USING WEB BASED ANIMATION SOFTWARE WITH ALGORITHMIC PARAMETERS IN ORDER TO SIMPLIFY GRADING WHILE STILL MAINTAINING OVERSIGHT OF THE STUDENT'S WORK

Richard Stanley
Kettering University

Abstract

Animation software for an introductory *Dynamics* course has been developed, which will be a feature of the web-based learning system, WileyPLUS (John Wiley and Sons, Inc. New York). This interactive software is unique because each animation is directly linked to a homework problem and each homework problem is embedded with algorithmically generated values. The animations are hard-coded in Adobe Flash Action Script, so no external computer programs are needed.

The deliverable submitted by the student is a printed "screen-shot" of the problem and the animation, which is paused at the appropriate time and position. Supporting calculations are submitted with the screen shot. The instructor validates the final answers by comparing the variables displayed on the screen shot with the student's calculated values. The instructor ensures that that correct equations and methods were used by examining the supporting work of the student.

A total of 55 students analyzed several pulley system configurations during the fall term of 2008, where the software was used for both in-class demonstrations and homework assignments. An anonymous survey was conducted regarding the effectiveness of the software. The students agree that using pseudorandom variables in the animation program is a better method than using current "fill in the blank" type on-line learning tools. The students' understanding of pulley systems was significantly improved by using the program. They consider the software easy to use and recommend it to instructors who teach introductory *Dynamics* classes.

In this paper, the software functionality will be briefly explained. The results of the assignment will be detailed, along with a representative example of a student's work. Additionally, pedagogical advantages will be clarified via survey results and the comments of students.

Introduction

In typical *Dynamics* courses, most homework problems require the student to solve for a given variable at an instant in space and time. The professor typically assigns a set of homework problems and the students solve each problem by hand. The student knows that his or her calculations are correct by checking answers in the back of the book.

In reality, the subject of particle *Dynamics* is the study of motion and not the calculation of a particle's point at a particular instance in time. This differentiation is probably lost in the traditional classroom. It is the author's opinion that computer animations are necessary in order for the students to fully understand the "time and space" nature of the subject of *Dynamics*.

The animation of *Dynamics* problems can be done via several commercially available software programs[1,2]. Animations created by these software packages can be converted into computer- based movies, which can be played on any computer. For interactivity, though, the software must be loaded on the user's computer, which can be expensive and inconvenient. If a professor wants to use any of these software packages to create interactive *Dynamics* animations, he or she must take the time to create each individual problem, which can be overwhelming.

Web based interactive animation software has been developed in the recent past by creating Java Applets or by writing computer programs in Adobe Flash Action Script.[3,4,5,6,7,8,9,10] These animations can run on any web browser, but none of the animations referenced 1) are directly linked directly to homework problems, or 2) contain variables that are created by a pseudorandom variable generator. As of this date, no comprehensive and interactive web-based animation software for educators has been developed on a mass scale (probably due to cost[11,12,13]).

Previous papers have been published regarding the advantages of the animations software presented in this publication. These advantages include[1,2]:

- There is no software to install.
- The animations can be played on virtually any computer; the Adobe Flash Player is installed on 98.8% of internet-enabled desktops worldwide[14].
- Each animation is directly linked to a homework problem or sample problem in the text.
- There is absolutely no programming required of the user.
- The software is extremely easy to use; the controls are similar to those of a DVD player.
- Because the program is “hard-coded” in Adobe Flash Action Script, there is an abundance of control in the advancement of the software package.
- The cost and time of development is relatively low because all images are duplicated directly from the textbook and intricate graphics and backgrounds are not included in the animations.

Additional improvements and additions to the software, which will be discussed in this paper, are:

- Select variables are embedded in the problem statement and the animation via a pseudorandom variable generator, which has been developed by the author in JavaScript, Adobe Flash ActionScript, and Extensible Markup Language (XML).
- A new category of problems has been created: pulley systems.

Software Intent and Audience

It must be emphasized that the software is not intended to eliminate the grading of homework for the professor.

The primary objective of the software is to increase the engineering student’s fundamental understanding of the subject of *Dynamics* via a user friendly, cost effective, and readily available web-based interface.

The principal audience is composed of educators who wish to enhance their students’ overall comprehension of *Dynamics* via simulations.

Explanation of the Software: Pulley Systems

Each homework problem is displayed in a single web page, which is composed of three sections (Figure 1). The problem statement is displayed in the left section, the center portion holds the animation, and the right side provides the student with an explanation of what is required of him or her in the current assignment.

There are many categories of particle kinematics and kinetics problems that are included as part of the main animation package; many homework and example problems are included in each category[1,2]. Categories include, for example:

- <u>2D-XY Kinematics:</u> Two Dimensional (2-D) Kinematics in the Rectilinear Coordinate System (C.S.)
- <u>2D-nt Kinematics:</u> 2-D Kinematics in the Normal-Tangential C.S.
- <u>BLOCK-RAMP Kinetics:</u> Kinetics of a Block Sliding Up/Down a Ramp (with friction)

- PULLEY: Kinetics and Kinematics of Several Types of Pulley Systems

Pulley systems with mechanical advantages of one, two, three, four, and five have been recently developed. For the purposes of this paper, a pulley system with a mechanical advantage of two is explained (Figure 2). The problem statement and corresponding animation contain several pseudo arbitrary values: the weight of the piano, the weight of the anvil, and the distance traveled by the piano.

The ranges and precisions of the pseudo random variables are stored in an external XML file (Figure 3). For example, the variable V00 corresponds to the weight of the piano. V00 can vary from a low value (varLow) of 400 lbs to a high value (varHigh) of 850 lbs, with a precision (varPrec) of 0. The weight of the piano (constrained by the values of V00) is seamlessly converted to its mass, which has a precision (varPrec_1) of 3. Similarly, the variables V01 and V02 represent the weight of the anvil and the distance traveled by the piano, respectively. By using an external XML file, the variable ranges and precisions can be dynamically changed at any time by the developer or by the professor.

Figure 4 is a screen shot of the animation at the instant the web page is loaded. Notice that the masses and calculated weights of the anvil and piano are automatically transferred from the problem statement into the animation (compare Figures 2 and 4).

Figure 5 is a screen shot of the animation with the anvil's variables enlarged. The variables box contains two sets of variables. INPUT variables may be changed by the user. OUTPUT variables change with time. OUTPUT variables may be added or deleted by the user, if desired. Variable units and definitions can be displayed by hovering the mouse over any given INPUT or OUTPUT variable. (Details are available in[1,2].)

And finally, the SETUP section resides on the right hand side of the web page, which is used to let the student know how to proceed with the animation program. The SETUP section also explains what deliverables are required of the student. (Figure 6).

