# Golfing with the Pros: Teaching Experimental Statistics to Mechanical Engineering Juniors

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## Abstract

Teaching statistics to undergraduate mechanical engineers is one of the required ABET program criteria, a criteria that is included under, but also predates EC 2000. To more effectively teach statistics to junior mechanical engineers, an experiment was created using a modified commercially-available golf analysis system that included an array of 53 floor-embedded light-sensors. Students measured the tempo (swing time), club speed, club angle and trajectory, and projected ball trajectory of typical golf swings for golfers and non-golfers. Analyzing the data (and comparing the results to PGA Tour Pros) taught students the basics of statistical analysis, including using mean, standard deviation, Student's t-test, and the F-test for the analysis of variability. This study was co-sponsored by the PGA Tour and the World Golf Hall of Fame in St. Augustine, FL.

## Introduction

ABET's updated engineering criteria for mechanical engineering programs (also called Engineering Criteria 2000 or EC 2000) requires students to be familiar with experimental statistics. This requirement is implied in four places: program outcomes a, b, and k, listed under general criteria, and a specific curriculum requirement listed under the program criteria for mechanical engineering programs:

General Criteria:

(a) an ability to apply knowledge of mathematics, science, and engineering.

(b) an ability to design and conduct experiments, as well as to analyze and interpret data.

(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering.

Program Criteria specific to mechanical engineering:

"The program must demonstrate that graduates have...familiarity with statistics..."

In the Department of Mechanical Engineering at Grove City College, we have chosen to satisfy these general ABET requirements with the following specific course outcomes related to experimental statistics:

1. Students calculate mean values only (where parametric statistics in not appropriate) and draw conclusions based on the values.

2. Students calculate linear regression, mean, and standard deviations; compare means (t-test) and standard deviations (F-test).

This paper describes an experiment we have used in our department for the past four years that helps students understand these concepts and highlights the differences between deterministic and stochastic analysis.

**Golf Experiment Description**

Our experiment was created using a modified commercially-available golf analysis system that included an array of 53 floor-embedded light-sensors (Fig. 1). During the first year, the system included a special shock-absorbing screen with the projected image of a golf course. In subsequent years, this large screen was replaced with a portable, less-expensive shock-absorbing net.

**Figure 1 - Golf-Motion Measurement System.** Note the floor-imbedded light sensors, golfer, and projected image on screen.

Ball and club motion was measured by the light-sensors and transmitted via a serial interface to a computer that calculated the projected direction and speed of the club face and ball.

**Student Use of Golf Experiment**

Students interacted with the golf experiment in the following ways:

> **Phase 1**. A team of students created the initial system by modifying commercially-available components. Hardware was created and special software was written that calculated club and ball speed, and compared a subject's swing with a PGA professional golfer (Figs. 2,3).
>
> **Phase 2**. Another group of students modified the initial system as part of a special studies course to French Canada. The system was modified for portable installation in a museum in Ottawa, Canada (Fig. 4) and museum visitor behavior was analyzed (Figs. 5,6).
>
> **Phase 3**. The system was permanently installed in the mechanical engineering laboratory, where students measured the tempo (swing time), club speed, club angle and trajectory, and projected ball trajectory of typical golf swings for golfers and non-golfers. This experiment is now a required part of the mechanical engineering curriculum.

**How the Golf Experiment Was Used to Teach Statistics**

In phase 1, students recorded club speed, club angle and trajectory, and projected ball trajectory for golfers and non-golfers, as well as tempo for golfers, non-golfers, and PGA pros. In the mean, males hit golf balls further than females (all differences tested at the $p < 0.01$ level); this difference applied to non-golfers, amateur golfers, and professional golfers. More experienced golfers hit golf balls further than non-golfers. There were no significant differences between the mean tempos of the groups of non-golfers, amateur golfers, and professional golfers, however repeated measurements of tempo showed significant differences between individuals, both for professionals and amateurs.

The results indicated that the kinematic parameter that could most easily match pro and amateur golfers was tempo. Experienced golfers had highly consistent, reproducible tempos that varied widely between individuals. In phase 2, students explored ways to communicate this and other statistical data to museum visitors, in addition to evaluating visitor behavior (e.g. % of visitors that stopped at the exhibit, etc.). Students found that not all data lends itself to a rigorous statistical analysis, an important insight into using standard tests based on parametric statistics.

