Virtual Online Tensile Testing Strength Simulation

Introduction

This TUES Type 1 project proposal is submitted by Sinclair Community College (Dayton, OH) in collaboration with Bloomsburg University of Pennsylvania (PA) and the national office of Project Lead The Way (IN) to develop and disseminate an open source, online virtual tensile strength testing simulation. Materials created from this project will be utilized by engineering technology and engineering students in higher education as well as pre-engineering high school students in the Project Lead The Way network of 2,459 high schools nationwide. The research question being addressed: Can online learning be better AND less expensive?

Testing the tensile strength of materials is a common component of entry-level undergraduate engineering and engineering technology courses. Testing related to strength and mechanics of materials is a process taught not only in mechanical engineering courses, but in many introductory engineering courses. At Sinclair Community College, the tensile test is used by four faculty members involving 140 students per year. If just 1,000 of the 1,655 community colleges teach tensile testing to 50 students per year, the simulator would benefit 50,000 undergraduate students every year. At the high school level, Project Lead The Way pre-college engineering programs incorporate materials selection and tensile strength testing for product design at thousands of high schools.

“Perhaps the most important test of a materials mechanical response is the tensile test” in which a tensile test specimen is subjected to a load and controlled displacement (Roylance, 2001). A transducer connected in series with the specimen provides an electronic reading of the load corresponding to the displacement. Students able to interpret the resultant stress-strain curve can apply mathematical concepts of graphing and predicting and applied knowledge of material properties to their developing understanding and application of the engineering design process.

The virtual tensile testing tool will have broad academic and financial benefits. At the academic level: Colleges and high schools owning testing equipment will benefit from using the virtual simulator as an introduction to the topic before students conduct the actual physical tests. Research indicates that when a simulation game is embedded in a program of instruction, better instructional outcomes are achieved than when it is used merely as a standalone simulation (Stizmann, 2011). When simulation games are used as a supplement to other instructional methods, the simulation game group had higher knowledge levels than the comparison group.

At the financial level: The equipment required for students to do the physical tensile test is cost prohibitive for small colleges and most high schools. As a result, many students are unable to participate in this foundational engineering experience with no other viable option. Schools able to purchase low-end tensile test equipment often cannot subsequently afford to maintain it, purchase necessary materials to test, or repair damaged parts that wear out.

The PLTW national office did an extensive search to locate existing virtual tensile strength simulators to adopt and found simulators on both ends of a continuum from simple to complex. On one end, simulators focused on student learning but were overly simplistic; they are designed like a game, skimming the concepts. The most critical flaw of existing student-focused simulators is they do not require students to do calculations as part of the simulation. Others are inaccurate or incomplete, and do not adequately support student learning or provide a
comprehensive learning experience. At the other end, existing commercial simulators are too sophisticated, designed to meet the needs of researchers and engineers in industry who enter and extract data, with no focus on teaching the concepts entry-level undergraduates or high school students must grasp. Currently, PLTW uses a simulator developed in South Wales, Australia (http://lrrpublic.clt.det.nsw.edu.au/lrrSecure/Sites/Web/tensile_testing/main.htm) which has inaccuracies. In summary, current simulators are either too simplistic, inaccurate, or too complex to meet the needs of the target audience. Clearly, a cost effective, educationally sound alternative is needed. A virtual, open source virtual tensile strength testing simulator would receive a high volume of use in secondary and postsecondary institutions across the county.

This project proposes to bridge the gap between products that are either too simple or too complex. The project will design, develop, and implement an open source, virtual tensile strength simulation for undergraduate engineering technology students and pre-engineering high school students. Once developed, the project team will evaluate the effectiveness of the tensile strength simulation through a quasi-experimental study, comparing the performance of students using tensile testers in their schools or at local businesses against students using the virtual simulator.

Project’s Motivating Rationale

Why a Simulation?

A simulation is being proposed for the instruction of tensile strength testing for two reasons. The first reason is that research strongly supports the use of simulations for instruction. Simulation games are a proven method of improving learning, engaging students, and providing a blend of individual and collaborative work in both real-life and virtual settings (Rupp, Gushta, and Mislevy, 2009).

