2006-780: THE EFFECT TECHNOLOGY AND A STRUCTURED DESIGN PROBLEM HAS ON STUDENT ATTITUDES ABOUT THEORY IN A DYNAMICS CLASS

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The Effect Technology and Structured Design Problems Have on Student Attitudes about Theory in a Dynamics Class[1]

Abstract

For many universities, engineering students enroll in Dynamics during the sophomore year and may take the course as a two semester Mechanics sequence: the first semester course has an emphasis on Statics; and the second an emphasis on bodies in motion. Since students in Dynamics typically concurrently enroll in a non-linear differential equations mathematics course, calculations in the Dynamics course are performed for a point in time. Student feedback indicates that some of them struggle with the notion that they are computing time functions at a single point in time. It seems they lose sight of the fact that the mechanism is in motion. Other feedback comments suggest the students also struggle with a lack of motivation for what they are doing. Many students indicate that they do not "connect" the theory presented in lectures to any practical application. To address these issues, a two-component experiment was designed to investigate the effect technology and a simple design problem might have on student attitudes about theory presented in class.

In the first part of the experiment, students were presented with relatively simple dynamics problems that "appear" to have simple behaviors. Problems were presented to the students, and they were asked to make predictions about the associated behavior. After making their predictions, the students were shown the true behavior which is usually different than their prediction. Then they were asked to explain the observation using simple theory that was presented in class. Whenever possible, the instructor used computer simulation to "test" the student theories. Finally, students identified "real world" applications for each phenomenon under study then make similar predictions on similar applications.

In the second part of the experiment, students were asked to perform a simple design. After investigating a device used in factory automation, the students were asked to "design" a force to apply that would make the system run more optimally. The design was structured because the students know they are looking for a force, but it is open-ended because an entire class of forces will satisfy the constraints. Several students approached the design by "guessing" and used the technology to "test." Others realized this behavior would not produce results and began to apply theory covered in class.

This paper presents some of the modules or challenge problems that were used in the course. The authors did not create these problems: they were copied from a number of sources and developed to the point that they have classroom materials associated with them. The paper also presents the design problem and gives a web link to download the modules and the design. The software simulations used in class are described and discussed; and assessment of student attitudes before and after these "interventions" is presented.

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Introduction

Student enrollment in the College of Engineering at the University of Texas El Paso is very healthy. With student demographics in excess of 70% Hispanics and large class sizes, UTEP is one of the largest producers of undergraduate Hispanic Engineers. UTEP graduates can be found in the nation's top graduate schools, in the upper echelons of the nation's leading corporations, in National Laboratories and as entrepreneurs. In Hispanic Business Magazine recently, UTEP was named Number One in the Top Ten Engineering Schools for Hispanics [1]. Clearly, UTEP produces a large number of high quality baccalaureate graduates. Despite these encouraging signs, the authors believe the success rates in lower division engineering courses need improvement.

The concern that the shortage of engineers in the U.S. will not meet the needs of the technological 21st century is well documented in the literature. To exacerbate the situation, attrition rates among the under-represented groups of women and minorities is high. One goal of the authors is to produce even more baccalaureate graduates at UTEP with even better qualifications, faster than ever before. This More, Better, Faster (MBF) goal is being pursued by a number of faculty at various levels of the curriculum. This paper discusses one component of the MBF strategy: the implementation of Real World Software Technology (RWST), tools used by engineers to practice engineering; and structured design problems. The specific implementation was in a required sophomore level "lecture" course on Dynamics. For example, automobile design and test engineers use MSC.Adams to design and analyze suspensions, lifting mechanisms for engine hoods plus many other kinematic/dynamic related problems. RWST is not educational technology (on-line computer based testing, for example); and, therefore, is much more versatile and complex.

Since dynamics is required in the second year of the undergraduate engineering curriculum by all UTEP engineering departments, except Electrical and Computer Engineering/Science, it impacts the majority of the undergraduate engineering students. The average pass rate of students in Dynamics since fall 2000 is 55.3%. Of course, many of the unsuccessful students repeat and pass; but an initial failure certainly slows their progress to graduation. The interventions described in this paper attempt to increase the number of graduates by helping more students learn the concepts in Dynamics so they become successful the first time they take the course.