Problem Solving

The problem shown in Figure 2 was given as part of an assignment to 55 students in *Dynamics* during the fall term of 2008. The following section provides 1) a sample of a single student's work and 2) the results of the class as a whole.

Sample of a Single Student's Work

In the current problem, an 836 lb piano travels upward due to a lighter 515 lb anvil, which is attached to the opposite end of a pulley system (Figure 2). The student is asked how long it will take for the piano to travel upward 5.4 feet, given two scenarios:

- The 515 lb anvil is attached (Figure 2, CASE 1).
- The anvil is replaced by a force equivalent to the weight of the anvil (Figure 2, CASE 2).

The student is then asked to explain why there is a difference in the two cases.

STEP 1: The student solves CASE 1 by hand and finds that it will take t = 2.238 seconds for the piano to travel upward 5.4 feet (Figure 7: **CALCULATED TIME = 2.238 sec).**

STEP 2: The student runs the animation with its default values and pauses the animation once the piano has traveled upward 5.4 feet. He verifies his answer of t = 2.238 seconds (Figure 8: **ANIMATION TIME = 2.238 sec).** He then prints a screenshot of the problem and the animation.

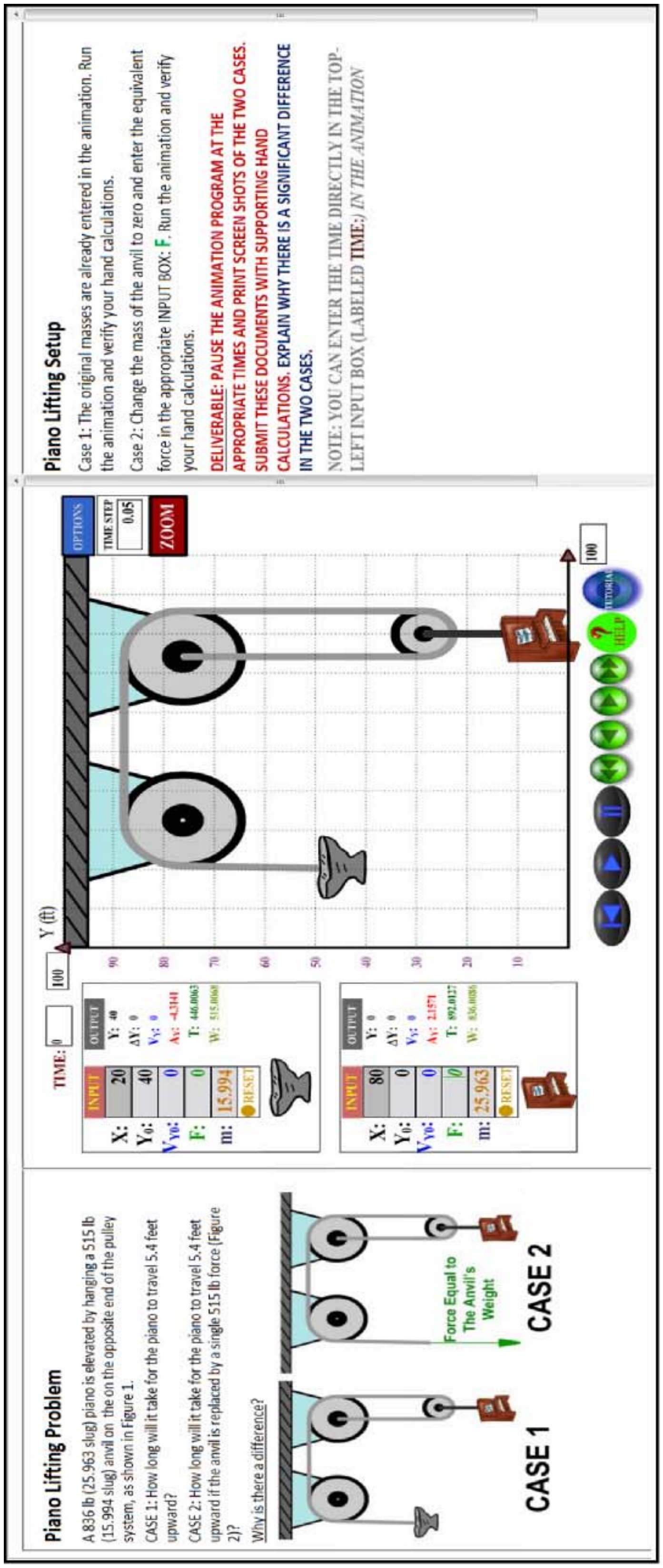

Figure 1. Full Screes Shot: Sample Pulley Problem.

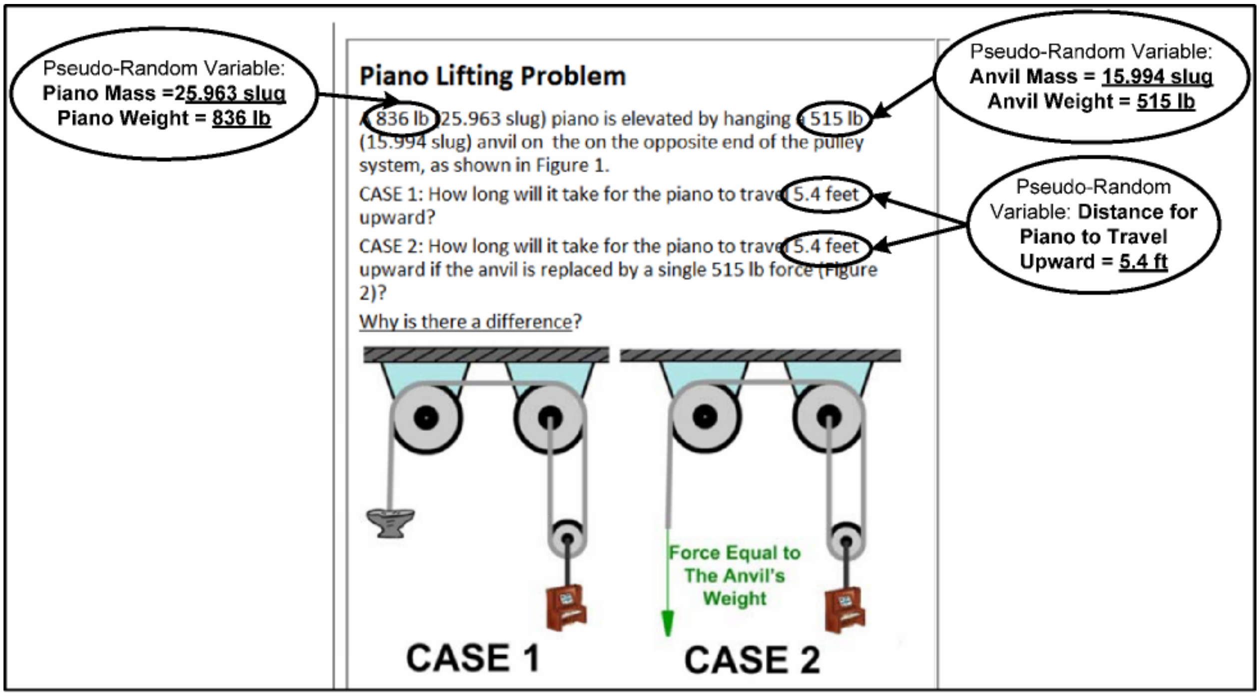

Figure 2 Problem Statement.

