AC 2010-1548: ATTITUDES AND INTERESTS OF STUDENTS IN INTRODUCTORY ENGINEERING COURSES WITH EXPERIMENTS RELATED TO SPORTS

Jennifer Kadlowec, Rowan University

Ali Navvab, Gloucester County College

© American Society for Engineering Education, 2010

Student Interest in Introductory Engineering Courses with Experiments Related to Sports

Abstract

In an effort to introduce engineering students to mechanical aerospace and chemical engineering principles through a familiar context of sports and sports performance, a multidisciplinary team of faculty and students from two universities and a county college have developed a set of hands-on modules. Experimentation in the modules allow for students to explore topics such as aerodynamics, mechanics of materials, dynamics and transport at an introductory level. At the university, all of these topics are covered in a freshman introduction to engineering course. The students conduct four module experiments; then after this guided instruction, the freshmen work in small teams to develop experiments. In some cases the student chosen experiments may be extensions of those they have completed or changed to incorporate these principles in other sports related testing. These team projects are a major component and design part of the course, after which the students submit a final laboratory report and present their finding in an oral presentation. Additionally, ethics related to engineering and sports are discussed in the freshman course. In the engineering materials course at the county college, students perform experiments in mechanics of materials, as this is the topic of the course. Students later bring in other products to test a section or material sample. The purpose of this paper is to briefly explain the modules and their incorporation into each of the courses and evaluate their attitudes and interests in the sports in engineering topics.

Introduction

Faculty at two universities and a county college have developed a set of modules for teaching engineering from an applied, hands-on point of view. The basis of the project are the facts that the world of sports provides for an exciting platform to study multidisciplinary engineering principles and that most students can relate to sporting activities in some way or another, either as a participant or spectator. A large portion of the United States population over the age of 6 is frequent exercisers or participants in recreational sports. For example, a 2007 report by the Sporting Goods Manufacturers Association, over 100 million people over the age of 6 walk for fitness and over 75 million of these are walk frequently, defined as greater than 50 days per year. The 'Big Three' team sports are football, basketball and baseball. Lacrosse, rugby and field hockey on the rise among team sports; and badminton, racquetball and tennis are showing participation gains among the racquet sports.[1] Due to the popularity of sports, studying technology and its effect on sports and sports performance provide a good way to teach basic theories. "Studying some of the dynamic effects contained in sports, we can introduce all of the dynamic systems that we are trying to teach our students. Students tend to tune out when studying the same old greasy gearbox."[2]

These ideas were combined with the key features of the undergraduate engineering program, (1) multidisciplinary education through collaborative laboratory and course work; (2) teamwork as the necessary framework for solving complex problems; (3) incorporation of state-of-the-art technologies throughout the curricula; and (4) creation of continuous opportunities for technical communication[3], to develop this project.

Some goals of the project are to:

- generate excitement among undergraduate students by integrating sports and engineering,
- engage students and improve learning through novel hands-on experimentation,
- provide undergraduate students with the opportunity to work on projects related to sports and sports technology

The purpose of this paper is to introduce modules that were developed and the courses in which they were implemented. Since participation in and even viewing of sports activities are relatively common among the students, we wanted to use this familiar context of sports in hands-on laboratory experiences to reinforcing science and engineering concepts with undergraduate students. Further we were interested if using sports concepts into engineering courses, would increase interest in engineering or sports engineering, which they may not have realized involved engineering design.

Description of modules

Module 1 – Mechanics of sporting materials

A wide variety of elastomers and foams are used in sporting equipment such helmets, knee-pads, golf and tennis balls, shoe soles and athletic field surfaces. There have been many efforts to improve the materials with which sporting goods and equipment are made to improve performance. Sports ball, for example, were originally made with materials including hair, feathers, wool or cork often wrapped in cloth or leather. With the invention of the vulcanization process for rubber, players in sports such as tennis experimented with the new 'bouncy,' rubber balls. Rubber and foam were also incorporated into padding materials for American footballs as well as soccer balls and athletic shoe soles.

Materials are chosen based on properties such as elastic modulus and durability to meet the demands that a given sports component will be subjected to in play. Investigating these properties for a variety of materials and performing experiments to determine properties for specific elastomer materials became important to game play and design of sporting equipment.

The *objectives* are: (1) Perform background research on foam and elastomer materials. (2) Develop experiments to compress a sample of foam or elastomer and measure force and deformation. (3) Use the concepts of stress and strain along with Hooke's Law to compute a modulus of elasticity. (4) Compare moduli for a variety of materials and associate properties with their function in a specific sports application.

Measurements and Calculations: Students place a material sample in a universal testing machine and use an LVDT and load cell to record the displacement and force during the compressive deformation. These data are used to plot the data and calculate stress, strain and modulus of elasticity.