This paper describes an experiment using RWST in a classroom environment. It is expected that a properly designed curriculum using RWST will increase graduation rates with students better qualified for engineering practice. The rationale is that:

- real tools will provide intrinsic motivation to solving real problems; thereby, retaining more students in engineering by making engineering relevant to them;
- real tools will allow students to thoroughly explore fundamental concepts; thereby, generating a deeper understanding of engineering; and
- real tools will allow students to graduate with more marketable skills.

Due to their power and complexity, RWST is expected to alter the cognitive, emotive and physiological responses of students who are placed in a complex problem-solving environment. To properly design curricula using RWST, these responses must be understood. As an example of this, consider the study by Everett, Alexander and Wienen [2] conducted with 187 students enrolled in an engineering science course that studied conceptually- versus procedurally-oriented students. During the study, two distinct evaluation methods were used: a traditional evaluation focused on procedural analysis and a second focused on conceptual understanding. One result of the study is shown in Figure 1. The abscissa of the figure shows a measure of conceptual performance and the ordinate shows procedural performance. The diagonal lines indicate potential grade breaks that reward individuals who demonstrate both analytical and conceptual understanding. Note that the one individual, marked A, performed poorly along the analytical axis yet scored high along the conceptual. These data suggest students possess differing abilities in at least two knowledge categories.

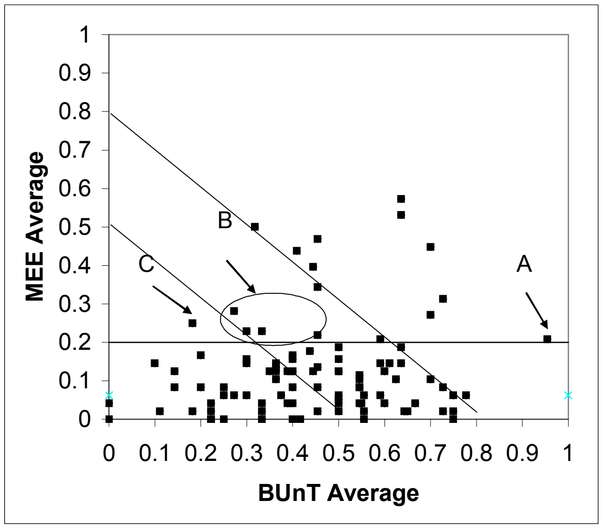

Figure 1 A Comparison Between Conceptual (Abscissa) and Analytical (Ordinate) Performance.

Another purpose of the present work was to investigate the effect of RWST on students who might be more conceptual than procedural with the hope of "turning on" the conceptual students by allowing them to apply "big idea" thinking about problems and allowing the RWST to handle some of the details. The preliminary program described in this paper addresses these issues by trying to assess what the students think about the intervention.

Positive results are not a forgone conclusion. There are some obvious advantages with the use of technology; for example, information technology tools can provide instant feedback to learners [6, 7]. This is generally considered a good thing. In general, use of information technology tools has also helped with visualization of difficult-to-understand concepts [8]. Several studies suggest however that mere presence and use of information technology may not result in learning gains [3, 4, and 5]. Researchers studying human learning conclude that the differentiation of declarative and procedural knowledge and their interaction on human memory and cognition are important issues to study if information technology is to have any beneficial effect on human learning [9, 10, 11, and 12].

Information technology-based tools have been used to obtain learning gains in domains such as mathematical problem solving, communication abilities and other scientific disciplines [13, 14, 15, 16, 17, and 18]. The most important among these include:

- the ability to bring real world problems and contexts into the classroom (a goal of the present work),

- use of information technology as a scaffolding tool to assist in problem solving (a goal of the present work),
- opportunity for continuous feedback (not a part of this work), and
- opportunities for building a community of global learners with easy sharing of learning strategies, methods and success stories (not a part of this work).

