



Virtual Online Tensile Strength Testing Simulation

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Abstract

Supported through NSF-DUE, this TUES Type 1 project is 1) developing an open source, virtual, online tensile testing laboratory simulation; 2) conducting research to compare the costs and learning outcomes for using on-site, hands-on tensile testing equipment versus an online simulation; 3) creating close industry ties through blended learning opportunities for students; and 4) disseminating the simulation via faculty development. The project is testing the hypothesis that online learning improves outcomes and simultaneously reduces instructional costs. It is bridging a gap between existing tensile testing software products that are either too simple or too complex. The project is using a comprehensive assessment of student learning, along with a quasi-experimental research design, to determine the impact of the simulator on students and their instructors compared to traditional learning without the simulator. Although the proof of concept in the project pertains to a common engineering learning activity, the research is applicable to other engineering areas and other disciplines. The project includes activities that can be easily adopted by other institutions with little cost. The open-source tool being developed will be disseminated to undergraduate and high school faculty members who teach strength of materials and similar courses, thus increasing the likelihood of adoption. Access to a virtual lab will allow groups with limited resources to attain desired learning outcomes without large capital investments for tensile strength testing equipment.

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Introduction

ABET Criteria for Student Outcomes in engineering and engineering technology programs indicate that an ability to test and conduct experiments is an important outcome for students and serves as a primary basis for this work¹.

The Engineering Accreditation Commission (EAC) of ABET GENERAL CRITERION 3. STUDENT OUTCOME (b) an ability to design and conduct experiments, as well as to analyze and interpret data

The Engineering Technology Accreditation Commission (ETAC) of ABET GENERAL CRITERION 3. STUDENT OUTCOMES

- A. For associate degree programs, c. an ability to conduct standard tests and measurements, and to conduct, analyze, and interpret experiments;
- B. For baccalaureate degree programs, c. an ability to conduct standard tests and measurements; to conduct, analyze, and interpret experiments; and to apply experimental results to improve processes;

Any work done to improve learning outcomes in these areas would be of benefit to a large number of students. Additionally, the tensile test is a well-known standard test most institutions use within their engineering and engineering technology programs. Further, “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)ⁱⁱ.

The virtual tensile testing tool being developed as part of this project targets entry-level engineering students at both the high school and collegiate level and 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 is embedded in a program of instruction, better instructional outcomes are achieved than when it is used merely as a standalone simulation (Stizmann, 2011)ⁱⁱⁱ. 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 options. 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.

Project Lead The Way (PLTW), the nation's leading science, technology, engineering, and math (STEM) solution in over 8,000 schools across the U.S., 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.cli.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.

Background, Goal and Objectives

The research question being addressed:

Can online learning be better AND less expensive?

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 developed 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)^{iv}. A meta-analysis (study of studies) conducted of 55 research papers related to the use of simulation game 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 mega-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 location to use the equipment.

Battaglino, Haldeman, and Laurans, Chapter 3 authors of **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)^v. 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.

Goal & 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. Project objectives have been defined as specific activities for the project.

Activities

1. Develop a virtual, online tensile testing laboratory simulation.

The simulator is being developed:

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

The Tensile Strength Simulator incorporates three instructional modes to provide the maximum instructional benefit.

The first mode of instruction is the Demonstration Mode that provides an overview of the entire procedure for testing materials. Learners observe the placement of the materials within the simulator and observe how the test is conducted. The mode also provides results and explains to the learner the relationship between the applied force, or load, and the elongation of the specimen. Graphed data and information are provided.

The second mode is the Practice Mode to guide learners through the process of how to conduct a tensile test by the simulator. The simulator provides 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 provides 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).

The functionality of the Americans with Disabilities Act (ADA) compliant, online tensile strength testing simulator includes:

- A learning-focused simulation to support student learning (as opposed to 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 that walks 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 to present questions and provide an opportunity for student note taking.

2. Conduct research to compare the costs and learning outcomes for using on-site tensile testing equipment 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

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. 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

- 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.

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

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.

Type of Assessment	Paper Test	Performance Test
Format of Assessment	Multiple choice	Checklist/Rubric
Type of Knowledge Assessed	Knowledge	Application

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.

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.

4. Disseminate the simulation via faculty development. Project objectives have been defined as specific activities for the project.

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)^{vi}

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)^{vii}. 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 delivery
- Instructional assessment
- 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 instruct 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 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 2016.

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.

Successful completion of the project work will result in the following project deliverables:

1.0 Virtual online tensile testing tool

- Software, video, graphics, etc.
- 2.0 Online simulation user manual
 - Documentation on how to use the tool, how to implement the tool
- 3.0 Professional development materials for:
 - Community college faculty in strength of materials courses
 - Project Lead the Way teachers of Principles of Engineering
 - Dissemination via presentations at ASEE and ASME Educator conferences
 - Dissemination via summer teacher training
- 4.0 Research outcomes
 - Research report
 - Publication in professional journals

Status

Progress is being made on all of the project activities, however, the project schedule has slipped. This is due primarily to the tensile tester at Sinclair Community College breaking down. Original tensile test data as input for the simulator could not be gathered on a timely basis. Ironically, this event further highlights the cost and expense of maintaining physical tensile testing equipment. To date the status of activities is:

1. Develop a virtual, online tensile testing laboratory simulation.

The tensile test simulator has been developed and is undergoing pilot testing and review.

iit.bloomu.edu/TensileSimulation/story_html5.html

The Introduction prompts students to enter their name/date for documenting their activity and provides an overview including the Objectives of the simulation. Additionally, it leads users to a 'Mode Select Slide' allowing them to select 1) Demonstration Mode, 2) Practice Mode or 3) Test Mode. The demonstration mode includes a video of a tensile test and provides an overview of procedures, definitions, formulas and an explanation as to why each step is important to complete. The practice mode provides guided practice where users can test their knowledge of the tensile test procedure. Two attempts are permitted in this mode with help provided along the way if needed. In test mode it is assumed that users understand the requirements and procedures of conducting a tensile test. Guidance is not provided and a report is generated at the end of the process to document student knowledge.