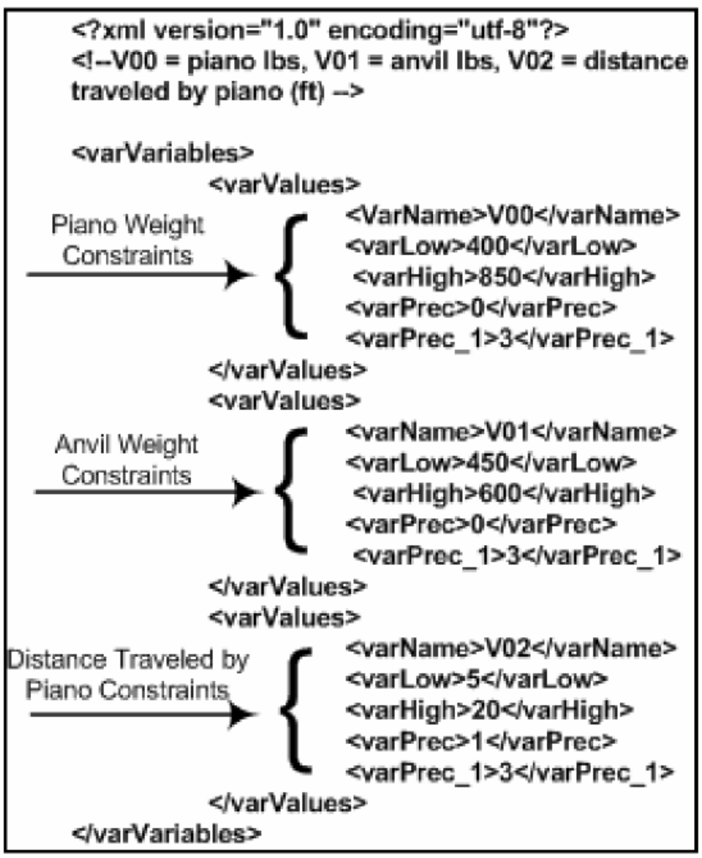

Figure 3 External XML File.

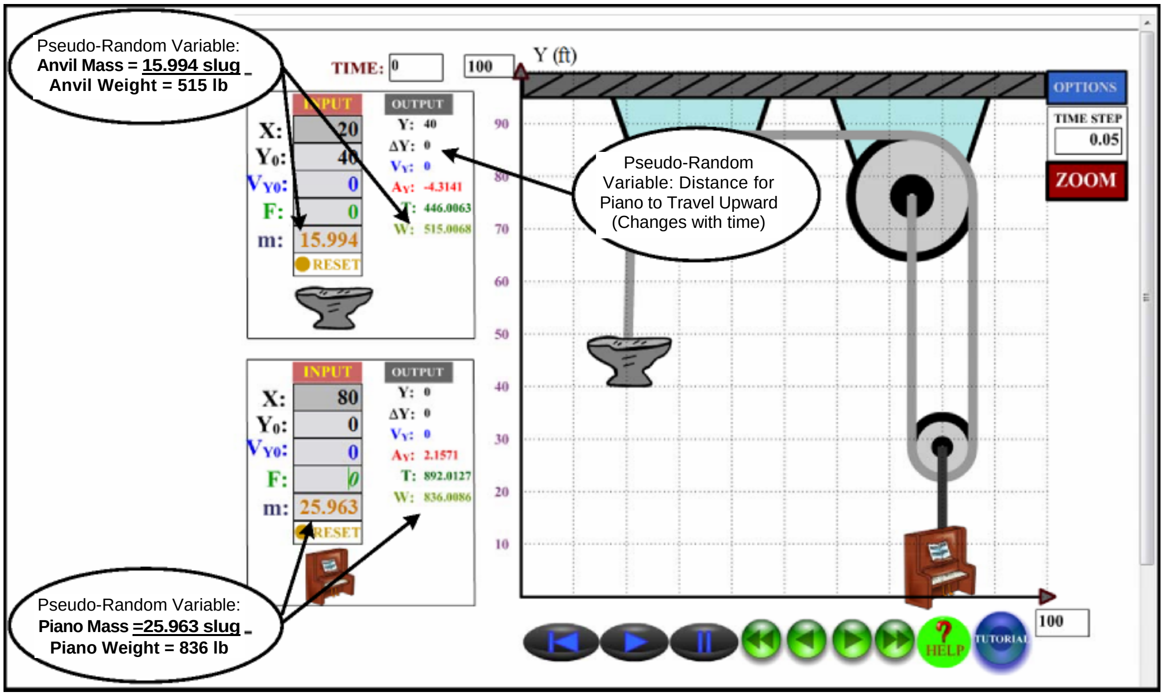

Figure 4. Animation at time = 0 seconds.