A meta-analysis (study of studies) conducted of 55 research papers related to the use of simulation games indicated that simulation games can help trainees achieve a higher confidence in applying learning from a training session to a job situation when the training is simulation game-based (Sitzmann, 2011). The meta-analysis reveals that people participating in simulation game learning experiences have higher declarative knowledge, procedural knowledge, and retention of training material than those people participating in more traditional learning experiences. Examining the effectiveness of computer-based simulation games related to comparison groups, it was found that declarative knowledge was 11% higher for trainees taught with simulation games than a comparison group; procedural knowledge was 14% higher and retention was 9% higher (Sitzmann, 2011). What was not reported in the study, and is the focus of this project, is the effectiveness of a simulation as compared to the use of an actual piece of equipment. Adding to the body of knowledge, the project team will learn the rates of learning of declarative knowledge, procedural knowledge, and retention as it relates to hands-on use of a piece of equipment versus a simulated version of the equipment.

The second reason a simulation is being proposed is to determine if the cost of training the instructors to use the free simulation in the classroom is more cost effective for the schools than purchasing the actual tensile strength testing equipment or having students travel to another

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1 Simulation games were defined as “instruction delivered via personal computer that immerses trainees in decision-making exercises in an artificial environment in order to learn the consequences of their decisions.”
location to use the equipment. The key question to be addressed is this: *Can online learning be more effective in teaching concepts AND less expensive?*

Battaglino, Haldeman, and Laurans, authors of Chapter 3: The Costs of Online Learning, in *Education Reform for the Digital Era*, conclude that “The promise of online learning is two-fold: More effective uses of technology have the potential to both improve student outcomes and to create a more productive educational system” (Finn, 2012). They indicate the estimated cost per pupil expenditure for the traditional model is $10,000; for the blended model is $8,900, and for the virtual model is $6,400. However, they questioned the learning outcomes of the fully virtual model in their discussion of productivity.

The lack of high quality data on learning outcomes of virtual models makes it difficult to draw meaningful conclusions regarding productivity. The need for better outcome data is an important next step. Although this pilot focuses on a specific tensile test activity, the impact for the mechanical engineering educators is far reaching. Additionally, a framework would be established for materials development for other types of engineering testing.

**Goals & Objectives**

*The overarching goal* of this project is to design, develop, and implement a virtual, online tensile strength simulator and to conduct an analysis to compare the costs and learning outcomes using on-site tensile testing equipment compared with the virtual, online tensile strength simulation. Project objectives include:

1. Develop a virtual, online tensile testing laboratory simulation.
2. Conduct research to compare the costs and learning outcomes for using on-site tensile testing equipment compared with an online simulation.
3. Create close industry ties through blended learning opportunities for students.
4. Disseminate the simulation via faculty development.

**OBJECTIVE 1 - Develop a virtual, online tensile testing laboratory simulation**

The simulator will be developed:

- For use in undergraduate strength of materials courses and the high school Project Lead The Way Principles of Engineering (Principles of Engineering) course.
- With *three modes*: demonstration, practice, and test.
- With ancillary instructor materials and IT implementation materials.

The tensile strength simulation will be developed in conjunction with Bloomsburg University’s Institute for Interactive Technologies (IIT) located in Bloomsburg, PA. The IIT has experience building educational simulators for a variety of educational institutions and corporations. The most similar to this project is a simulator they developed within the field of aviation called the ACT 600A Test Box which is used by Associate of Applied Science programs to closely replicate the equipment used by aircraft technicians. ACT 600A is used to test the transponders of aircraft. It is used by avionics technicians as they test and prepare a plane for takeoff. The simulator was designed to satisfy the need for the Pennsylvania College of Technology Avionics students to be able to identify and operate buttons, knobs, switches, and dials to accurately perform tests on the flight transponder box without damaging internal or external components of the an actual ATC 600A.
To measure the effectiveness of the ACT 600A Test Box simulator, 30 Avionics students at the Pennsylvania College of Technology were assessed in terms of knowledge gained after using the simulator. All students that completed the instruction scored between 87%-100% on a post-test, indicating that students with very limited knowledge of the ATC600A were able to complete the knowledge assessment with a very high performance level after only one forty minute self-paced training session. Through the experience using the simulator, students were able to learn at their own pace, did not risk damage to the avionics equipment, and scored large knowledge gains.

Using the same development approach as the ATC600A, the Tensile Strength Simulator will have three instructional modes to provide the maximum instructional benefit. The first mode of instruction will be the Demonstration Mode that will provide an overview of the entire procedure for testing materials. Learners will observe the placement of the materials within the simulator and observe how the test is conducted. The mode will also provide results and explain to the learner the relationship between the applied force, or load, and the elongation of the specimen. Graphed data and information will be provided.