Phase 3 has seen all students gain exposure to this lab and to the use of statistics to analyze experimental data.

**Conclusions**

Our students have benefited from applying statistics to a real-world system with high intrinsic interest.

# ...when Senior ME's go golfing

***A GCC mechanical engineering student research team recently designed a virtual reality golf analyzer using light-activated switches interfaced to a computer - the resulting device became one of 18 major exhibits anchoring the new $55 million "World Golf Village" complex in St Augustine, FL. ME seniors Rob Lanphear and Josh Brumbaugh (along with faculty advisor Mark Reuber) are continuing development of this sports aid. The following is an excerpt from the St. Augustine Record, Jan. 6, 1999, in which sports editor Brian Peterson describes his experiences with the device.***

"...it's hip to be Tiger. Or at least it was a year or so ago, when television commercials were the rage. Me? I'm Paul Azinger. No, not because I'm a big Azinger fan...But after three trips through the Swing Analyzer at the World Golf Village, there's no disputing it.

The Swing Analyzer is similar to a golf simulator. Participants hit three balls into a screen that looks like your typical golf hole. The flight of each drive is displayed on the screen (along with other parameters)...then it tells you which touring pro's swing your swing most closely resembles...

I tried it three times over a two-day period. Each time it came up Azinger, which can't be good news for the Zinger. However, the analyzer is good news...Consider this: Jack Nicklaus...took in the WGV recently. While there, he gave the analyzer a whirl.

So whose swing does Jack's resemble? As the story goes, Sam Snead's.

Slammin' Sammy's name probably doesn't come up often on the Swing Analyzer. It's one thing to confuse my swing for Azinger's...but quite another to compare a participant's swing to that of the great Snead.

And the Tip of the Day for Jack? It supposedly touched on the role the hips play in the golf swing.

Nicklaus battled hip problems in 1998."