Computer scaffolding (where software is used as the main learning framework for problem-solving activity) has been shown to aid thinking and problem solving by providing support to learners engaged in activities beyond their abilities [19] resulting in the development of numerous scaffolding tools [20, 21]. In other words, scaffolding is building on existing knowledge through the use of computer software or the ideas of others more skilled and knowledgeable in a particular area under investigation. Experts differ on how exactly to scaffold to maximize learning gains: some researchers report success with computer-based scaffolding methods with problem solving in a team environment and others [22, 23] advocate an apprenticeship model of scaffolding. And some researchers [24, 25] view computer scaffolding tools in a symbiotic relationship with the human learner, but only when these tools are designed to capture the dynamic nature of the human-machine system.

With all this as background, the experiment employed RWST in a required sophomore class for two main purposes: (1) to help students visualize problems so they can "see" machines in operation before they are asked to compute something about them; and (2) as a scaffold to allow them to think about the overall concepts while performing a design so as to connect with the conceptually-oriented students. Student attitudes were then assessed.

The Experiment

Approximately once per month, students were exposed to a demonstration and/or RWST. The technology was used in two modes. One mode posed a question to the students that appeared to have an obvious answer. A subsequent demonstration then showed the opposite. This was done to introduce cognitive conflict so the students could begin to rebuild their conceptual framework regarding this particular concept. The second mode utilized the technology to demonstrate or explain how something worked followed by a session where the students "dig deeper" into the behavior. It is this second mode that is being described in this paper.

One specific RWST that was used in class was MSC.Adams, a dynamic system simulator. Some of the simpler visualizations that were used in class consisted of a slider crank mechanism. The visualization was used to show the students how the machine moved and where the velocity of the piston was maximum and minimum (and that those locations correspond to zero acceleration). A sample of the output is given in Figure 2. Of course the students can rotate the slider crank (the engine) around in 3D so they can see how it is interconnected. The students are always shocked when they see that the acceleration is zero when the velocity is maximum and minimum, but it has to be since the piston (the green box) moves on a straight line. When using the simulator, the students are asked to compute the velocity and acceleration by hand and match their results to the simulation. Another useful bit with the simulator is that it is trivial to display the force between the piston and the cylinder wall. The students are then asked to predict what would happen to the force (or acceleration or other variable) if some parameter were changed. For example, if the running speed is doubled, what is the maximum acceleration?