The second mode will be the Practice Mode to guide learners through the process of how to conduct a tensile test by the simulator. The simulator will provide reinforcing feedback and information concerning the proper placement of materials and whether or not the learner is properly performing the test. Once a learner performs a step in the testing procedure, the simulator will check the step and provide immediate feedback. This mode will provide a chance for the learner to practice each step in the process and receive immediate feedback as to whether or not the procedure was performed correctly.

The final mode is the Test Mode where learners receive no guidance or assistance from the simulation. Learners must know what to do. Each step in the procedure will be evaluated by the simulation and, at the end of the testing procedure; the learner will be evaluated and given a score.

These three modes will provide multiple levels of difficulty which allow learners with different knowledge levels to benefit from the same simulation. The instructor will select the proper mode for the learners or allow the learners to choose the mode they believe is most appropriate for their knowledge levels. The three modes allow for an effective and timely transfer of knowledge because the instruction will be targeted specifically to the level of knowledge of the learner, from low-level (demonstration mode) to high level (test mode).

A storyboard draft of the content for the new Tensile Strength Simulator (see the attachments) will be a starting point for development. Co-PI Karl Kapp will work with consultant Wes Terrell,
PLTW Director of Curriculum and Instruction and Co-PI Steven Wendel to develop a pilot virtual, online simulator that is compliant with the Americans with Disabilities Act. Industry representatives will review and provide input on the simulator design and content. The functionality of the online tensile strength testing simulator will include:

- A learning-focused simulation to support student learning (as opposed to current research-focused tools).
- Simulation of the process to test standard engineering materials (steel, brass, aluminum, etc.) as well as elastic materials (plastic, etc).
- A function to allow learners to print a report for review by their teachers.

In addition, instructor materials will be created to support the use of the tensile strength testing simulator in classroom settings:

- A User’s Manual will walk the instructor through each of the three modes of the simulator and present best practice options for integrating the tensile strength testing simulator into class, including:
  - The objectives covered by the virtual tool
  - A list of acceptable answers for the questions posed to students

- A Learner’s Guide will present questions and provide an opportunity for student note taking.

**OBJECTIVE 2 - Conduct research to compare the costs and learning outcomes for on-site tensile testing instruction compared with an online simulation**

The research will compare learning outcomes between the onsite, hands-on instructional delivery vs. the online simulation delivery method. One outcome will be the identification of what aspects of the online simulation make it effective or not effective; what aspects of the on-site, hands-on make it effective or not effective. The research will analyze the impact on student learning of the sequence of instruction in the three modes of operations: demonstration, practice, and test. Questions include:

- What is the impact of the online simulation on the future career aspirations of students?
- What is the cost differential for implementation?
- What is the student motivation level comparison?

In addition to data concerning student learning, data will be gathered from teachers to determine their reactions, gain insights into how they may use it within the high school and postsecondary classroom, and to uncover any obstacles or hesitation that the teachers may have toward the simulation. Input will also be sought from students to determine their reaction to the simulation and their preferred delivery method to learn tensile strength concepts. While researching the instructional effectiveness of the simulation, the project team will investigate the following parameters of both on-site experiences and virtual online simulations:

- Student motivation and engagement;
- Learning outcomes (declarative knowledge, procedural knowledge, retention); and
- Cost of implementation and time required to implement

The research related to the curricular content and pedagogy will be conducted by Karl Kapp,
Ph.D., Professor of Instructional Design, Bloomsburg University (PA).

Involved in the research will be:
- Universities and colleges teaching undergraduate strength of materials courses and
- Project Lead the Way certified high schools teaching Principles of Engineering (POE)

There will be 10 faculty participants; six will be college and four will be high school. All college faculty members will teach strength of materials undergraduate courses with diverse student populations. One of the faculty participants will be from Sinclair Community College, and the other five college faculty participants will be identified and recruited through the listservs of the Engineering Technology Division of the American Society for Engineering Education (ASEE) and American Society of Mechanical Engineers. The six participants will be selected through an application process, with a preference toward selecting faculty members who teach at colleges serving diverse student populations including female and other underserved populations.

The four high school faculty participants will be Project Lead the Way instructors in Ohio certified to teach Principles of Engineering (POE). Sinclair Community College is the Ohio PLTW Affiliate and has close working contacts with programs across Ohio. Ohio currently has over 286 PLTW programs and trained teachers in place for the Principles of Engineering course. Of the Ohio Pathway to Engineering programs, 81 are nationally certified, meeting high standards in areas such as instruction, facilities, and equipment, partnerships, student diversity, student assessment, and articulation agreements between secondary and postsecondary institutions.

