Integrating Standards into Courses on High Performance Garment Systems and Human Protection and Comfort at North Carolina State University
by Donald B. Thompson, Roger L. Barker, and Emiel Den Hartog

Introduction
North Carolina State University (NCSU) was awarded cooperative agreements by the National Institute for Standards and Technology (NIST) as a part of NIST’s Standards Services Curricula Development Cooperative Agreement Program (NIST-SSCD-2013-01; NIST-SSCD-2014-01). The cooperative agreements were awarded to integrate content on standards and standardization into courses that are part of a new graduate course on Protective and Functional Textiles and Clothing being developed in the College of Textiles at NCSU. This paper describes how these grants are enabling the development of new content that will eventually enable a master’s level educational program in the applied science and technologies of materials, clothing, and gear. The courses will prepare students for developing high performance athletic and outdoor wear and creating new levels of protection for medical workers, the military, and firefighters and emergency responders. The critical role of valid test methods, materials and ensemble performance, and robust conformity standards in these areas will be emphasized.

The Need for Standards Education in Personal Protective Science and Technology
Standards are essential to protective clothing and equipment. Users must have confidence that the ensembles and equipment will perform as expected in hazardous environments. The way to achieve that objective is to have reliable performance standards, test methods, and sound performance criteria. Consequently, standards organizations such as the International Organization for Standardization (ISO), the American National Standards Institute (ANSI), ASTM International, and the National Fire Protection Association (NFPA), and agencies such as the National Institute for Occupational Safety and Health (NIOSH), the International Safety Equipment Association (ISEA), the European Committee for Standardization (CEN), and the National Institute for Justice (NIJ) play a crucial role in creating uniform testing and performance standards. Professionals and students need to understand the role of standards, the processes required to create standards, the requirements that tests and standards are based on, reliable measurement procedures, and the requirement to use statistical procedures to define reproducibility, repeatability, precision, and bias (accuracy).

While organizations such as emergency medical, law enforcement, and fire departments have extensive training programs that include information on standards, existing educational resources are often inadequate. In addition, undergraduate and graduate students rarely receive education directed at this important area. Very few end users of high performance and personal protective equipment (PPE) clothing systems or students majoring in traditional college curriculums are educated on standardization and the principles of reliable, standardized testing protocols. As a result, when they are employed by manufacturers or agencies in which standards are an integral part of the job, they must learn about them in an ad hoc manner.

The Center for Research on Textile Protection and Comfort (TPACC, http://www.tx.ncsu.edu/tpacc/), a world recognized research center for protective and functional textiles located in the College of Textiles at NCSU, has long been involved with PPE standards and standards development processes. TPACC conducts leading edge research that has lead to the development of new test instruments and methods that have been incorporated into ASTM, ISO, and NFPA standards for PPE. We have (Continued on page 3)
also worked with NIST Building and Fire Research Laboratory scientists and many other expert organizations to develop test methods that have been adopted by standards organizations.

TPACC scientists are active members of key technical committees for numerous standards organizations. We are not aware of any other academic organization that has such a broad knowledge of, and as many years of experience with, key standards development groups in the areas of performance clothing and personal protective systems.

Standardized test methods and performance standards are the life blood of performance textiles and innovative personal protection technologies. We are now developing course content and methodologies that will facilitate effective integration of essential standards-related principles as a key part of educating students in the College of Textiles at NC State and beyond. The courses will support new innovation in clothing and equipment, help to ensure conformity of systems to national and international standards, and prepare a new generation of students for involvement in regulatory and standards organizations to create robust standards and standardization procedures.

**Integrating Standards Education into Courses in Personal Protective Sciences and Technology**

The TPACC faculty are creating new course materials that will enable the incorporation of standards principles into courses that address protection and comfort performance of textile and clothing technologies used for protecting against exposures to fire and intense heat, chemical and biological, and mechanical and ballistic hazards. Methodologies for incorporating instruction on standardized tests and the formation of performance criteria and the basics of standardization processes are being incorporated into courses devoted to particular types of PPE for firefighters and first responders.

