# Virtual Materials Testing

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# Virtual Online Tensile Testing Strength Simulation

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**Introduction**

One of the challenges of educating high school students about tensile strength testing is the lack of available equipment or the non-systematic approach to teaching. It was postulated that an online virtual simulator may address the issue. This research study was a collaborative effort that focused on the development and implementation of an open source, online virtual tensile strength testing simulation designed to emphasize the equations used as part of tensile testing. The created module from this project was 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. The research question being addressed: *Can an online learning simulation be effective for tensile testing instruction?*

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 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 with the ability to interpret the resultant stress-strain curve can apply mathematical concepts of graphing, predicting and applied knowledge of material properties to their potential understanding and application of the engineering design process. Our developed simulation was designed to focus on and exploit these concepts.

The PLTW national office did an extensive search to locate existing virtual tensile strength simulators. They discovered the most critical flaw of existing student-focused simulators; students are not required to do calculations as part of the simulation. In addition, many simulators are inaccurate or incomplete, and do not adequately support student learning or provide a comprehensive learning experience. The more robust commercial simulators were discovered to be 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.

In summary, current simulators are either too simplistic, inaccurate, or too complex to meet the needs of the target audience. Our cost effective, educationally sound alternative proved to be valid and effective for tensile testing instruction. Through data collection and analysis, we compared pre-test and post-test results of 96 confirmed participants. The results indicated a significant improvement when comparing the pretest results (mean score of 53.16) with the posttest results (mean score of 72.42, out of 80).

**Theoretical Framework**

There are many models of simulation based on the singular premise that student learning will be enhanced via relating experiences (e.g., experiential learning) (Jeffries & Rogers, 2007). Appropriate assumptions of experiential learning considered for our framework included: (1) ideas are not fixed and absolute, but reiterative through experience and (2) learning should be considered a process where concepts are derived from, and continuously modified by, experience (Kolb, 1984). Consequently, any implementation of simulation could be considered an attempt at providing experiential learning experiences. Implementing a learning simulation framework generally presumes individuals will differ in skill levels with differing needs for engaging in simulation (Harris, Eccles, Ward & Whyte, 2012). Furthermore, a simulation experience should provide an environment that is interactive and learner-centered (Jeffries, Rodgers, & Adamson, 2015). Considering these parameters, a simulation was the core of instruction for the tensile strength, as an effort to improve learning, engage students, and provide a blend of individual and collaborative work (Rupp, Gushta, and Mislevy, 2009). Research indicates when a simulation is embedded as a form of instruction, better outcomes are achieved than when it is used merely as a standalone simulation. When simulations are used as a supplement to other instructional methods, the simulation group had higher knowledge levels in comparison (Stizmann, 2011).

A meta-analysis (study of studies) conducted of 55 research papers related to the use of simulations indicated that a simulation can help trainees achieve a higher confidence in applying learning from a training session to a job situation when the training is simulation and/or game-based (Sitzmann, 2011). The meta-analysis reveals that people participating in a simulation learning experience have higher declarative knowledge, procedural knowledge, and retention of training material than those people participating in more traditional learning experiences.

Examining the effectiveness of online simulations related to comparison groups 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. Our designed and developed tensile strength simulation has the foundational elements to improve learning, enhance user engagement, and motivate learners while improving learning rates and knowledge retention. This project can provide fundamental improvements in teaching and learning with technology through a comprehensive assessment of student learning. Although our model 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.

**Development | virtual online tensile testing simulation**

The tensile strength simulation was developed in conjunction with Bloomsburg University's Institute for Interactive Technologies (IIT) located in Bloomsburg, PA.

The Tensile Strength Simulator has three instructional modes to provide the maximum instructional benefit (*figure 1*). The first mode, the Demonstration Mode (*figure 2*), provides an overview of the entire procedure for testing materials. Learners observed the placement of the materials within the simulator and how the test is conducted. The mode also provided results and explained to the learner the relationship between the applied force, or load, and the elongation of the specimen. Graphed data and information was provided.


Figure 1. Three instructional modes

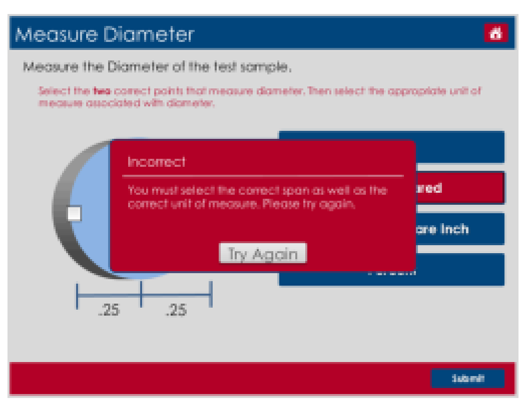


Figure 2. Demonstration mode

The second mode, the Practice Mode (*figure 3*), guides the learner 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 corrective feedback. The intent is to engage the learner in *deliberate practice* (Ericsson, Krampe, & Tesch-Römer, 1993), which is designed to be more than going through the motions. Designed deliberate practice provided opportunities for learners to appropriately develop skills through engaging in tasks and situations relevant to the domain of interest (Harris *et. al*, 2012).