The initial 10 high school and college faculty members and other adopters will participate in a community of practice that will allow them to interact with other faculty members as well as members of industry. Members of industry will participate as subject matter experts and will serve as the foundation for the community of practice. The community of practice will be a key strategy in informing the higher education community about the tensile testing simulation and provide a pathway for the simulator to be adapted into current higher education programs.

Two Columbus Ohio PLTW schools, Columbus Metro High School and Worthington Kilbourne High School, were selected and agreed to participate (see commitment letters in attachments).
- Columbus Metro High School in Ohio serves a student population that is 88% economically disadvantaged. In 2009, there were 40 high school students enrolled in POE. Of these students, 76% (32) were minority students and 24% (10) were female.
- Worthington Kilbourne, High School in Ohio serves a more affluent population of students (4% are economically disadvantaged). In 2009, there were 30 high school students enrolled in POE consisting of 16% (5) minority and 6% (2) female.

There will be 310 student participants randomly assigned to either an experimental or control group. The experimental groups will use the virtual online tensile strength testing simulator and the control groups will use the hands-on equipment. Of the 310 student participants, 240 will be undergraduate students and 70 will be high school students. All 10 faculty members (college and high school) will use the new simulation tool with one section of students and use their traditional teaching methods with another section of students. Faculty will be offered stipends for their participation in the research, which will be paid after they submit the required data on both
student groups. Faculty will also be asked to participate in a faculty survey inquiring about their experiences with the new simulation tool.

A small group of students at the Columbus Metro High School will participate in a focus group. All other high school and college students will participate in a pretest-posttest design. Using two data collection methods will provide the team with qualitative and quantitative input on the impact of the simulation.

<table>
<thead>
<tr>
<th>310 Student Participants in the Study</th>
<th>Experimental Group</th>
<th>Control Group</th>
<th>Pre/post- Test</th>
<th>Student Focus Groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>College students at 6 institutions nationwide</td>
<td>120</td>
<td>120</td>
<td>240</td>
<td>0</td>
</tr>
<tr>
<td>Columbus Metro High School (OH)</td>
<td>20</td>
<td>20</td>
<td>28</td>
<td>12</td>
</tr>
<tr>
<td>Worthington Kilbourne High School (OH)</td>
<td>15</td>
<td>15</td>
<td>30</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>155</strong></td>
<td><strong>155</strong></td>
<td><strong>298</strong></td>
<td><strong>12</strong></td>
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</table>

In the small focus group for the simulation, the project team will have the learners use the simulation and “think aloud” to obtain insights into their experiences with the simulation and the impact the simulation is having on them. This process will primarily address the research question involving the engagement of the students and whether or not the students perceived the simulation as being motivational. A similar “think aloud” focus group process will occur with students in the on-site, hands-on group.

To determine if students learned subject matter content from the simulation, a pre/post test instrument will be administered. The pre/post test will be developed jointly with Project Lead the Way and the project team to ensure the content validity of the questions. There will be two types of assessments. One will be paper-based and one will be performance-based (checklist/rubric) as indicated in the table below.

<table>
<thead>
<tr>
<th>Type of Assessment</th>
<th>Paper Test</th>
<th>Performance Test</th>
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<tbody>
<tr>
<td>Format of Assessment</td>
<td>Multiple choice</td>
<td>Checklist/Rubric</td>
</tr>
<tr>
<td>Type of Knowledge Assessed</td>
<td>Knowledge</td>
<td>Application</td>
</tr>
</tbody>
</table>

Each group will take the pretest. One group of students will participate in the experimental treatment of the simulation and then take the post test. They will also be given the test mode of the simulation and observed to test their application of skills. Statistical analysis will consist of a chi-square test to determine whether any observed measure of pre- and post-test gains differed significantly from a chance distribution and a t-test to determine whether the difference between the pretest and posttest mean is statistically significant.

The group of students participating in the on-site, hands-on training will also take the pre-test, participate in the hands-on lesson on tensile strength and then take a post-test. This group will use the equipment and be observed by the project team and rated on the checklist/rubric to determine how well they were able to apply the knowledge. The same statistical analysis will be undertaken for the hands-on group as for the simulation group.

One week later, each group will again be asked to take a test to determine knowledge loss or retention and asked to again perform on the equipment or test mode of the simulation to determine application. The goal of the research team is to determine both educational and statistical significance of any changes as a result of the experimental treatment (using the
simulation). The results will allow the project team to determine the effectiveness of the simulation as compared to actually using the equipment.

