth. Diverse outputs and accomplishments were achieved, in terms of program graduates and research products. It was oriented strongly towards engineering aspects of OSH, while also being influenced by its place within the larger ergonomics and human factors engineering graduate concentration. Trainees were exposed to a wide variety of health and safety issues, including such topics as system safety, industrial hygiene, traditional physical ergonomics, engineering design, and human factors research methods.

The program was successful in terms of graduating a consistent number of well-qualified trainees, who generated substantial research products (e.g., journal and conference papers) and who have gone on to future careers emphasizing occupational safety and health. As was described above, however, the effects of TPG funds went well beyond the direct influence on student tuitions and stipends. The award was a key aspect in the maintenance and continual improvement of the training curriculum, and facilitated numerous other activities both intra- and extra-curricular.

The program has undergone some revisions during the prior project period. Among these, the major ones have been changes in leadership and faculty involvement, an increasing focus on doctoral-level training, and an expansion of the program to emphasis OSH in construction. A continual evolution will likely occur, as we strive to both improve and grow the program in the future.

PUBLICATIONS RESULTING FROM TRAINEES

The list immediately below contains publications that were generated by trainees supported by the training grant (current or prior reporting period); supported trainees are underlined. In addition to these, other trainees generated >70 journal papers (published or in-press) and >80 conference presentations on topics related to occupational safety and health in the reporting period.

Papers in Archival Journal:

1. Gausepohl K, Winchester W, Arthur JD, Smith-Jackson T: [2011] Using Storytelling to Elicit Design Guidance, Ergonomics in Design 19:19-24.
2. Gausepohl K: [2010] Knocking down brick walls: An HF/E student's entry into the healthcare field, Ergonomics in Design 18:24-25.
3. Ikuma LH, Babski-Reeves K, Nussbaum MA: [2009] Experimental manipulation of psychosocial exposure and questionnaire sensitivity in a simulated manufacturing setting. International Archives of Occupational and Environmental Health 82:735-746.
4. Ikuma LH, Nussbaum MA, Babski-Reeves K: [2009] Reliability of physiological and subjective responses to physical and psychosocial exposures during a simulated manufacturing task. International Journal of Industrial Ergonomics 39:813-820.
5. Kim S, Seol H, Ikuma LH, Nussbaum MA: [2008] Knowledge and opinions of designers of industrialized wall panels regarding incorporating ergonomics in design. International Journal of Industrial Ergonomics 38:150-157.
6. Mehta RK, Horton LM, Agnew MJ, Nussbaum MA: [2011] Ergonomic evaluation of hospital bed design features during patient handling tasks. International Journal of Industrial Ergonomics, In Press.
7. Young-Corbett DE, Nussbaum MA: [2009] Dust Control Technology Usage Patterns in the Drywall Finishing Industry. Journal of Occupation and Environmental Hygiene 6:315-323.
8. Young-Corbett DE, Nussbaum MA: [2009] Dust Control Effectiveness of Drywall Sanding Tools. Journal of Occupational and Environmental Hygiene 6:385-389.
9. Young-Corbett DE, Nussbaum MA, Winchester WW: [2010] Usability evaluation and redesign specifications for drywall sanding tools. International Journal of Industrial Ergonomics 40:112-118.

Conference Papers:

1. Barker LM, Hughes (Ikuma) LE, Babski-Reeves KL: [2006] Efficacy of using thermography to assess shoulder loads during overhead intermittent work. Paper presented at the Human Factors and Ergonomics Society 50th Annual Conference. Santa Monica, CA: Human Factors and Ergonomics Society.
2. Beaton R, Gausepohl K, Winchester W: [2011] Using A Sustainable User Interaction Design Approach to Increase Goal and Objective Completion Accuracy. Poster accepted at Human Systems Integration Symposium, Vienna, Virginia.
3. Gausepohl K, Winchester W, Arthur JD, Smith-Jackson, T: [2009] Understanding Context-of-use in a Healthcare Environment. Presented at Usability Professionals'

Association International Conference, Portland, Oregon.