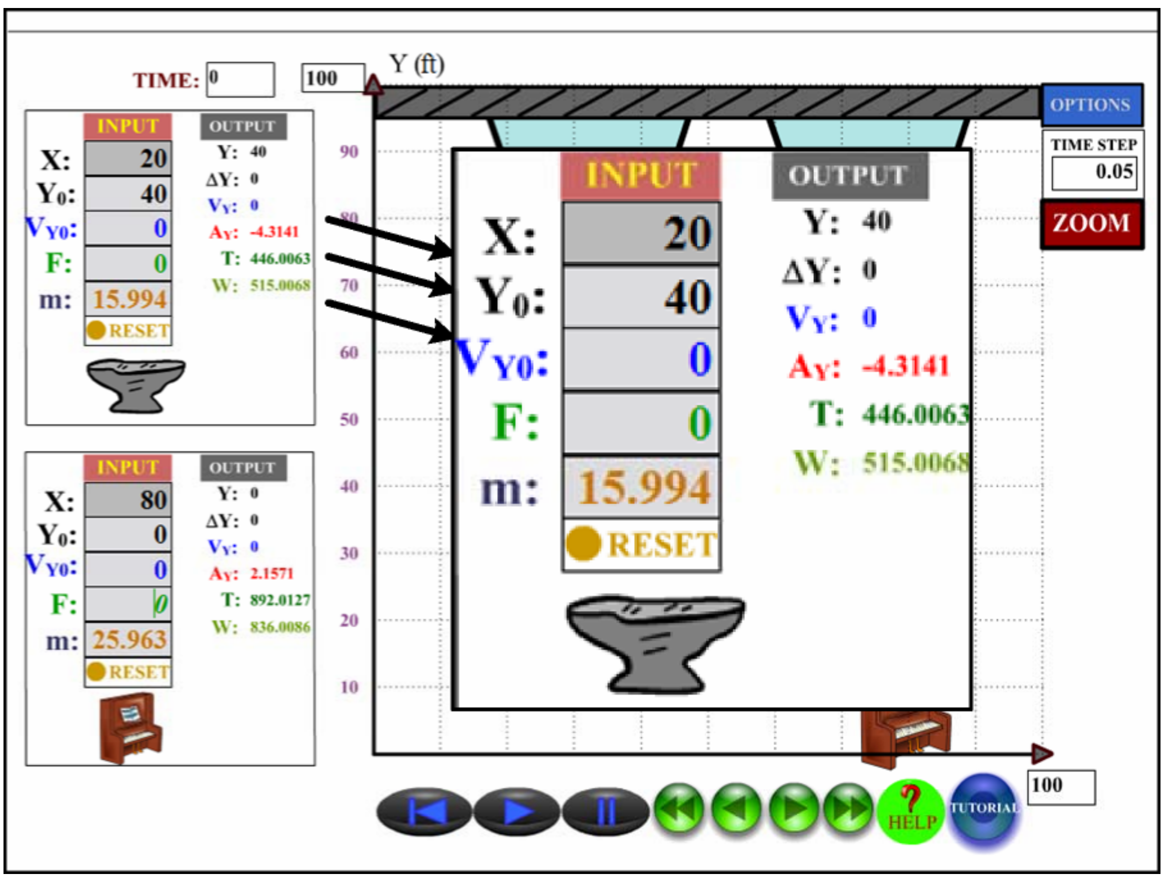

Figure 5 INPUT and OUTPUT Variables of the Anvil.

Piano Lifting Setup

Case 1: The original masses are already entered in the animation. Run the animation and verify your hand calculations.

Case 2: Change the mass of the anvil to zero and enter the equivalent force in the appropriate INPUT BOX: **F**. Run the animation and verify your hand calculations.

<u>DELIVERABLE</u>: PAUSE THE ANIMATION PROGRAM AT THE APPROPRIATE TIMES AND PRINT SCREEN SHOTS OF THE TWO CASES. SUBMIT THESE DOCUMENTS WITH SUPPORTING HAND CALCULATIONS. EXPLAIN WHY THERE IS A SIGNIFICANT DIFFERENCE IN THE TWO CASES.

NOTE: YOU CAN ENTER THE TIME DIRECTLY IN THE TOP-LEFT INPUT BOX (LABELED TIME:) ***IN THE ANIMATION***

Figure 6 Setup.

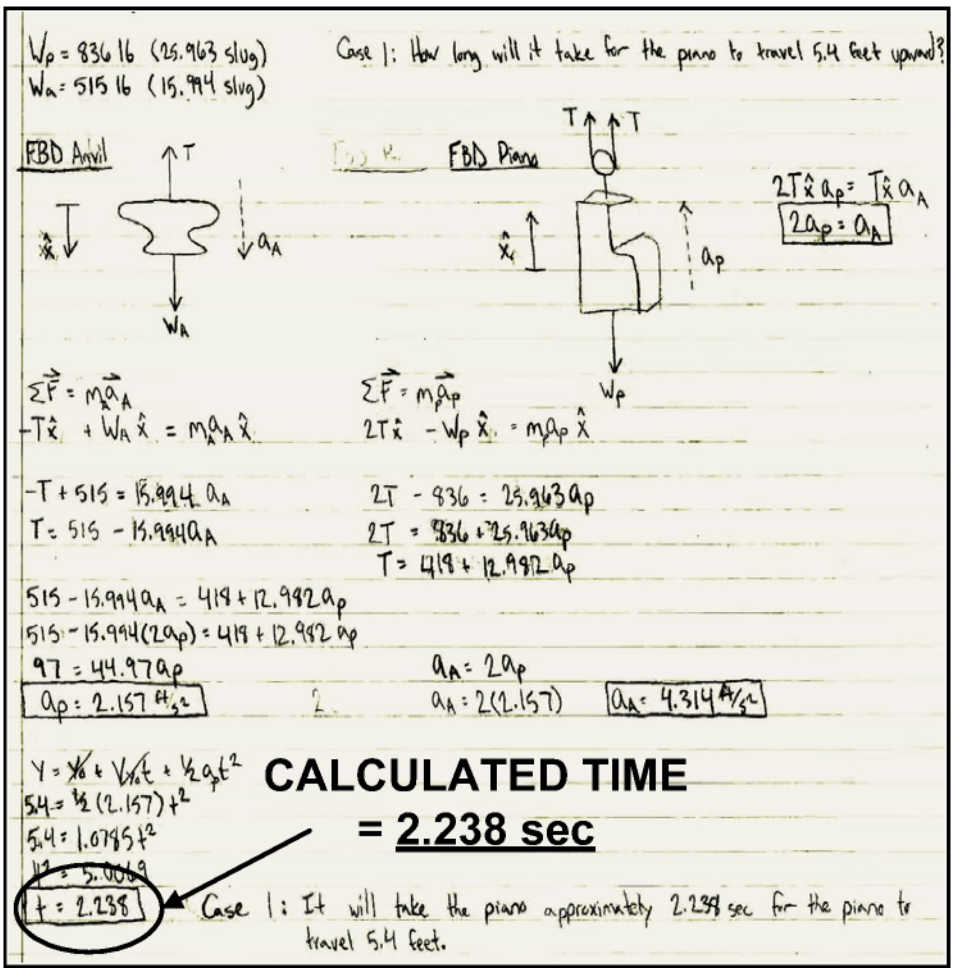

Figure 7. Student Calculations: CASE 1.