**Costs**

The PLTW National Office developed a purchasing manual for equipment utilized in each of their courses. Using the manual as a starting point, the project team will identify costs associated with the on-site, hands-on laboratory version of the activity and compare this to the virtual simulation tool model utilizing the same cost component categories shown in the *Costs of Online Learning* of Education Reform for the Digital Era. The cost analysis will be performed at the two Ohio high schools, permitting a detailed cost analysis that will include variations in costs at different schools in the respective districts.

**OBJECTIVE 3 - Create close industry ties through blended learning opportunities for students**

An important component in the development of the virtual online tensile strength simulator is the creation of close ties and cooperation between industry and students. Bloomsburg University will integrate career information into the tensile test simulations by introducing students to real-world careers and companies that use such an application. The online simulator will also integrate links to CareerME.org into the learning opportunities. CareerME.org, created by the National Center for Manufacturing Education, with support from the SME Education Foundation, is a website targeted primarily to young people in grades 11-14, providing them with positive information about careers in advanced manufacturing and connecting them with job shadowing information and opportunities. A final component to promote ties between industry and students, Bloomsburg University will integrate videos into the online simulator that will demonstrate how tensile testing is used in real-world company operations.

**Industry Collaboration**

Industry representatives will help identify the learning content and appropriate videos for use in the simulator. Instron and MTS are two of the largest suppliers of tensile test equipment in industry. Their equipment is also installed in many college and university labs across the country. Both companies use software (Instron uses Bluehill 3; MTS uses TestWorks) with their tensile testing machines; however, neither is developed for student learning. Collaborating with prominent suppliers of industrial tensile testing equipment will enhance student understanding of the equipment most utilized in industry. The project team will create links to tensile testing equipment companies within the simulator and/or ancillary materials to be developed. Representatives from companies like Instron and MTS are best positioned to identify companies (their customers) with applications of tensile testing that would be of most interest to high school and undergraduate students. They will also be of assistance in identifying companies using their equipment in close geographic proximity to the students.

**OBJECTIVE 4 - Disseminate the simulation via faculty development**

Project dissemination will take two distinct professional development tracks: (1) Higher education instructors and (2) PLTW Principles of Engineering teachers. The professional development activities are based on the belief that “Teacher quality matters. In fact, it is the most important school-related factor influencing student achievement” (Rice, 2003).
Track 1 - Dissemination and faculty development for higher education instructors

Dissemination to the higher education community will be through papers, conference presentations, webinars, and journal articles to targeted audiences in the engineering and engineering technology education community. The dissemination activities will provide:

- An overview of the project and a summary of results
- Professional development on use of the tensile test simulator and implementation methods in higher education
- The download link for the open source tensile tool simulator and user manual
- The experiences of the community of practice

The National Center for Manufacturing Education (NCME) website will host the tensile test simulator download link and the webinars for faculty development. The faculty professional development presentations and webinars will be designed based on a recent publication, *Developing Metrics for Assessing Engineering Instruction: What Gets Measured is What Gets Improved* (National Academy of Sciences, 2009). This publication states that content expertise, although necessary, is not sufficient to ensure teaching excellence. It identifies other components the project team will incorporate into the professional development activities, such as:

- Instructional design
- Instructional assessment
- Instructional delivery
- Course management

Specific conferences that will be targeted for dissemination include the ASEE annual June conference and the annual ASME International Mechanical Engineering Education Conference. These venues are premier events for mechanical engineering department heads and faculty leaders who are looking for strategies to improve and enhance their instructional programs.

Track 2 - Faculty development for PLTW Principles of Engineering teachers

Because PLTW teachers have backgrounds in STEM areas other than engineering, many have never completed a strength or mechanics of materials course. Those with backgrounds other than engineering may not have been exposed to any course work, formal training, or professional development related to strengths/mechanics of materials.

Current PLTW professional development is a three-phase program designed to teach the content and pedagogical skills needed to teach each PLTW course. It is focused on proper preparation, in-depth training, and continuing education. The three phases of professional development are:

1. Readiness Training
2. Core Training
3. Ongoing Training

The new virtual tensile test simulator and related materials will be required Phase 2 Core Training for PLTW Principles of Engineering teachers. Teachers who come from an engineering background and have already taken strength/mechanics of materials courses will be familiar with the content and would move quickly to the final mode of the simulator, the test mode. After quickly reviewing the functionality of the simulator—without additional guidance, they could explore the functional limits of the tensile test simulator. Those teachers with adequate math,
science, and technology backgrounds who lack prior strength/mechanics of materials training would experience and learn using the tensile test simulator in the same progression as their students; first in demonstration mode, then practice mode and finally test mode.