**Introducing Standards Education into Courses on Human Protection and Comfort**

We are developing course content on personal protective equipment standards as well as the processes used to create standards used to certify PPE with regard to human protection and comfort. The objectives of the instruction are 1) to teach students about various standards for protective textile technologies, 2) to utilize innovative pedagogical procedures to deliver the information to students, and 3) to develop testing instruments to evaluate the effectiveness of the curriculum and delivery system. We are incorporating modules on standards into courses on performance wear, protective clothing, and equipment, and clothing physiology. The instructional content will be delivered through traditional courses, through distance education courses, and by demonstrations of standard testing methods using virtual laboratories. Students will learn about the need for standards and the role that standards play in the protection of users; the procedures used to develop and validate test methods; processes used to adopt standards by standards bodies; and the limitations of standards. The following basic elements related to standards are emphasized:

- the necessity to have reliable reference standards for instruments and test methods, including calibration requirements;
- the requirements for reliable reference standards: the need to quantify test precision and reproducibility accepted practices for validating measurement and test procedures;
- the strengths and limitations of standardized tests with respect to real-world applications. This will include the need to analyze the problem or risk that the test methods are intended to characterize and to explicitly address the appropriateness of the proposed test procedures for the intended application;
- familiarization with organizations and examples of relevant standards groups. Instruction will address consensus processes used for establishing test methods by groups including ASTM, ANSI, NIOSH, NIJ, ISEA, CEN, ISO, and others. The development of consensus performance standards and regulations will be presented in detail for each type of clothing and equipment; and
- the role of standards in promoting innovation and new material and systems development for PPE.

These courses are being taught by instructors who are experienced in PPE and functional clothing standards, and who have incorporated standards in their own research to develop innovative PPE. This experience has taught us that an important aspect of standards education can be achieved by imparting an appreciation of the use of standards as an integral part of innovation in PPE technologies. We will incorporate case studies, many taken from our own leading edge research in PPE and experience in standards development, to illustrate the role of standards in developing innovative PPE technologies.

**Methodology**

The developed standards education modules will be incorporated into courses for students enrolled in traditional MS and PhD programs as well as within selective undergraduate courses. The NCSU College of Textiles delivers over forty asynchronous online classes to degree-seeking students. These students are usually enrolled full-time at the university and may be on or off campus. The delivery method for the materials vary, but most are delivered through a technology called Mediasite by Sonic Foundry. This delivery mechanism allows the student to see the professor and the presentation materials at the same time as if they were in a local classroom environment. Some classes also provide supplemental materials that aid in the learning process. Asynchronous courses are delivered to industry for professional training, such as the current forensic training course available for any law enforcement official in the United States. This course utilizes recorded lectures with labs that were conducted in the field in areas of archaeology, entomology, anthropology, and scattered remains. Courses contain a component in the learning management system (LMS) called Moodle. This LMS allows the instructor to give quizzes, tests, and deliver any PowerPoint presentations, documents, and online learning materials to enrolled students.

A group of NCSU experts on distance education course development within the College of Textiles will work with the project team to plan and create the distance education modules. The IT team has helped create innovative virtual laboratories such as the Virtual Microscope (www.tx.ncsu.edu/virtualmicroscope) which illustrates...
the potential power of using virtual training for testing and calibration exercises within standards education.

**Interactive Learning and Assessment**

The Moodle learning management system will facilitate the development of methods used to assess student learning for each of the distance education courses. Objective assessment tools will also be used for the traditional course modules. A learning objective will be established for each module, and test instruments will be developed to measure whether students achieved understanding of course content. Other metrics will be developed to assess initial awareness of standards so that the training will be differentiated from the general knowledge of students. These instruments will enable continuous improvement in both content and pedagogical approaches.