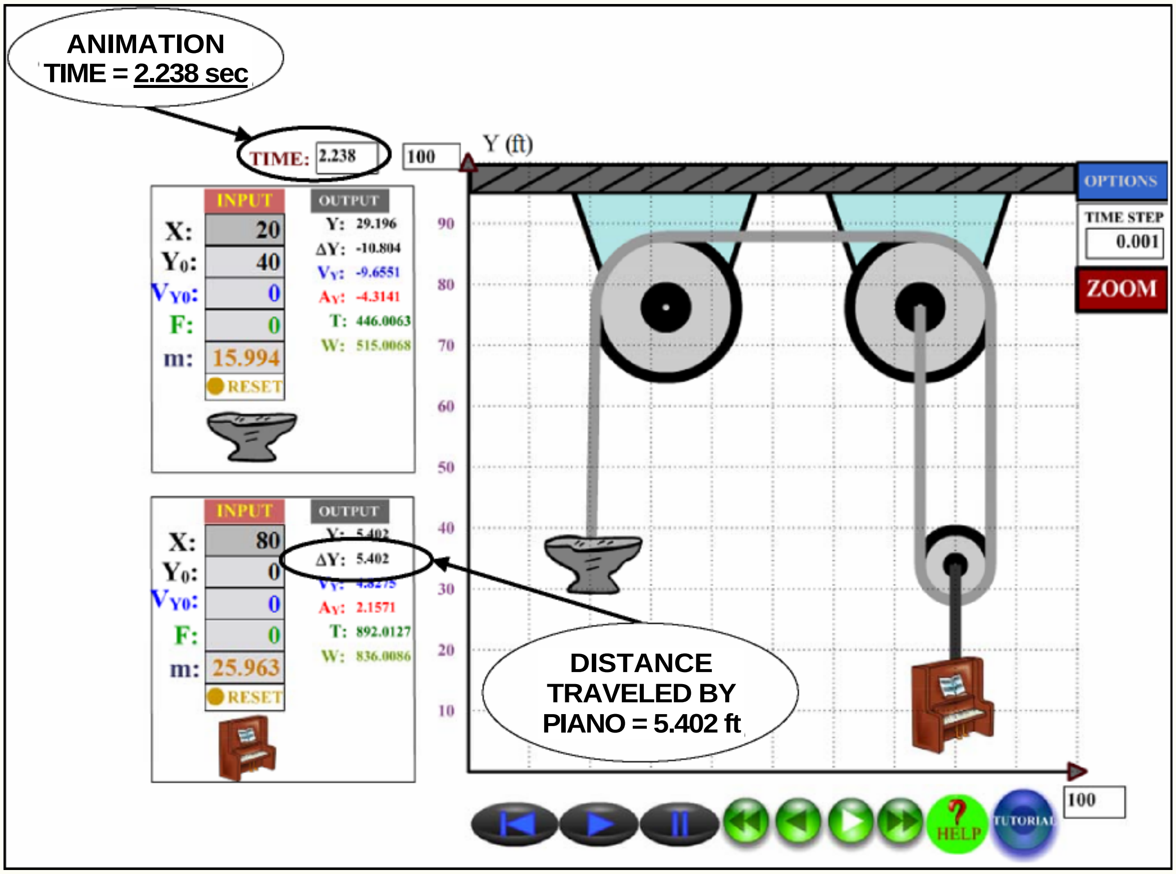

Figure 8 Animation Paused When the Piano Has Traveled ~ 5.4 Ft Upward (CASE 1).

STEP 3: The student solves CASE 2 by hand and finds that it will take only t =1.202 seconds for the piano to travel upward 5.4 feet when the anvil is replaced by an equivalent force. (Figure 9: **CALCULATED TIME = 1.202 sec**).

STEP 4: The student changes the mass of the anvil to 0 slugs and its corresponding force to 515 pounds. He runs the animation and pauses it when the piano has traveled upward 5.4 feet, verifying his answer of t = 1.203 seconds (Figure 10: **ANIMATION TIME = 1.203 sec**). He prints a screenshot of the problem and the animation.

STEP 5: The student explains in plain terms why the piano accelerates less when pulled by the weight of an anvil as opposed to being pulled by the anvil's equivalent force.

STEP 6: The student submits the assignment and the professor checks both the final answers and the corresponding calculations.

Example Problem Results and Discussion

The problems submitted by the 55 students were graded. Following are the results and some comments.

1) Almost all of the students correctly solved for the time for the piano to travel the necessary distance (in both CASES: 1 and 2).
2) Approximately 75% of students answered the qualitative question correctly: "Explain why there is a significant difference in the two cases?"

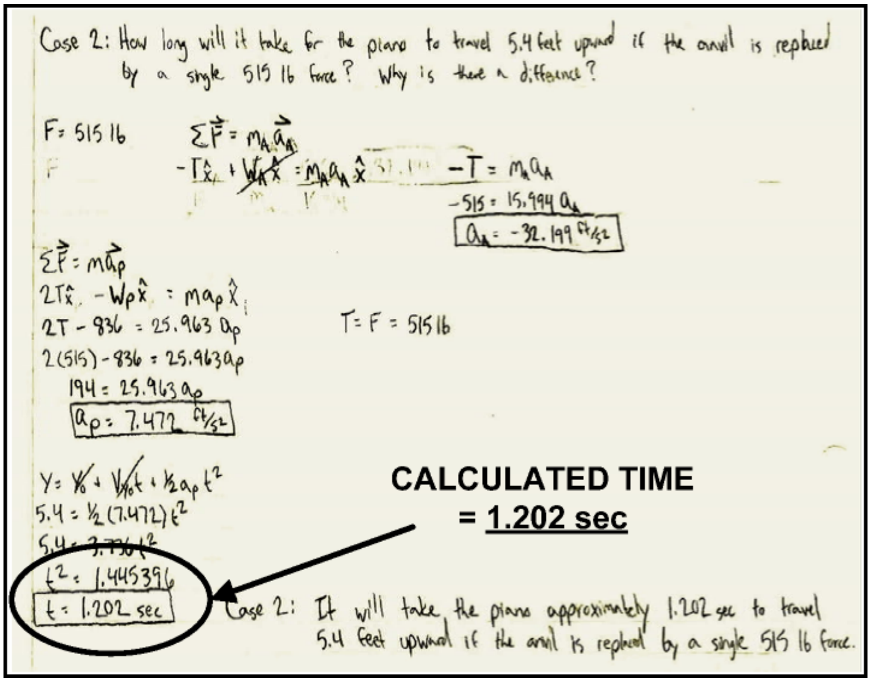

Figure 9. Student Calculations: CASE 2.