*Train the Trainer*—Through partnerships with more than 48 colleges and universities across the country, 10,500 teachers have attended two-week Core Training sessions for PLTW courses. Core training instructors are master teachers and affiliate professors well versed in the content of the Principles of Engineering course and experienced in the activities, projects, and problem-based learning, the approach used by PLTW to provide hands-on classroom experiences. Core training instructors will learn about the tensile test training simulator in their train-the-trainer sessions held in the spring prior to summer training. In cooperation with the national office of PLTW, the project team will train-the-trainers in use of the tensile test simulator. Additionally, having the national PLTW office involved as part of the project team will allow for direct integration of the tensile test simulator and ancillary materials into the PLTW curriculum. The current core PLTW curriculum, Principles of Engineering Lesson 2.3: Material Testing (see attachments) will be improved by including the tensile testing simulator into Activity 2.3.2, Tensile Test Simulation.

PLTW affiliate universities, including Sinclair Community College serving as the Ohio PLTW Affiliate, offer intensive, two-week training sessions for the PLTW program on their campuses across the country each summer. Taught by the PLTW core training instructors, it is expected that 500 – 700 Principles of Engineering teachers will be trained in 2015.

*Ongoing PLTW Training*—Over 2,000 of the approximately 10,500 teachers in the PLTW Network have been trained for Principles of Engineering. The PLTW Network hosts a virtual academy where professional development materials are posted for PLTW trained teachers. Additionally, Affiliate Universities offer a conference each year providing update training opportunities for teachers in the PTLW Network. Training materials and update training sessions will be made available to the PLTW Network of teachers to learn about the availability of the tensile test simulator. Principles of Engineering teachers will learn how the tensile test simulator is embedded directly into their Principles of Engineering course.

**Deliverables, Activities, Timeline**

<table>
<thead>
<tr>
<th>Successful completion of the project work will result in the following project deliverables:</th>
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<tbody>
<tr>
<td>1.0 Virtual online tensile testing tool</td>
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<tr>
<td>• Software, video, graphics, etc.</td>
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<tr>
<td>2.0 Online simulation user manual</td>
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<tr>
<td>• Documentation on how to use the tool, how to implement the tool</td>
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<tr>
<td>3.0 Professional development materials for:</td>
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<tr>
<td>• Community college faculty in strength of materials courses</td>
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<tr>
<td>• Project Lead the Way teachers of Principles of Engineering</td>
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<tr>
<td>• Dissemination via presentations at ASEE and ASME Educator conferences</td>
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<tr>
<td>• Dissemination via summer teacher training</td>
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<tr>
<td>4.0 Research outcomes</td>
</tr>
<tr>
<td>• Research report</td>
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<tr>
<td>• Publication in professional journals</td>
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The deliverables will be developed and implemented as outlined in Figure 3 below.
Timeline for the Development of Deliverables

Figure 3: Gantt Chart for Tensile Test Simulator
Deliverables Development and Implementation
This Project Addresses the Needs of Underserved Populations

The tensile test simulator will provide equity for underserved groups and serve as a bridge to technology, as spelled out in *Investing in America’s Future: A Blueprint for Transforming Career and Technical Education* (U.S. Department of Education, 2012). New and emerging technologies are viable ways to solve problems of limited access, and uneven quality and rigor of academic and technical curricula. This project employs the use of technology-enabled learning solutions that are accessible to, and usable by, students with disabilities and students served by institutions that cannot afford to purchase and maintain actual tensile strength testing equipment. The project will create access to high-quality learning opportunities, including to technical courses and virtual work experiences. Through technology, the project will serve students who are disconnected to postsecondary institutions due to geography as well as to business and industry. In addition, preference will be given in selecting participating colleges that serve large numbers of underrepresented students.

Management Plan

The project management functions are based upon the successes of previous grants and have been identified as vital for the successful implementation of NSF ATE projects (Siefert, 2003). Each function will be tracked against a rigid timeline and budget. The project will be managed using activity-based budgeting. The three-year project will be divided into a series of discrete activities with a leader, deliverable, timeline, tasks, and budget. Co-PI Wendel will monitor performance and conduct quarterly reviews of evaluation data. PI Kapka will ensure completion on time and on budget.