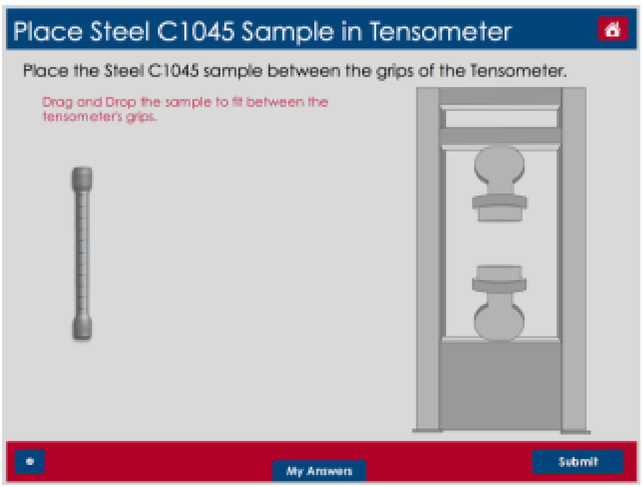


Figure 3. Practice mode.

Finally, the Performance Mode *(figure 4)*, learners received no guidance or assistance from the simulation. Learners must know what to do. Each step in the procedure is evaluated by the simulation and, at the end of the testing procedure, the learner was evaluated and given a score.


Figure 4. Performance mode.

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 allowed for an effective and timely transfer of knowledge, as the instruction will be targeted specifically to the level of knowledge of the learner, from low-level (demonstration mode) to high level (performance mode) (Harris *et al.*, 2012).

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

- A User's Manual 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 presents questions and provide an opportunity for student note taking.

**Research | virtual online tensile testing simulation**

The research analyzed the impact on student learning of the sequence of instruction in the three modes, demonstration, practice, and performance. While researching the instructional effectiveness of the simulation, the project team investigated the learning outcomes (declarative knowledge, procedural knowledge, retention) through a provided pre- and posttest.

There were both collegiate and high school faculty participants. One of the faculty participants was from Sinclair Community College; the other faculty participants were recruited through the listservs of the Engineering Technology Division of the American Society for Engineering Education (ASEE) and American Society of Mechanical Engineers.

The high school faculty participants were all Project Lead The Way instructors in Ohio, certified to teach Principles of Engineering (**POE**). Two Columbus Ohio PLTW schools, Columbus Metro High School and Worthington Kilbourne High School, were selected and agreed to participate.

To determine if students learned subject matter content from the simulation, a pre/posttest instrument was administered. The pre/posttest was developed jointly with Project Lead The Way and the project team to ensure the content validity of the questions. There were 376 recorded student participants that used the virtual online tensile strength testing simulator. Of the 376 student participants, 96 completed both the pretest and posttest.

**Results**

The module was made available to interested participants on October 19, 2016 through the web link http://www.iitcf.bloomu.edu/tensile/ (*figure 5*) where the Pre-Test, Post-Test, and Tensile Strength module were accessible after the user logged in (*figure 6*). To make the process more efficient, Instructors and students were provided separate username and passwords to organize the accessibility of the provided instructional facilitator guides. At each section, instructions were provided to clarify purpose and clarity to the user (*figure 7*). This study relied on pretest-posttest scores on an 8-item assessment on both the procedural elements and equations of the Tensile Test.


Figure 5. Instructor/Student Login.


Figure 6. Index page after login.

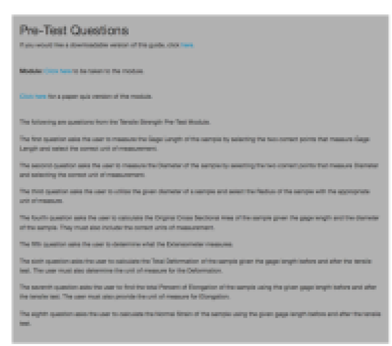


Figure 7. Instructions for use of use.

Data collection procedures were put in action through JavaScript that recorded the results of Pre-Test and Post-Test and a PHP code that sent captured results to a secure (login/password required) Google Spreadsheet. The Pretest was to be taken prior to the start of study to determine prior knowledge of terms and concepts related to the Tensile Test. Participants were then tested again, with the same questions, after they completed the online simulation; same conditions applied. The time between tests varied pending the time provided to the students. Some reported scores (JavaScript captured timestamp at time of submission) the same day, but others had several days between completion of each. The results of these tests were then compared to determine study significance. A paired-samples t-test was conducted to compare the scores of each learner for the pre- and post-test. The pre-test mean score was 53.16. points with standard deviation 20.12, while the post-test mean was 72.42 with a standard deviation 10.28 (Table 1), showing a significant improvement ($t = 8.2027$, $p < .0001$) after the experience. These results suggest the online learning simulation had a positive effect on learning.

Table 1: Paired-Samples Statistics

| | **Mean** | **N** | **S.D.** |
|---|---|---|---|
| *Pre-Test* | 53.16 | 96 | 20.12 |
| *Post-Test* | 72.42 | 96 | 10.28 |

**Conclusion**

Current simulators can be too simplistic, too complex, or often inaccurate to meet the needs of the target audience. Our cost effective, educationally sound alternative proved to be valid and effective for users to garner a deeper understanding of learned equations during tensile testing instruction. Through data collection and analysis, we compared pre-test and post-test results of 96 confirmed participants. The results indicated a significant improvement, which we intend to further improve through future iterations. To fully determine the value of this simulation, future iterations will be implemented through a blended approach with a focus on sequencing.

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