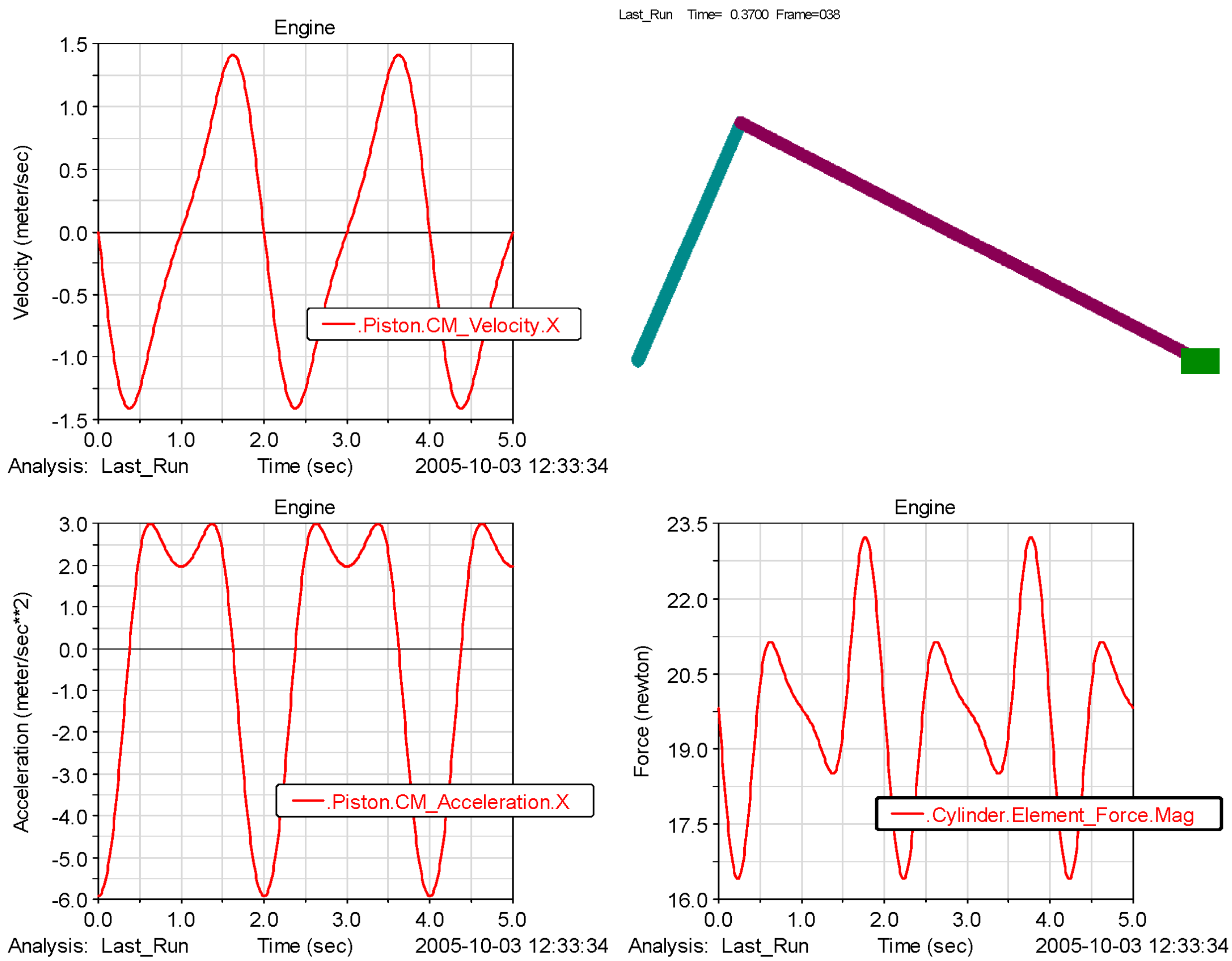

Figure 2 - Results from a Slider Crank Analysis.

Of course a simple engine is relatively easy to simulate. So to demonstrate a more complex problem, consider the variable stroke engine shown in Figure 3. This device was modified from a class assignment given by Dr. Benjamin Mooring. The device has two degrees of freedom, which is a difficult concept for students, and most students do not believe the machine can actually move. The viewing perspective of the simulation can be rotated while it is in motion which helps the students understand the motion. This particular simulation was constructed by an upper-division student using Unigraphics NX-3.