4. Gausepohl K, Winchester W, Arthur JD, Smith-Jackson T: [2009] Storytelling as a Novel Elicitation Method for Medical Device Requirements. Poster presented at the 21st Annual Society for Health Systems Conference, Chicago, Illinois.
5. Gausepohl K, Winchester W, Arthur JD, Smith-Jackson T: [2009] Investigation of Storytelling as a Requirements Elicitation Method for Medical Device Requirements. Presented as part of the Virginia Tech Center for Human Computer Interaction Summer Seminar Series, Blacksburg, Virginia.
6. Gausepohl K, Beaton R, Winchester W: [2011] Using Linguistic Structures to Create Consistent Measureable Requirements in Meeting Interoperability Goals & Objectives. Poster accepted at Human Systems Integration Symposium, Vienna, Virginia.
7. Horton L, Nussbaum MA, Agnew MJ: [2011] The effects of job rotation frequency and task order on localized muscle fatigue and performance. Proceedings of the XXIIIrd International Occupational Ergonomics and Safety Conference. Baltimore, MD. June 9-10. pp. 106-110.
8. Horton LM, Mehta RK, Kim S, Agnew MJ, Nussbaum MA: [2009] Effects of alternative hospital bed design features on physical demands. Proceedings of the Industrial Engineering Research Conference (IERC). Miami, FL. May 30 – June 2. pp. 937-942. [NOTE: Received best paper award in the Ergonomic and Human Factors Track]
9. Humphries W, Gausepohl K: [2007] Integrating the Usability Engineering Lifecycle in Tool Development. Presented at 8th Annual Sakai Conference, Newport Beach, California.
10. Ikuma LH (Invited speaker): [2007] Effects of psychosocial and individual factors on WMSD risk factors while typing. Presentation at the Marconi meeting, Holland, MI. Sponsored by the Office Ergonomics Research Committee (OERC).
11. Kim S, Hurley MJ, Nussbaum MA, Hughes (Ikuma) LE, Babski-Reeves KL: [2006] Residential wall panel designers' knowledge and attitudes toward ergonomics. Poster presented at the Human Factors and Ergonomics Society 50th Annual Conference. Santa Monica, CA: Human Factors and Ergonomics Society.
12. Young DE, Kleiner BM: [2008] Drywall finishing industry: macro-ergonomic evaluation and intervention design. Proceedings of the 9th edition of Human Factors in Organizational Design and Management (ODAM) International Symposium. L. Sznelwar, F. Marcia and U. Montedo (Editors); Sao Paulo, Brazil.

Ph.D. Dissertations:

1. Hughes, LE: [2007] The Influence of Multiple Risk Factors on WMSD Risk and Evaluation of Measurement Methods Used to Assess Risks, Ph.D. Dissertation, Virginia Tech.

2. Young-Corbett, DE: [2007] Evaluation of Dust Control Technologies for Drywall Finishing Operations: Industry Implementation Trends, Worker Perceptions, Effectiveness and Usability, Ph.D. Dissertation, Virginia Tech.

M.S. Theses:

1. Grove, KL: [2008] Evaluation of Package Delivery Truck Drivers: Task Analysis and Development/Validation of an Objective Visual Behavior Measure to Assess Performance, M.S. Thesis, Virginia Tech.

2. Gausepohl, KA: [2008] Investigation of Storytelling as a Requirements Elicitation Method for Medical Devices, M.S. Thesis, Virginia Tech.

The following lists additional Dissertations and Theses generated by trainees who graduated in the reporting period

Ph.D. Dissertations:

1. Alali, KA: [2011] Azimuthal Localization and Detection Distance of Vehicular Backup Alarms Under Electronic and Non-Electronic Hearing Protection Devices in Noisy and Quite Environments, Ph.D. Dissertation, Virginia Tech.

2. Artis, S: [2007] The Effects of Perceived Organizational Support on Training and Safety in Latino and Non-Latino Construction Workers, Ph.D. Dissertation, Virginia Tech.

3. Barker, LM: [2009] Measuring and Modeling the Effects of Fatigue on Performance: Specific Application to the Nursing Profession, Ph.D. Dissertation, Virginia Tech.

4. Callison, MC: [2009] Identification, Evaluation and Control of Physically Demanding Patient-Handling Tasks in an Acute Care Facility, Ph.D. Dissertation, Virginia Tech.