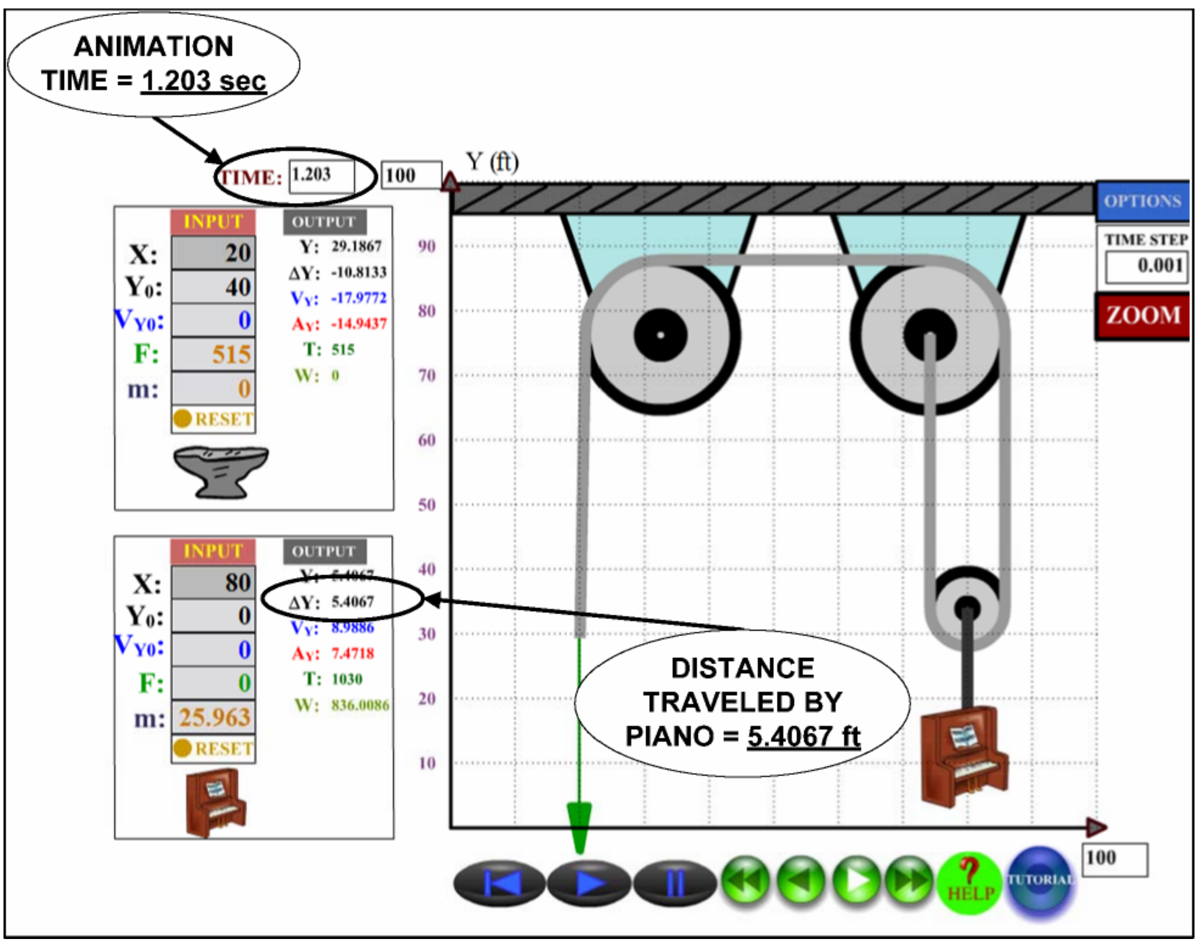

Figure 10 Animation Paused When the Piano Has Traveled ~ 5.4 Ft Upward (CASE 2).

Representative correct answers:

- "The smaller time is due to the fact that there isn't the mass of the anvil to accelerate."
- "The answers are different because the mass of the system is different, resulting in a different tension."

Representative incorrect answers:

- "Because there is no weight in a force."
- "This occurs because CASE 1 includes the weight of the anvil." (incomplete answer)

3) It took approximately 15 minutes to grade the 55 problems.

From the above, it can be concluded that:

1)Most of the students understand how to calculate basic dynamic parameters of pulley systems.
2)A majority of the students have a qualitative understanding of how the inertia force affects the motion of the components in a pulley system.
3)Even though grading of these assignments is not automatic, the amount of time required for grading assignments is reasonable.

Comparisons to Current Web-Based Products

There are several commercially available packages that provide algorithmic variable generation in homework problems and quizzes[15,16,17]. The software explained in this paper is compared to these packages in the following paragraphs (reference Figure 11).

1) **Automatic Grading:** ***Less Effective***: Conventional software packages provide an inherent incentive for professors to assign graded homework, due to automatic grading. The ability to have homework graded automatically adds little or no extra time to the workload of the professor. The animation software is less beneficial because its focus is not the student's calculation of the final answer.
2) **Pseudo-Random Variables:** ***Equally Effective***: Both the animation software package and current web-based software packages provide pseudo random variable generation.
3) **Does Not Rely on Final Answer:** ***More Effective***: Modern web-based programs focus mainly on the student finding the correct answer. In contrast to this, this paper illustrates that the problem solving process is an integral part of the grading process with the animation software package.
4) **Shows a Student "How Wrong" an Answer Might Be:** ***More Effective***: Current web-based packages do not inform the student "how wrong" his or her answer may be when a mistake has been made. The animation software provides students with visualization of "how incorrect" his or her answer might be.
5) **Shows Dynamics Behavior of a Particle:** ***More Effective***: Current web-based software does not provide the student with a simulation of a particle in motion. The animation software clearly illustrates a particle's dynamic behavior

Student Surveys

The animation software was used in two sections of *Dynamics* at Kettering University (Flint, MI) during the fall term of 2008. A total of 55 students were surveyed at the end of the term regarding the effectiveness of the software. The students surveyed were assured that their answers would remain anonymous.

Questions from three categories were asked.

1) Opinions Regarding Pseudo Random Variables: Observations of how the use of pseudo random variables as a part of the animation program is an advantage to the student.
2) Pulley Concepts: How the software enhances pulley concepts.
3) General Opinions: How animation software enhances the overall learning of the student.