Qualifications of Principal Investigators

**PI Larraine Kapka** is an Associate Professor and Department Chair, Engineering Technology Design at Sinclair Community College. She has extensive project management experience as a previous PI for the National Science Foundation Grant Program (DUE 0202131), July 2002—June 2006 and her work as the Chair of Sinclair’s *Women in STEM* program. She currently serves on the Engineering Technology Accreditation Commission of Accreditation Board for Engineering and Technology, Inc.

**Co-PI Steven Wendel** is the Director of National Center for Manufacturing Engineering (NCME) and the Director of Project Lead The Way Ohio Affiliate, Sinclair Community College (OH). He leads the NCME in developing strategic professional alliances to promote manufacturing education and in serving as a national resource for the development and dissemination of advanced manufacturing technician curriculum.

**Co-PI Karl Kapp, Ed.D.**, Professor of Instructional Design, Bloomsburg University, PA. Dr. Kapp has overseen a number of simulation development projects and has extensive experience serving as external evaluator for two ATE Funded programs, the Information and Communications Technology Center (Springfield Technical Community College, MA) and the Plastics Resources for Educators project (Penn State University-Pennsylvania College of Technology).
Consultant Wesley Terrell is the national Director of Curriculum and Instruction for Project Lead the Way, the leading national provider of rigorous and innovative science, technology, engineering, and mathematics education curricular programs used in middle and high schools across the country. He has served PLTW as project manager and lead author for a variety of courses.

Roles and Responsibilities

The following identifies the primary project management functions of the core team.

<table>
<thead>
<tr>
<th>Name</th>
<th>Primary Project Responsibility</th>
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<tbody>
<tr>
<td>PI Larraine Kapka</td>
<td>Provide consultation on the design and delivery of the virtual simulation tool at the undergraduate level; monitor budget, support training of Sinclair’s faculty in use of tool, assist with dissemination.</td>
</tr>
<tr>
<td>Co-PI Steven Wendel</td>
<td>Serve as project manager, with responsibility for start-up activities, day-to-day project management, NSF reports; work with PLTW and industry partners, conduct dissemination activities, and summative project evaluation activities.</td>
</tr>
<tr>
<td>Co-PI Karl Kapp, Ph.D.</td>
<td>Conduct research activities, oversee the development of simulator and the student and instructor print materials, assist Co-PI with dissemination, evaluation activities, and NSF reports, lead strategic thinking for project.</td>
</tr>
<tr>
<td>Consultant Wesley Terrell</td>
<td>Co-develop the simulator with Co-PI Kapp and industry subject matter experts, provide trouble shooting assistance, guide the integration of the new curriculum into PLTW programs across the nation.</td>
</tr>
</tbody>
</table>

Sustainability Plan

The sustainability plan is based on creating the online simulator as an accessible, open source product and on providing ongoing access to the simulator, user manual, and other project deliverables through the Manufacturing & Engineering Technologies Education Clearinghouse (METEC). METEC is a searchable database of materials submitted by educators from around the world. The user manual developed with grant funds will provide a turnkey process for adopting institutions to use after the grant. The grant funds will be used to develop the simulator to teach basic concepts, which are not likely to change every year. However, as technology advancements create the need for updates, currency will be accomplished by faculty users and their instructional media support teams, in the same manner as they update other course content.

At the high school level, Project Lead The Way will make the simulator a part of the Principles of Engineering curriculum, and will provide PLTW ongoing professional development through their standard processes. Ongoing access to the project deliverables is also assured through the PLTW website. The project will result in lasting improvement in undergraduate and high school STEM education by improving learning outcomes at a reduced cost.

Evaluation Plan

Co-PI Steven Wendel will be responsible for the overall project evaluation which will include quantitative and qualitative methods in data collection and analysis (Steven, Lawrenz, & Sharp, 1992; Frechtling & Sharp, 1997). Working with data provided by the researcher Dr. Kapp, Mr. Wendel will analyze results and compile the findings for annual and final reports. There will be two major components to the evaluation plan: formative and summative.
Formative Evaluation Process: The formative evaluation will track whether the project is being conducted as planned and will monitor the short-term and annual results of activities. Formative evaluation determines the extent the project's goals and objectives are being met. This performance information will be used to influence program decision-making and resource allocation. Once the detailed evaluation plan is finalized, activities will be integrated into the project plan. Co-PI Wendel will monitor the evaluation plan’s activities and share formative evaluation reports twice a year with the project team to inform process improvements.