**Figure 2 - News Article on Student Work.** This project generated some nice publicity for our students and school.

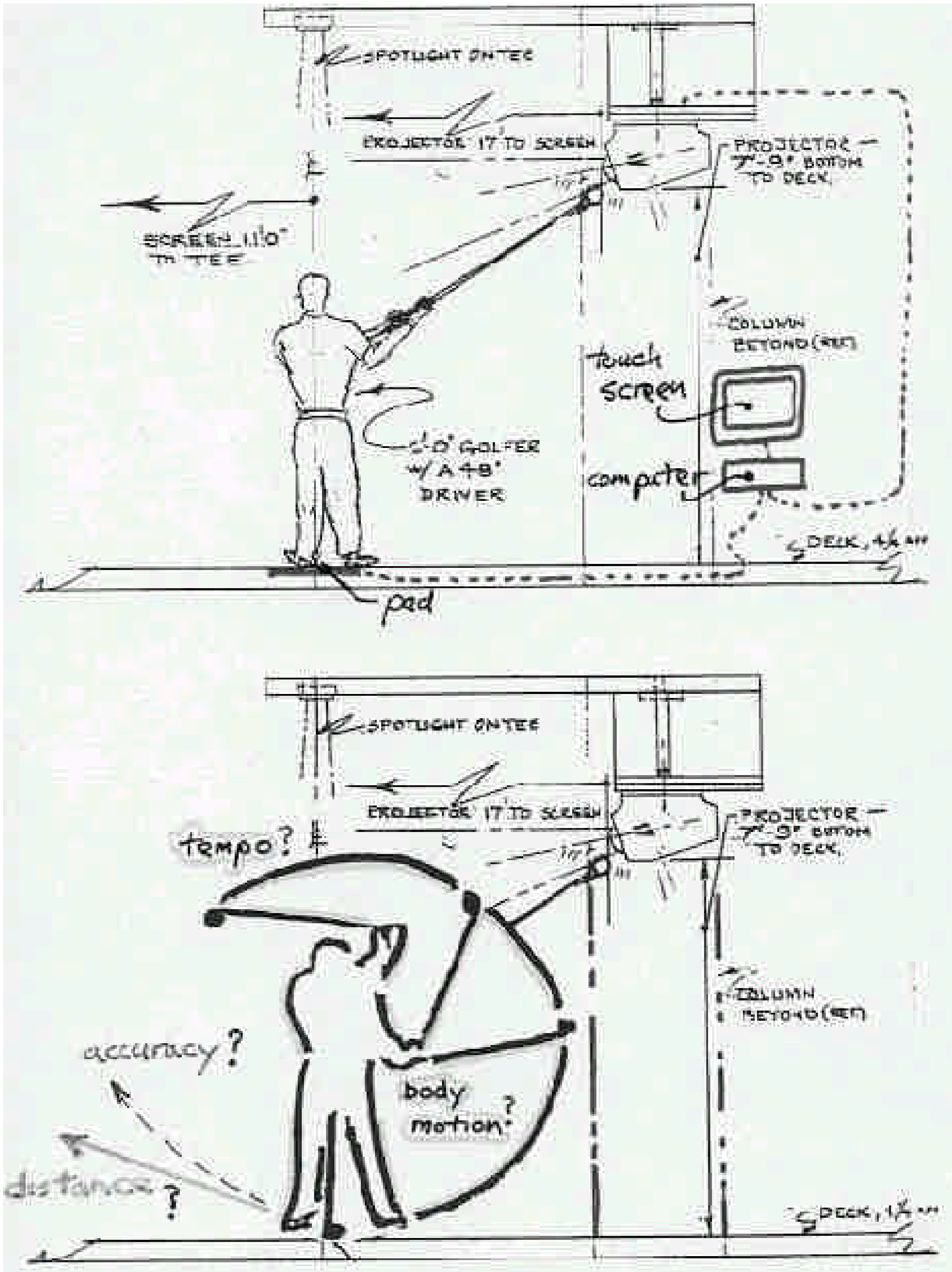



**Figure 3 - System Schematic.** Golfer swings club, sensors send information to computer, and software projects club and ball trajectory and compares swing to PGA pro.