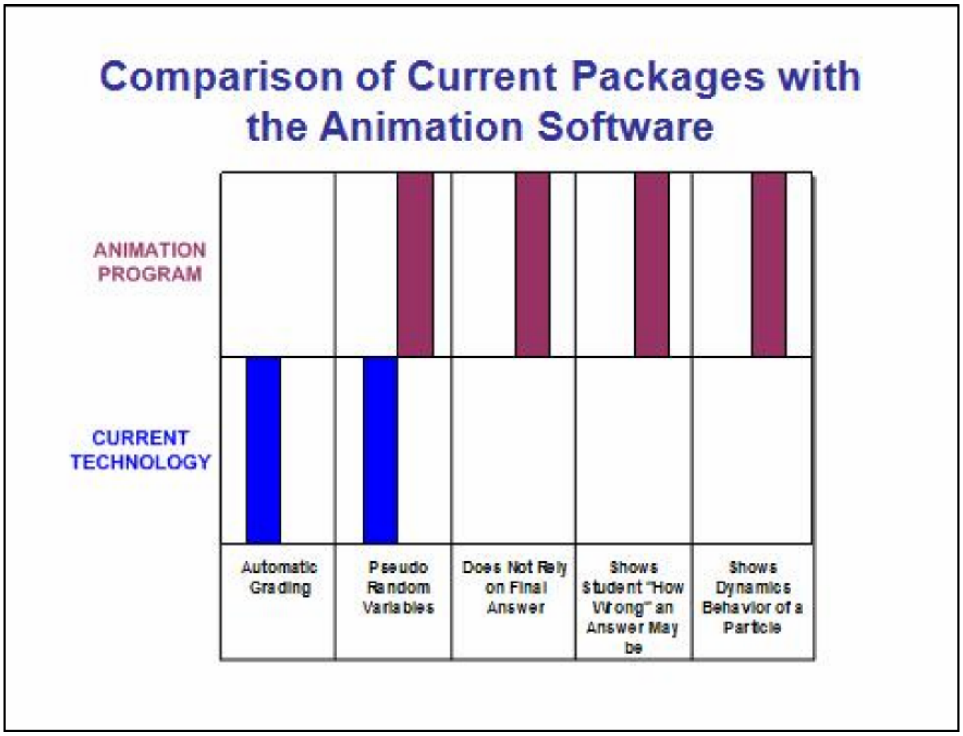

Figure 11 Software Comparison.

Survey Results: Opinions Regarding Pseudo Random Variables

Approximately 70% of the students surveyed had used web-based "fill in the blank" type software in previous classes. Two questions were asked of this group. According to the results shown in Figures 12 and 13:

1) Almost 90% of students surveyed agree that the use of pseudo random variables is an effective way to use the software (Figure 12). Some student comments are:
   - "Keeps students from copying directly. Still can copy processes, but must perform calculations."
   - "They help increase the independence of the assignment, requiring students to do the problems individually. If students work in teams it requires the problems to be done symbolically, which enhances understanding."

3) Almost 95% of students surveyed agree that the animations program is superior to traditional "fill in the blank" type web based systems (Figure 13). Some student comments are:
   - "When working through problems for a fill-in the blank solution, lack of visuals can cause misinterpretation of the question. The animations program still requires that you work through the problem to obtain a solution, but you can also verify if the answer obtained is correct or not. The animations program allows you to test what would happen if certain variables were changed which enhances the overall learning."
   - "With fill in the blank problems you can not see what went wrong, with the animations program you can actually see how every variable affects the problem.

The above comments and survey results reinforce the opinions of the author, as stated previously in this paper.

Survey Results: Pulley Concepts

A great deal of effort has been spent by the author by developing a new category of animations: PULLEYS. This category was developed because pulley systems tend to be

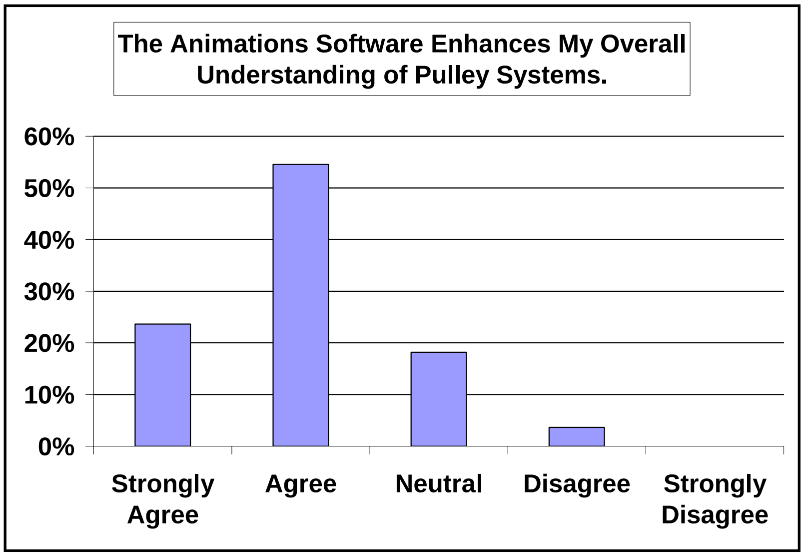

Figure 12 Survey Results: Question #*1*.

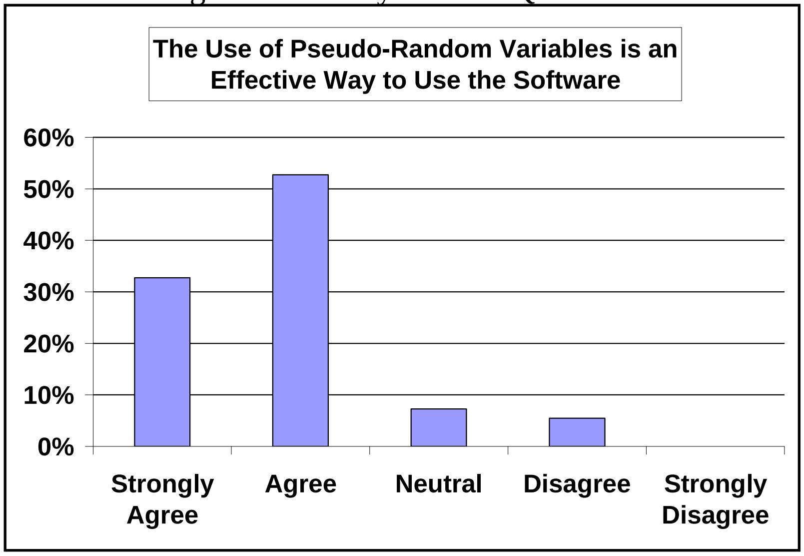

Figure 13 Survey Results: Question #2.