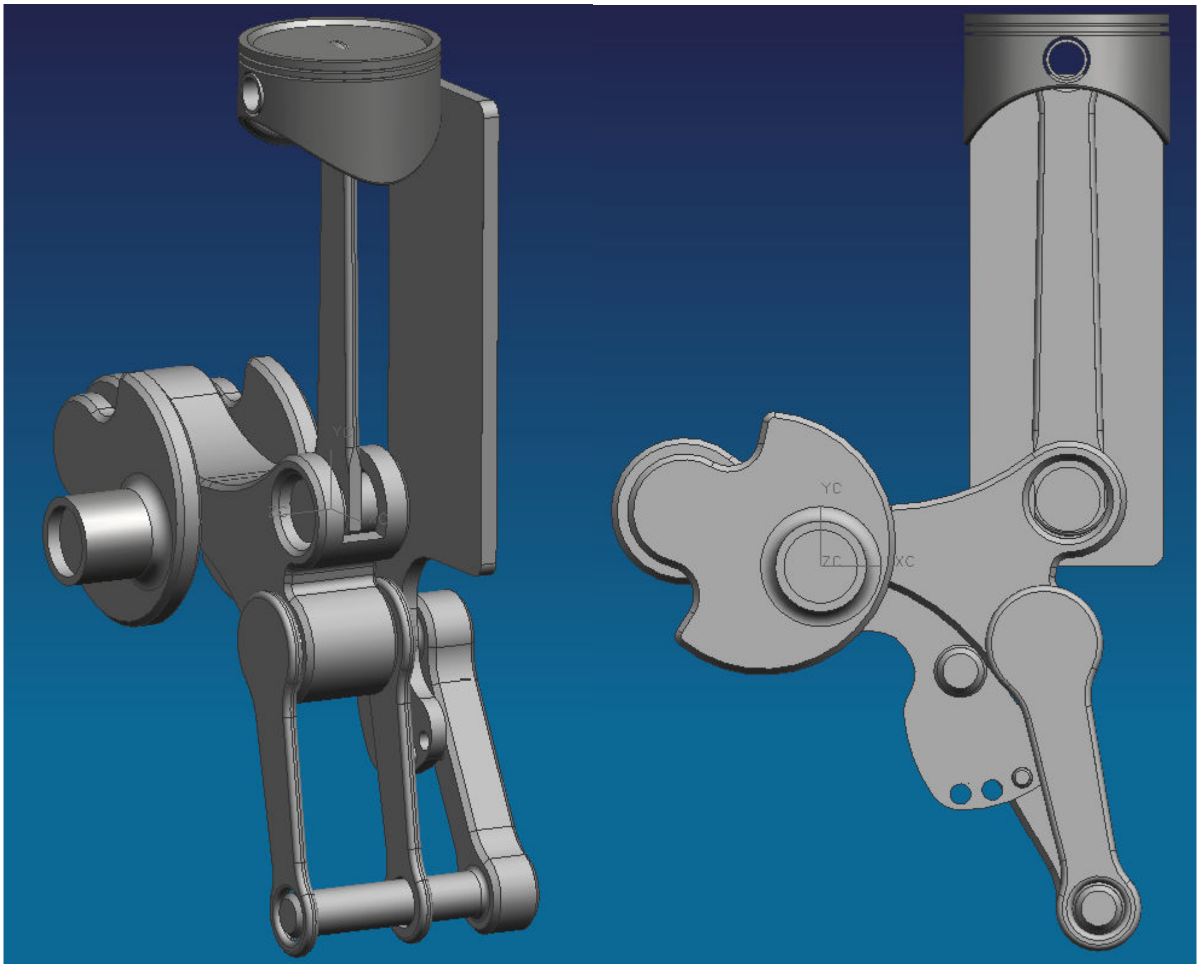

Figure 3 – A Two Degree of Freedom Machine.

The Design Problem – A Bowl Feeder

This module demonstrates a bowl feeder (BF). A BF is a bowl that vibrates both clockwise and counter-clockwise such that objects placed in the bowl are made to move up an inclined spiral, see Figure 4. The rotational motion is small with a high enough frequency that the bowl looks stationary. When observing it, the students say it looks like the objects in the bowl move because of magic. Students are asked to explain the phenomenon.

Figure 4 – A Bowl Feeder.

Some of the solutions offered by the students are:

- Centripetal acceleration forces the objects against the bowl. If the students say this, they are shown a video of a linear feeder.
- Some say there is a rotating magnet beneath the bowl, so we drop in a rubber eraser which also moves.

What actually happens is that the bowl rotates one direction "gently" enough to not exceed the friction force between the object and bowl. Then it rotates "hard" the opposite direction so as to break the friction loose, and the object remains at a relatively constant position while the bowl moves under the object. The cycle is repeated multiple times moving the object up a ramp cut as a spiral inside the bowl. The BF demonstrates the concept of momentum and impulse, and static and kinetic friction.

The assignment given the students is:

"You are to design a linear part feeder by specifying its parameters and the force or acceleration you want applied to the bowl.

The part feeder should move a block (the screw) as quickly as possible. You may set the following values within the following limits:

- Screw mass – 10 grams – 100 grams
- Bowl mass – 500 grams – 1 kilogram
- Static Friction coefficient – 0.5 – 0.9
- Kinetic Friction coefficient – 80% - 95% of the static.
- The force applied to the bowl should not exceed 500 Newtons.
- The bowl can move no more than 1 cm.
- You may make the width and height of the bowl anything you want."

The instructor's solution

To achieve the desired motion a periodic acceleration is applied to the bowl. The motion consists of two constant accelerations[2]: one slightly less than what static friction can support and the second one slightly less than what the maximum force would create. Each acceleration is applied for a time that produces zero impulse over the cycle. The period of the motion is then adjusted to make the maximum bowl displacement less than the design value.