Module 2: Why does a curve ball curve? Does a good fastball rise?

In baseball, a curve ball is thrown by imparting a high angular velocity on the ball in addition to its translational velocity. In the early half of the 20th century, there was still debate in the scientific community over whether a curve ball actually curved or whether it was an optical illusion. Anybody who ever tried to hit a curveball found this debate to be curious since it was obvious that a curve ball did indeed curve. It is now well known that a curveball curves because of an effect called the Magnus effect. This effect is a result of the no-slip condition at the surface of the spinning baseball, which results in a velocity differential between the two sides of the baseball. Because of the Bernoulli effect, the velocity difference results in a pressure difference, which causes the curveball to curve, which indeed it does.[4]

A good fastball is often said to actually rise. Typically, a fastball is thrown with backspin on the ball. Theoretically, the same Magnus effect described above can result in enough upward lift on a fastball to cause it to rise. The question is, can a human being impart enough backspin on a fastball to make it rise? So, students will examine the effect of angular rotation on the lift of a sphere.

The *objectives* of this module are to (1) Perform background research to determine the translational and angular velocities of a typical curveball and baseball. (2) Conduct an experiment in a wind tunnel to determine the lift coefficients for a sporting ball (baseball, tennis ball, golf ball) as a function of the relative flow speed and rotation rate using a wind tunnel. (3) Measure the lift and drag forces on a baseball as function of Re and angular velocity. (4) Interpret the results in terms their impact on a curveball and fastball.

Measurements and Calculations: Students perform experiments using a 0-100 mph, 12"x12" cross section wind tunnel. The lift force is measured with a load-cell on a free-floating system consisting of a motor and controller to set the rotational speed of the ball. Students calculate lift force as a function of Reynolds number and angular velocity.

Module 3: The Dangers of Overhydration

In the 2002 Boston Marathon, a female runner died from hyponatremia, which is the result of severe overhydration. When she became exhausted and ill during the race, emergency personnel assumed that she was dehydrated and treated her accordingly. She died immediately upon the administration of hypotonic fluids (water with dilute electrolytes). The subject of overhydration among marathon runners and other endurance athletes has received increasing attention in recent years. In a study published in the New England Journal of Medicine, researchers present stunning evidence of the magnitude of this problem.[5] Analysis of blood samples collected from runners in the 2002 Boston Marathon suggests that 1,900 runners had dangerously low sodium levels and 90 runners had critically low sodium levels at the end of the race, putting them in risk of confusion, seizures and death.

Overhydration is a result of excessive fluid intake such as that which can occur during a marathon when a runner follows the mantra "drink before you feel thirsty". When the extracellular fluid is diluted, fluid becomes hypotonic with respect to the interior of the cell. Cell membranes are semipermeable and allow water to be transported freely across them in order to maintain osmotic equilibrium. Water flows into the cell by osmosis, leading to rapid swelling of the cell, which often results in bursting (lysis). Severe hyponatremia can be treated with the IV administration of hypertonic (3% saline) solution; ingestion of water can be fatal. In this module, students will explore the role of osmosis on hydration status in biological systems.

The *objectives* of this module are to (1) perform background research on osmosis in biological systems (2) explore quantitatively the effect of concentrations of different species (salts, sugars, and proteins) on osmotic pressure of a fluid (3) to determine the effect of solute concentration on the osmotic water flux across a membrane.

Measurements and Calculations: Students conduct a simple experiment using thin slices of zucchini as a biological system. The slices are weighed before and after soaking in a hypertonic or hypotonic solution (e.g., water, saline, or sports beverage), and the rate of water transport into or out of the cell will be determined.

Module 4: Bicycle Power

With alternative and green energy solutions pouring into the marketplace, one simple solution is to generate electrical power by human bicycling power. A simple system was developed using a mountain bike with the front forks mounted on stands. The rear tire of the bicycle rolled on a shaft in line with that of a motor, which was used in reverse as a generator. Not only was it interesting for students to work with an electro-mechanical system, but this also provided a good platform to discuss ethics and design of simple solutions for developing nations.

The *objectives* of this module are to (1) Investigate engineering concepts and principles of speed, torque, mechanical and electrical power, (2) Measure voltage and current in an electro-mechanical circuit to determine resistance and electrical power, (3) Determine relationships between rotational speeds and torque using dynamics principles and gear ratios.

Measurements and Calculations: Students measure diameters of the components in the mechanical power system of the bicycle. One team member pedals the bike and attempts to sustain comfortable speed for a set timeframe, one measures the angular speed generator shaft using the tachometer and another team member reads the voltage and amperage using the multi-meters in the circuit with the generator. Teams then calculate power and plot a power curve.