**Program Progress to Date:**

Two new courses have been developed as the foundational courses for the new concentration under the first award, and three additional courses are in the final stages of development for submission to the Graduate School under the second award. In addition, content from the first two courses has been added to the undergraduate textile testing course taken by Textile Engineering and Polymer and Color Chemistry students, and integrated into an extension course on Technical Textiles. Three additional courses are being developed as a part the new concentration. The remaining courses will be selected from among existing courses at NCSU. The two approved courses and the three courses in planning are described below.

A course entitled *Clothing Comfort and Personal Protection Science* was first offered in the fall of 2013, and again in the fall of 2015. Thirty graduate students were enrolled, and the course has been approved by the Graduate school as a Textile Engineering course (TE 550). The course included a number of class modules and exercises about standards and standardization. Topics addressed included the basics of standards and standardization, including the role of standards; risk assessment and analysis of the level of performance as a basis for tests and standards; processes used to create test methods; identification of standards organizations relevant to personal protective technologies; and the procedures used to propose and adopt test methods within standards. Class lectures and student assignments addressed the need to have reliable reference standards, the requirements for reference standards, the important consensus standards and regulatory organizations (ASTM, ANSI, NIOSH, NIJ, ISEA, CEN, and ISO), specific test methods and standards relevant to personal protective technologies, and the role of standards in innovation and certification of the performance of materials, ensembles, and personal protective technologies.

In addition to lectures, students visited testing laboratories located in the Textile Protection and Comfort Center to observe laboratory tests being performed according to ASTM, NIOSH, and NFPA standards requirements. Students were also asked to choose one user application where protective clothing and equipment are required, and the students were required to present to the class information regarding risks and risk mitigation for that application and the standards that are required. Students were assessed on their knowledge through questions during the presentation, through a written report, and by written exams.

A course entitled *Human Physiology for Clothing and Wearables*, was offered in the spring of 2014 (and approved as TE551, effective for the fall of 2015). The course used a number of approaches to emphasize the importance of standardized testing methods and performance requirements. The limitations of laboratory tests in predicting typical physiological burdens and performance limitations in the field were discussed. In one exercise, students created groups to decide how to investigate impacts of particular activities on bodily systems, including what standards and testing procedures would apply to that research. Standards topics discussed during the course included human testing limits, procedures for ergonomics and clothing functionality, and impact of protective gear on human physiology and heat stress.

Instructional activities included observation of laboratory instrumental tests as well as manikin and human tests. To assess learning, students were asked to describe the tests being performed, what the tests were designed to measure, the strengths and limitations of the tests, and how the results obtained could be interpreted. In addition to the group and laboratory activities, students were asked to discuss the topics during lectures, and questions were included on tests and homework assignments.

Learning assessments from tests administered in both courses found that students achieve excellent levels of mastery of the key learning objectives related to standards. Students indicated high levels of interest and satisfaction with the courses and indicated that they would recommend the classes to other students. Some suggestions for improvements were offered, and they are being integrated into the plans for the next cycle. In addition, some of the course content may be modified as the three additional courses are created so that more detailed information on some topics can be incorporated in those courses.

Three additional courses are now being developed. *Thermal and Mechanical Protective Clothing and Equipment* will discuss materials used in hot environments, clothing systems, and other PPE, risk assessment for thermal and mechanical hazards, test methods used for materials and systems, burn modeling, and impact protection. Performance requirements under OSHA regulations and standards requirements for NFPA, ISO, CEN, and ANSI will be discussed, including how standards are created. Critical analysis of strengths and gaps of standards and test methods, including ASTM methods, will be presented. How standards are used in certification of clothing systems as well as the strengths and limitations of standards will be discussed.