The students' solution

Many of the students express the idea that "this is a simple problem," then they actually try some forces/accelerations and discover it is not as simple as they expected. First, most students seem to catch on very quickly that the force needs to be periodic. They typically first do what they remember from mathematics: they apply a sine or a cosine. They then fiddle with the period amplitude, phase shift and DC offset in an attempt to "get anything to work."

With some encouragement, the students apply the concept of impulse/momentum and realize it is possible to rule out certain types of forces/accelerations.

Another typical "confusing" point for the students is that the problem statement does not completely constrain the design. The students will ask questions such as:

- How do I know what friction to use?
- How do I select the period?
- How can I be sure the "bowl" does not move too far?

Assessment Results and Future Work

To assess the effect of these interventions, the students were asked what they felt. The questions were posed with positive and negative wording to assess internal consistency of the questionnaire. The questions were then randomly listed. When the questionnaire was constructed, the questions were grouped based on what they were intended to determine. The questions that were asked are listed below. The questions are grouped as they were designed and the number in front of each question indicates where it occurred in the questionnaire the students read. The students rated each one from Stongly Agree = 1 to Stongly Disagree = 5.

Animations Help

1. The computer animations help me better understand how a part works, how it moves.
3. The computer animations have increased my interest in dynamics.
6. The computer animations have made me realize I don't need this class; I just need to buy some software.
13. The computer animations given in class have little to do with solving dynamics problems.
17. The computer animations given in class have helped me to solve dynamics problems.
24. After looking at the computer animations I can better understand the drawings on problems and exams.

Modules and the Questioning that Took Place

2. The questions that were asked while viewing the simulations/demonstrations helped me understand the lecture material.

[2] The instructor believes in the KISS principle of design; that is, "Keep It Simple Stupid".

7. The questions that were asked while viewing the simulations/demonstrations made me think more about dynamics than usual.
10. The questions that were asked while viewing the simulations/demonstrations confused me more than ever.
12. The questions that were asked while viewing the simulations/demonstrations had no relationship to the class material.
14. The simulations/demonstrations are a waste of quality class time.
20. The simulations/demonstrations have given me a different approach to dynamics.

Help Toward Exams

4. I think I performed better on the exams as a result of the simulations/demonstrations.
18. I think the simulations/demonstrations misled me when studying for the exams.

Modules Help Toward Design

5. The project is worked best by guessing.
22. The project helped me understand why theory is important when I am doing design.

Modules Change Attitude About Theory and Help Understanding

8. The demonstrations show a real-life side of dynamics that helps me understand dynamics.
11. The demonstrations help me understand the theory that makes things move.
15. The demonstrations are obviously contrived and I don't believe things really behave the way the demonstrations show.
19. The demonstrations do not help me understand anything.

Attitude About Collaborative Work

9. Although having to work in a group is hard, it helps in the long run.
16. I would rather work by myself because I know what I am doing.
21. Groups are just difficult and do not help me in the class.
23. Groups are helpful, because more than one perspective helps.

The raw data from these questions are shown in Figure 5. Since a rating of 1 means 100% of the students strongly agree, and 5 means 100% strongly disagree, ratings below 2 and above 4 are especially significant.

Consider the first category of questions. In particular question 6 seems to indicate that the RWST is giving the students the attitude we want, the students do not see the technology as supplanting the theory in class. They also fairly strongly suggest the animations are helping them visualize dynamics.

Consider the second category of questions. In particular consider questions 2, 7, 12 and 14. Essentially the students are saying the simulations help them understand lecture materials, the questions cause them to think more about the material, the students see a connection between the demonstrations and class material and feel it is valuable to spend time on them.

In the third category the students are nearly neutral on whether or not the materials help them perform on exams but are slightly leaning toward the positive that the materials help. The fourth category is interesting and suggests the students are applying theory when they do the design problem; however, they do say that guessing also seems to help. Perhaps they are confused by the fact that often one makes "educated guesses" during design and then verifies.

In the fifth category, the students say they believe the simulations are "realistic" and seem to accept what they show. They also accept that the simulations help them understand the theory. It seems the cognitive conflict may be a positive influence.

In the final category the students seem to understand the power of collaboration and that is that multiple ideas are generated.