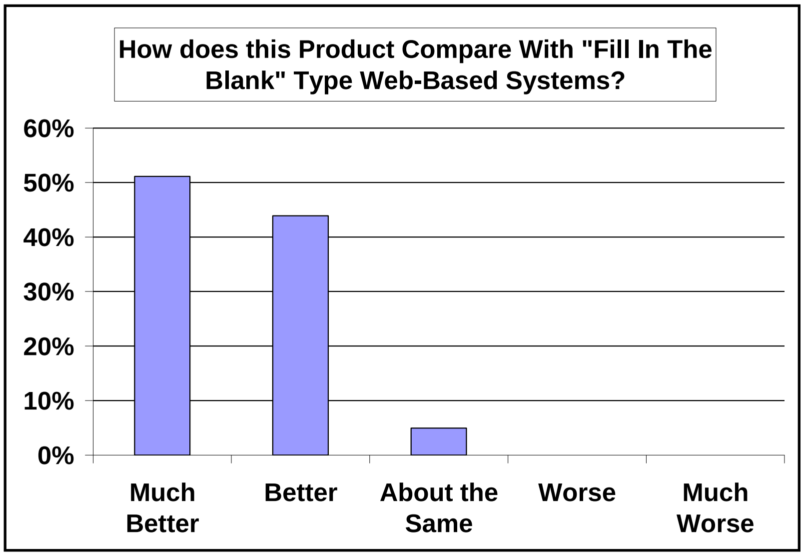

Figure 14. Survey Results: Pulley System Comprehension.

difficult to explain to introductory *Dynamics* students. It is the author's view that that animations would help students understand pulley systems better. According to the survey, the animation program helped approximately 80% of students understand the concept of pulley systems (Figure 14).

Survey Results: General Opinions

It is the author's opinion that animations are useful teaching tools that will be used more frequently in the classroom. Questions were asked of the students in order to validate this opinion. The results of this survey were in agreement with those found in previous publications.[1,2]

1) All students surveyed are visual learners.
2) Virtually all students believe the following:
   a. Animations will be used in future engineering disciplines.
   b. Animations enhance the student's overall understanding of particle kinematics and kinetics.
   c. Animations give students a reality check regarding how correct or incorrect an answer may be.
3) Students believe that linking a homework problem to an animation is effective.
4) Students think that the software is easy to use and that it makes learning fun.
5) Students recommend the animation program to instructors who teach Dynamics.

Conclusions

The animations program originally explained in[1,2] has been enhanced by embedding pseudo random variables in the problem statement, which are seamlessly transferred to the animation. An example of how the professor can use the program for homework has been explained with a student sample.

1) It has been emphasized that the animation software primary function is to help the student appreciate and understand *Dynamics* concepts more completely; the animation program is not meant to be a means of simplifying the grading of homework assignments.
2) Combining pseudo-random variables with the animation program is a superior web-based learning tool for the following reasons:
   - Using random variables forces the students to solve the problems symbolically, thereby increasing the fundamental understanding of the problem. This instills that students must learn the problem solving process.
   - When the incorrect answer is calculated by the student, he or she is informed visually of "how wrong" his or her answers might be.
   - The student observes a particle behaving dynamically, so he or she does not lose sight that the subject of *Dynamics* is the study of motion.
   - The pseudo random variable generator lowers the possibility of cheating.
3) A new category has been developed: PULLEYS. Most students' fundamental understanding of pulley systems has been enhanced by using the animations software.
4) Although it is not direct evidence that the animations program helped students solve pulley system problems, most student who completed the pulley assignment:
   - Understand how to calculate basic dynamic parameters of pulley systems.
   - Have a qualitative understanding of how inertia forces affect the motion of the components in a pulley system.
5) The animation software is extremely easy to use and absolutely no programming is required
6) The animation program is unique in that each animation is linked to a homework or example problem; students unanimously support this way of utilizing the software.
7) Students overwhelmingly recommend the software to professors who teach the subject of *Dynamics*.

Future Considerations

1) Downloadable EXCEL files will be available, which can be used to graph time-based data and parametric studies.
2) Studies will be conducted with peer institutions that objectively measure the student's performance with and without the use of the software.

Bibliography

1. Stanley, Richard, "Interactive Web Based Animation Software: An Efficient Way to Increase the Engineering Student's Fundamental Understanding of Particle Kinematics and Kinetics", Proceedings of ASEE Zone 1 Conference, West Point, NY, March, 2008.

2. Stanley, Richard, "An Efficient Way to Increase the Engineering Student's Fundamental Understanding of Particle Kinematics and Kinetics by Utilizing Interactive Web Based Animation Software", ASEE Computers in Education Journal, Vol. 18, No. 3, pp 23 – 41, Jul-Sep, 2008.

3. Philpot, Timothy A., et al, "Assessment of Interactive Courseware for Shear Force and Bending Moment Diagrams", ASEE Annual Conference Proceedings, 2005.

4. Philpot, Timothy A., et al, "Teaching the Superposition Method with Internet-Based Instructional Software", ASEE Annual Conference Proceedings, 2004.

5. Philpot, T. A. and Hall, R. H., "Comprehensive Evaluation of Animated Instructional Software for Mechanics of Materials", Proceeding, 34th ASEE/IEEE Frontiers in Education Conference, October 2004.

6. Philpot, Timothy A., et al, "Is There a Better Way to Present an Example Problem?", ASEE Annual Conference Proceedings, 2003.

7. Philpot, Timothy A., et al, "Interactive Learning Tools: Animating Mechanics of Materials", ASEE Annual Conference Proceedings, 2002.

8. Fuentes, A. and Crown, Stephen, "Improving Conceptual Learning in Mechanics of Materials by Using Web- Based Games and the Involvement of Students in the Game Design Process", ASEE Paper # AC 2007-2818.

9. Zheng, H. and Kieth, Jason, "Web-Based Instructional Tools for Heat and Mass Transfer", ASEE Conference Proceedings, 2003.

10. Lumsdale, A., "Multimedia Tutorials for Drawing Shear Force and Bending Moment Diagrams", ASEE Conference Proceedings, 2003.

11. Ziegler, William, "Simulation and Animation of Engineering Systems: No Specialized Software or Programming Required", ASEE Paper # AC-2007-2177.

12. Pixar, http://www.pixar.com/featurefilms/ts/theater/teaser_480.html

13. Reimer, Jeremy, "The runaway costs of game development", ars technnica website: http://arstechnica.com/articles/paedia/hardware/crossplatform.ars/2

14. http://www.adobe.com/products/player_census/flashplayer/

15. WileyPLUS, John Wiley & Sons, Inc.

16. ARIS, McGraw-Hill Higher Education.

17. One Key, Prentice Hall, Inc.

Biographical Information

Dr. Richard Stanley has been a faculty member of the Mechanical Engineering Department at Kettering University (Flint, MI) since July of 1999, where he holds the rank of Associate Professor. He earned his BSME from The University of Michigan in 1990, his MSME from Wayne State University in 1996, and his Ph.D. from Wayne State University in 1998. His primary interest is to develop web-based internet animation software, which can be used to enhance the engineering student's understanding of mechanics principles. He is also the karate and jiu-jitzu instructor at Kettering University, where he incorporates many of the martial arts principles and methods in the classroom.