First draft versions of both an Instructor Guide and Student Guide have been provided. Both guides are organized/formatted following the outline of the simulator. Currently they are each deemed to be too long in length but serve as a good starting point for capturing in word documents, the contents of the simulation.

A screen-shot from the simulator introduction is shown below.

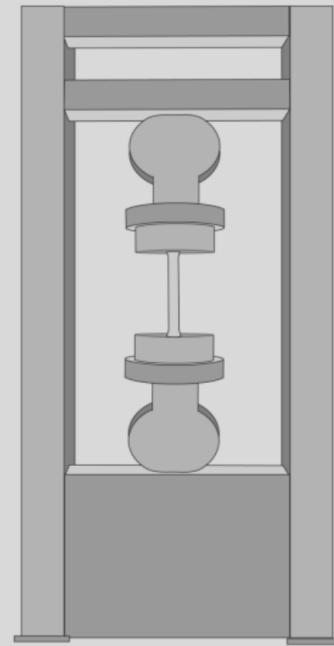
Learning Objectives



The purpose of this simulation is to replicate a tensile testing environment without having to conduct a tensile test with a real machine.

Throughout this module, you will not only learn about, but also simulate, the procedure of conducting a tensile test.

You will also be calculating various strength properties of numerous materials as if you were conducting a physical tensile test so make sure you have a calculator handy.



2. Conduct research to compare the costs and learning outcomes for using on-site tensile testing equipment compared with an online simulation.

Costs

Information is being gathered regarding costs. Insert Sinclair Community College information regarding repair costs as well.

Learning Outcomes

Learning outcomes by students have not yet been measured. Currently instructors at partner high schools and higher education programs are reviewing the functionality of the simulator for transition from alpha to beta version of the product. It is expected that learning outcomes will not be documented until 2017.

3. Create close industry ties through blended learning opportunities for students.

A-Lab Corp. (www.a-labcorp.com)

Sinclair Community College has historically worked with A-Lab, a full-service independent metals testing laboratory. The development of a specific case study in conjunction with an A-Lab affiliated company, L&H Threaded Rods, is being considered to provide additional context for

students. L&H Threaded rods is a major producer and distributor of threaded rods and U-Bolts. Primary products are truck and trailer U-Bolts. Providing an overview for the entire manufacturing process including the cold-forming and subsequent testing of a product that students are somewhat familiar with would help students see the ‘big picture’ for a manufacturing company and better understand how standards and testing are important components of the whole. A final step in their production process is available at: <https://www.youtube.com/watch?v=ow7XsE58ZrY&feature=youtu.be>

American Testing Services (americantestingservices.com)

Sinclair Community College became familiar American Testing Services as a result of working with partner high school Chaminade-Julienne. American Testing Services began as a small non-destructive testing facility in Dayton, Ohio, offering liquid penetrant, magnetic particle, conventional radiography, ultrasonic (contact method only), and visual inspections. Additionally, given their NDT roots, American Testing has established a unique niche market in testing for amusement parks. Amusement park rides see a combination of stresses and elements unlike any other comparable structures of their size and shape. - <http://americantestingservices.com/industries/amusement-park/#sthash.LU7SHPIG.dpuf> Case studies that provide high student interest are being explored.

4. Disseminate the simulation via faculty development.

Several dissemination opportunities have been identified for faculty, at both higher education programs and at high school PLTW programs. Higher education faculty reviewers have been recruited and have made an initial review of the simulator. In addition to providing excellent feedback for simulator improvement, the faculty are now aware of the project and interested in utilizing the next version of the simulator. A PLTW Summit event is scheduled for March 20-23, 2016. POE Master Teacher meetings will include an introduction of the simulator. Additionally Core Training sessions are being scheduled for summer 2016.

Next Steps

Following the same activity headings, next steps for the project include:

1. Develop a virtual, online tensile testing laboratory simulation.

Feedback from reviewers will be incorporated into the next version of the simulator. Instructor and Student Guides will be updated to include all of the screen captures/text as an appendix. The guides themselves will be condensed.

2. Conduct research to compare the costs and learning outcomes for using on-site tensile testing equipment compared with an online simulation.

Cost analysis will be expanded to incorporate maintenance costs. Learning outcomes pilots will be conducted with local high school students in preparation for full outcomes study spring, 2017.

3. Create close industry ties through blended learning opportunities for students.

Compare development ideas for best blended learning case study. Initiate development with testing services partner.

4. Disseminate the simulation via faculty development.

Continue dissemination activities at appropriate conferences including ASEE and ASME events.

Obtain feedback from PLTW training activities for 2017 training network improvements.

Complete project assessment and evaluation.

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ⁱⁱⁱ Sitzmann, T. (2011). A meta-analytic examination of the instructional effectiveness of computer-based simulation games. *Personnel Psychology*, 64(2), 489-528.

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^v Evidence-centered Design of Epistemic Games: Measurement Principles for Complex Learning Environments. University of Maryland. Finn, C. Jr. and Fairchild, D., Editors. (2012)

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