Summative Evaluation Process: The new simulation tool will be piloted on test groups and the data compared with data from the control groups. The research work will reduce threats to internal validity (e.g., determining the project impact) by using experimental and quasi-experimental evaluation methods as appropriate. During year one, Dr. Kapp will establish the protocols for the application of a quasi-experimental evaluation approach to pilot test the newly developed tool, with actual pilot testing occurring in year 2. During the project’s subsequent years, with a particular emphasis during year 3, the summative evaluation will focus on gathering data from core team members, industry representatives, partners, and students to measure its effectiveness. Data will be collected through surveys and focus groups. The table below illustrates the type of data and information that will be included in the final report.

<table>
<thead>
<tr>
<th>IMPACT AREAS</th>
<th>EVIDENCE OF IMPACT</th>
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<tbody>
<tr>
<td>Accountability:</td>
<td>• Project meeting notes</td>
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<td></td>
<td>• Records of dissemination activities</td>
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<td></td>
<td>• Interview responses</td>
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<tr>
<td>Educational Gains:</td>
<td>• Student pre- and post-test data comparison of pilot and control groups</td>
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<td></td>
<td>• Survey responses of students</td>
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<tr>
<td>Impacts:</td>
<td>• Surveys responses of students, faculty industry advisory members, and project team</td>
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<td></td>
<td>• Responses to interviews by external evaluator</td>
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<td></td>
<td>• Interview responses</td>
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<td>• Evidence of ongoing use of the learning objects and higher-level teaching methods</td>
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<tr>
<td>Unexpected Results:</td>
<td>• Project meeting notes; interview responses</td>
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<tr>
<td></td>
<td>• Surveys of students, faculty, industry advisory members, and project team</td>
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</table>

Co-PI Steven Wendel will provide a final evaluation report that will include a candid assessment of the following:
➢ Did the project achieve its outcomes and overall goal? What components were most effective?
➢ How were the deliverables disseminated? How can the project be replicated and transported?

Dissemination Plan

As described in objective 4, the project dissemination will occur through professional development activities for higher education faculty members and high school PLTW Principles
of Engineering teachers.

Higher education engineering faculty will receive an introduction to the virtual tool through conference presentations and journal articles. For more in depth information and exchange of ideas, webinars will be held quarterly during year three of the project. The community of practice faculty members who have already adopted the tool will be invited to be co-presenters for the webinars. The National Center for Manufacturing Education (NCME) website will host the simulator download link and the webinars for faculty development. The NCME website will track the number of “hits” the website receives from people downloading the tool.

Specific conferences that will be targeted for dissemination include the ASEE annual June conference and the annual ASME International Mechanical Engineering Education Conference. These venues are premier events for mechanical engineering department heads and faculty leaders who are looking for strategies to improve and enhance their instructional programs.

Training materials for new and current PLTW teachers will be made available through the PLTW network. Principles of Engineering teachers will learn how to use the tensile test simulator embedded directly into their Principles of Engineering course. The Train the Trainer program (described in objective 4) will extend the use of the virtual tool to thousands of high school teachers. By year 3 of the grant, 500-700 PLTW teachers will be trained, eventually reaching thousands of high school teachers nationwide. Additional high school teachers not in the PLTW network will also participate in webinars and download and use the tool.

Results from Evaluations of Prior NSF Support

Steven Wendel—The current grant for the NCME (DUE 0802305 for $1,600,000 from June 01, 2008 to May 31, 2013) is entitled “Manufacturing Engineering Resource Center: An NSF National Center of Excellence” and has a goal to increase the national impact of engineering and manufacturing technology reform through the dissemination of model programs, materials, and instructional curricula via a web-based clearinghouse, faculty professional development, and related outreach services. The NCME has provided national leadership in manufacturing education. It uses a vital mix of manufacturing and engineering technology expertise from around the country that helps the NCME provide insights, connections, and direction in manufacturing education. The NCME has a 15 year history and track record of success.

Dr. Karl Kapp—Dr. Kapp is currently a co-PI for Simulation and Modeling in Technology Education (SMTE) (0821965 for $2,537,314 from 5/01/08-04/30/13). The NSF DR-K12 project is designed to develop and research the academic potential of a hybrid instructional model and a set of prototypical materials that integrate 3-D simulation, educational gaming, and real-world physical modeling into middle school technology education programs. The physical modeling curriculum has been completed and alpha versions of all game elements have been created. Initial play tests indicate that the game is usable in middle school classrooms and that in general students enjoy playing parts of the game. The development team has been responsive to on-going feedback from teachers, students, and others, making adaptions and enhancements as needed. The next step is to conduct the research to compare the different types of curriculum to each other which is scheduled for the final year of the grant.