The second course, *Chemical, Biological, and Medical Protective Systems*, will discuss the history of chemical and biological protective systems, and how such systems have evolved. The test methods used to evaluate materials for barrier performance against chemical, biological, and aerosol threats will be discussed as well as penetration, permeation, and whole ensemble tests. Developments of antimicrobials, surface treatments, and the state of research on surfaces or treatments to degrade toxicants and biological threats will be introduced. Issues of protection against different threat levels and the balance between protection, system utility (ergonomics, functionality), and thermal burden will be discussed. Differences between respiratory and dermal hazards with
The intended student population includes master’s level concentration in Protective and Functional Textiles and Clothing to be offered by the NCSU College of Textiles. The intended student population includes on-campus students at NC State, and working professionals from industry, government agencies, or others seeking advanced education in personal protection and functional textile technologies and their relationship to human protection (PPE) and comfort performance.

The courses described above will provide the basis for a new concentration in Human Protection and Comfort Science within a current master’s degree offered by the College of Textiles at NCSU. The curriculum will include existing courses in the College of Textiles as well as courses across the NCSU campus. Students will take four core courses (Textile Manufacturing Processes, and three of the technical courses described above); the product innovation course, plus three additional management courses; a technical specialization course; and a capstone project course.

After it is added to the College of Textiles as a concentration, the program will also be submitted to the National Professional Science Association (NPSMA) for certification as a Professional Sciences Master’s (PSM) Degree. Professional Science master’s degrees are “designed to meet management needs of technology-based companies, government agencies, and non-profit organizations. Students pursue advanced training in science engineering while simultaneously developing valued business skills.” (NPSMA website). PSMs are interdisciplinary STEM (Science, Technology, Engineering, and Mathematics) programs that focus on educating students to solve today’s challenges and close the existing skills gap in the workplace. The PSM includes specific technical and management content in the curricula, and seeks to include high degree of engagement with local and global employers. The PSM is directed at people who intend pursue employment in, or are already employed by industry, governmental agencies, and non-governmental organizations. These careers demand the combined skill set of technological knowledge and management capability (project management, managing technical staffs, operations management, and global/supply chain technologies). This approach to education provides a dynamic new portal to expand the reach of education, including education on standardization and standards, to non-traditional students.

The new courses in the Master’s of Science in Textiles concentration/PSM will begin to be offered as a distance education program approximately one year after the program begins as a traditional curriculum. One of the main objectives of the program is to make education on high performance clothing systems available and accessible to interested students from industry, government agencies, standard organizations, and nonprofit agencies. A vital part of that education is the understanding of standards, standardization, certification, and robust performance criteria in high performance clothing and protective ensemble systems.

In addition to students in the degree program, other graduate students in traditional master’s degrees and PhD programs will be able to take the new courses, and standards content has been incorporated into the undergraduate Textile Testing course as described above. Over the next few years, we will create short courses for the Textiles Extension group in the NCSU College of Textiles and for interested standard organizations that will be based on the content of the courses taught in the Human Protection and Comfort Concentration. This is expected to include a certificate program for Human Protection and Comfort.

Conclusion

Since the founding of TPACC in 1994, the importance of standards, reliable test methods, and performance criteria for protective and functional textiles and clothing has been an essential part of the research and graduate educational activities in the Center. As TPACC has grown in both the scope of its research and the number of graduate student engaged in research projects on PPE and textiles for high performance sports applications, there is an increased need to develop course content on standards and standardization and to include them in a formal curriculum offered by the College of Textiles. Standards and standardizations are a critical element for educating scientists, engineers, and professionals working in emergency response, the military, and medical fields as well as those involved in developing performance clothing for sporting applications where conformity and adherence to meaningful performance criteria are essential. We are grateful to NIST for supporting the development of the new (Continued on page 6)
program through its cooperative agreements that support incorporation of standards in the education.

Acknowledgment
The funding provided by NIST has enabled us to accelerate the integration of content on standards, standardization and conformity into our programs on Human Protection and Comfort. We wish to thank the NIST Standards group and our program manager, Mary Jo DiBernardo for supporting our program and for their valuable input and encouragement.

References

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