Description of courses

All of the modules were used in a freshman introduction to engineering course at the four-year university. This course is used to introduce students to the science and art of design by evaluating the work of practicing engineering. The students are placed in multidisciplinary teams to learn scientific principles, and how these, cost, manufacturing, safety, environmental consideration and intellectual property impact engineering design. During the first part of the course, students learned these through experimentation in the modules previously discussed, which were followed by assignments and laboratory reports. After several weeks of these guided activities, the students in teams developed research questions of their own choosing and experiments related to the topics that were studied in order to answer those questions. In the latter part of the semester, the students conducted their experiments, analyzed data and wrote semester final reports, which also included that the professional issues be addressed.

At the county college, the mechanics of materials module was used in a second-year engineering materials course, which is traditionally lecture based. With a new, bench-top, universal testing available, students were also able to conduct experiments. As students were introduced to the concepts of stress, strain and Hooke's law, besides more typical testing of metal dog-bone samples, they were given various elastomer samples as mentioned. The students were particularly interested and brought in a variety of their own products, such as an old pair of boots from which they cut samples to test.

Results and Discussion

All four of the modules presented here were used in courses at the four-year institution in a freshman engineering course. The mechanics of materials module was the only module of these that was used in a course at the two-year county college. This is due to the fact that no introduction to engineering course was available, but engineering mechanics lent well to the use of the mechanics module. The modules were favorably received at both institutions. Students were given voluntary surveys in order for the authors to 1) assess the effect of the experiments on the level of student interest in engineering and in sports related to engineering and 2) assess the students' perception of how helpful the modules were to their learning of the material. Representative data are reported for the mechanics module, since this was the only module conducted at both institutions.

Table 1 – average results of survey responses for the mechanics module

Question	4 year university	2 year college
How did the module contribute to your understanding of material properties (1 no idea, 5 concept is clear)	4.3	4.2
How did the module contribute to your ability to determine stress and strain from force and displacement data	4.1	4.0
How did the module contribute to your ability to compute elastic modulus	4.1	3.8
How interesting was the subject material (1 dull, 5 interesting)	3.7	4.0
How interesting was the experiment (1 dull, 5 interesting)	3.3	3.7
How interesting were the analysis and results as a way to learn engineering principles (1 dull, 5 interesting)	3.6	4.0
Please rate the difficulty of the experiment (1 much too easy, 5 much to difficult)	4.3	3.3
Please rate the difficulty of the assignment (1 much too easy, 5 much to difficult)	3.2	3.4
Please rate the handout (1 useless, 5 very useful)	4.1	4.1
	n=11	n=10

The responses to the questions were favorable at both institutions, with all scores above neutral. The results show that while the freshman university students as a group believed that the module contributed more to their understanding ability to determine quantities and properties, this may be due to the fact that these students were required a full lab report in teams. In doing so, the students met to discuss the analysis and write the report, further reinforcing the concepts. Students from the county college were generally more interested in the experiment itself and as a way to learn these principles. Since students from the two-year college are sophomores, who have taken some introductory engineering courses and many of whom are most interested in mechanical or civil engineering, may have found more relevance in this topic. Students from the four-year university may be declared as chemical, civil and environmental, electrical and computer or mechanical engineering, so students that would not be taking mechanics may have been less interested. Overall all of the students found the experiment and assignment relatively challenging and appropriate (score 3 of 5) and the handouts to be useful or very useful.

Conclusion

Experimental modules were presented, which were designed and developed to teach engineering principles in the context of sports with which the students are familiar. Students responded favorably to the modules and believed that these were helpful in their learning of the material. Future work will discuss other sports modules and assessment of student perceptions and learning based on their use.

Acknowledgments

The authors thank Kyle Fitzpatrick, Kevin McGarvey, Dhaval Naik and Casey Oware for development of experimental hardware. We also thank the National Science Foundation for support under the CCLI program Grants DUE 0536307 and 0536229. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation or the college and universities with which the authors are affiliated.

References

---

1 https://www.sgma.com/press/5_-The-American-Sports-Scene%3A-An-Analysis-of-Sports-Participation-in-the-U.S. (accessed Jan. 2010)

2 http://www.prism-magazine.org/dec02/ballgame.cfm (accessed May 2005)

3 Rowan School of Engineering – A Blueprint for Progress, Rowan College, 1995.

4 R.D. Mehta (1985) "Aerodynamics of Sports Balls," Annual Review of Fluid Mechanics **17**, pp. 151-89

5 Almond, C. *The New England Journal of Medicine*, V 352: pp 1550-1556, April 14, 2005