5. Deshmukh, AR: [2007] Product Evaluation and Process Improvement Guidelines for the Personal Protective Equipment Manufacturers Based on Human Factors, NIOSH Guidelines and System Safety Principles, Ph.D. Dissertation, Virginia Tech.

6. Doerzaph, ZR: [2007] Development of a Threat Assessment Algorithm for Intersection Collision Avoidance Systems, Ph.D. Dissertation, Virginia Tech.

7. Fitch, GMJ: [2009] Driver Comprehension of Integrated Collision Avoidance System Alerts Presented Through a Haptic Driver Seat, Ph.D. Dissertation, Virginia Tech.

8. Haro, E: [2010] An Evaluation of Perceived and Observed Safety and Productivity in Residential Construction, Ph.D. Dissertation, Virginia Tech.

9. Hung, YH: [2010] How Technology Diffuses Through User Culture: An Innovation Design to Improve Safety Technology Adoption, Ph.D. Dissertation, Virginia Tech.

10. Lee, K: [2011] Effects of Earplug Material, Insertion Depth, and Measurement Technique on Hearing Occlusion Effect, Ph.D. Dissertation, Virginia Tech.

11. Lee, W: [2009] The Influence of Emotion on the Risk Perception and Situation Awareness of Clinician, Ph.D. Dissertation, Virginia Tech.

12. Lin, D: [2010] Effects of Localized Muscle Fatigue on Postural Control: Interactive Effects with Inclined Surfaces and Unexpected Loads, and Intervention Efficacy, Ph.D. Dissertation, Virginia Tech.

13. Liu, J: [2008] Ambulatory Fall Detection with Integrative Ambulatory Measurement (IAM) Framework, Ph.D. Dissertation, Virginia Tech.

14. McLaughlin, SB: [2007] Analytic Assessment of Collision Avoidance Systems and Driver Dynamic Performance in Rear-End Crashes and Near-Crashes, Ph.D. Dissertation, Virginia Tech.

15. Mehta, RK: [2011] Interactive Effects of Physical and Mental Workload: A Study of Muscle Function, Capacity, and Exertion Type, Ph.D. Dissertation, Virginia Tech.

16. Montague, EN: [2008] Understanding Trust in Medical Technology: Using the Example of Obstetrics, Ph.D. Dissertation, Virginia Tech.

17. Qu, X: [2008] Development and Evaluation of Postural Control Models for Lifting Motions and Balance Control, Ph.D. Dissertation, Virginia Tech.

18. Shi, W: [2007] The Age-Related Dynamic Accommodative Characteristics Associated with Light Intensity and Chromaticity, Ph.D. Dissertation, Virginia Tech.

19. Thongsamak, S: [2007] A Cross-Cultural Examination: Effects of Reward Systems and Cultures on Low Severity Risk-Taking Behavior in Construction, Ph.D. Dissertation, Virginia Tech.

M.S. Theses:

1. Baldev D: [2006] Design of a Construction Safety Training System using Contextual Design Methodology, M.S. Thesis, Virginia Tech.

2. Kant, R: [2007] Effects of Work Exposure on Maximum Acceptable Repetition Rates in a Manual Torquing Task, M.S. Thesis, Virginia Tech.

3. Lee, YS: [2007] An Approach to Identify Effective Learning Outcomes for a Training Program, M.S. Thesis, Virginia Tech.

4. Littlejohn, RAN: [2008] Thermographic Assessment of the Forearm During Data Entry Tasks: A Reliability Study, M.S. Thesis, Virginia Tech.

5. Muchenje, L: [2008] Determination of Backup Alarm Masked Threshold in Construction Noise, M.S. Thesis, Virginia Tech.

6. Olson, RL: [2006] Assessment of Drowsy-Related Critical Incidents and the 2004 Revised Hours-of-Service Regulations, M.S. Thesis, Virginia Tech.

7. Terry, TN: [2011] Comparing LED Lighting Systems in the Detection and Color Recognition of Roadway Objects, M.S. Thesis, Virginia Tech.

8. Thomas, CT: [2006] Influence of Acculturation and Individual Differences on Risk Judgments of Construction Laborers, M.S. Thesis, Virginia Tech.

9. Zhang, HB: [2006] Use of Statistical Mechanics Methods to Assess the Effects of Localized Muscle Fatigue on Stability During Upright Stance, M.S. Thesis, Virginia Tech.