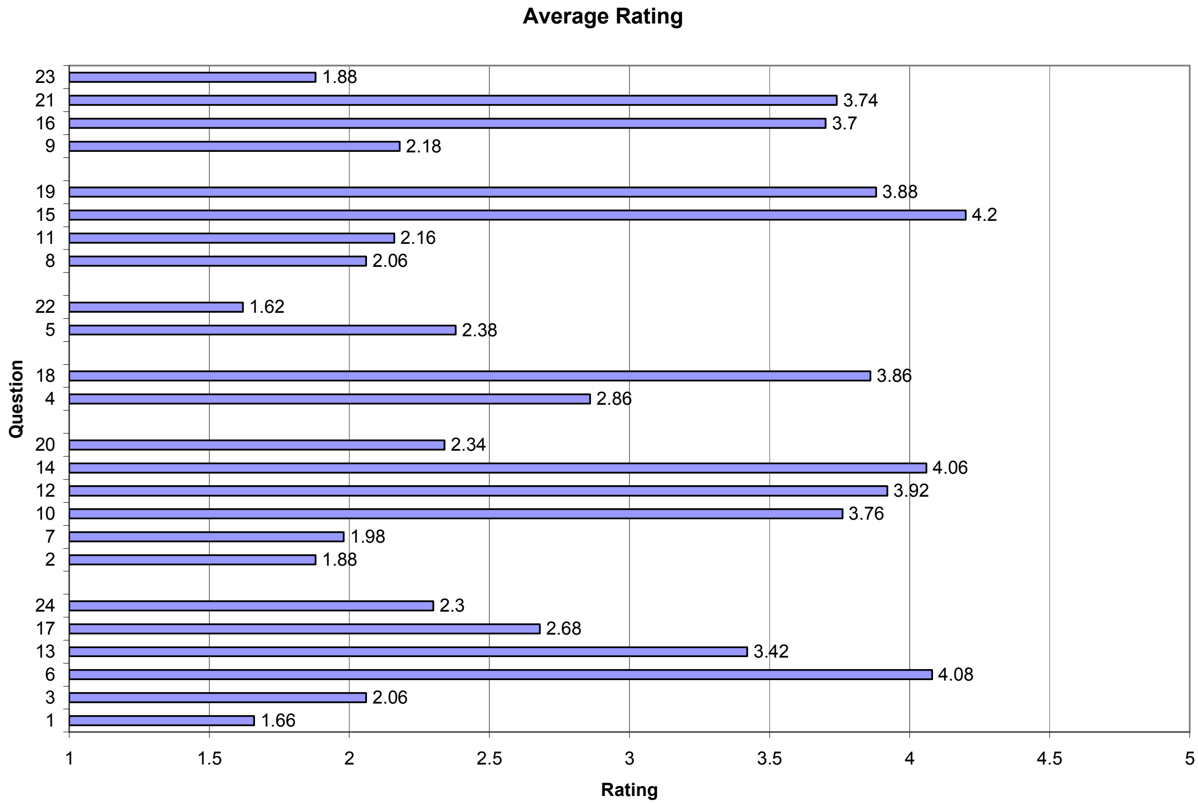

Figure 5 - Survey Results

Based on student responses, it appears there is some value in the small design projects using RWST in dynamics. The students report attitudes that are healthy. In the future, the projects may be better if they allow the students to implement their designs.

As time goes by, the design problems will need to be changed to maintain the spontaneity of prediction. One of the next designs under development at UTEP is a centrifugal clutch, one that connects the rotation of a small engine to a driven device. As the engine speed increases, the rotation causes several friction shoes to move outward from the engine rotation axis. As the shoes move outward, they contact the inside of a cup attached to the driven axle. Friction between the cup and shoes drive the driven axle. This is the typical driving mechanism in a golf cart. The students will be asked to design a "better" clutch by modifying the sizes, mass and inertia properties. The students will need to define their interpretation of "better."

The authors encourage other faculty to use the modules that have been developed and to help develop more "cognitive conflict" demonstrations and design problems. Collaboration to secure funding is also encouraged. Those interested are encouraged to register at http://research.utep.edu/pacelab. Interested readers will also find downloadable copies of the files used in class at the same link.

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