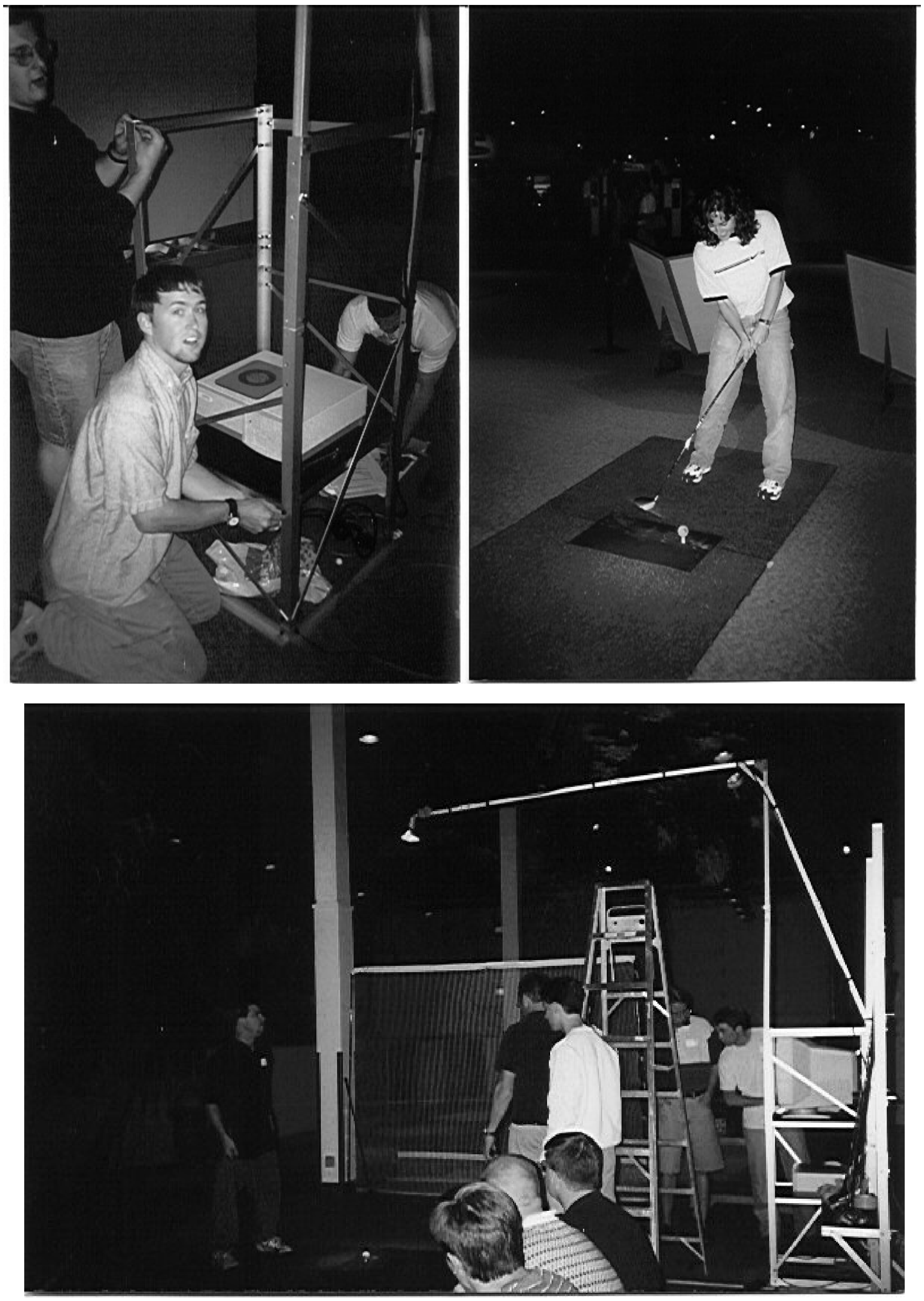
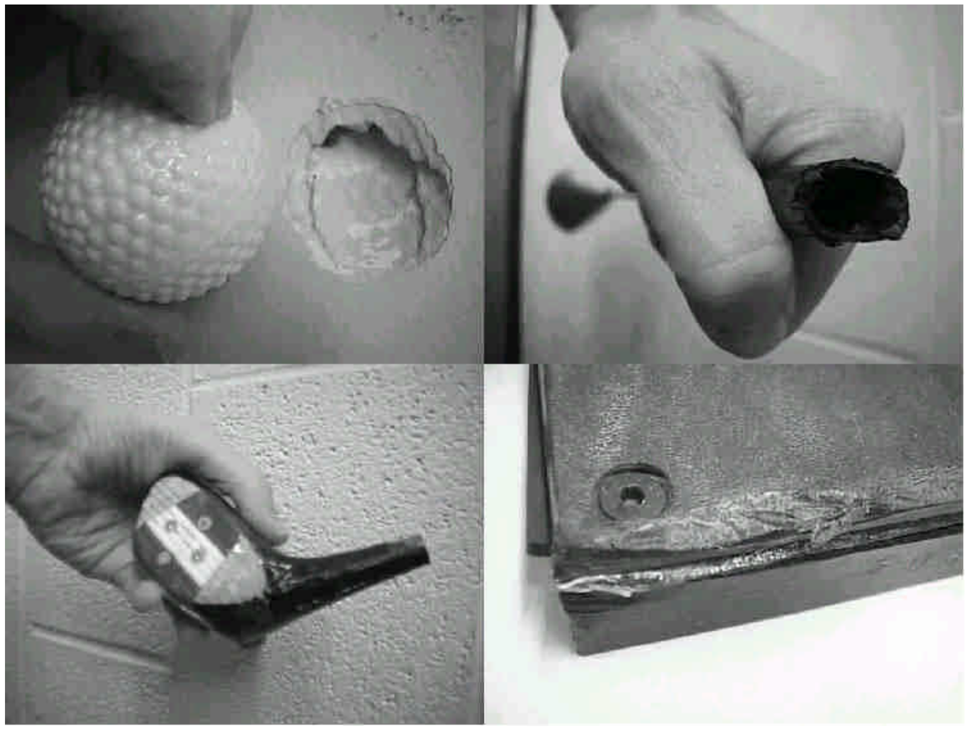


**Figure 4 - Portable Exhibit.** Students erect and test portable golf exhibit at National Science Museum for Canada.



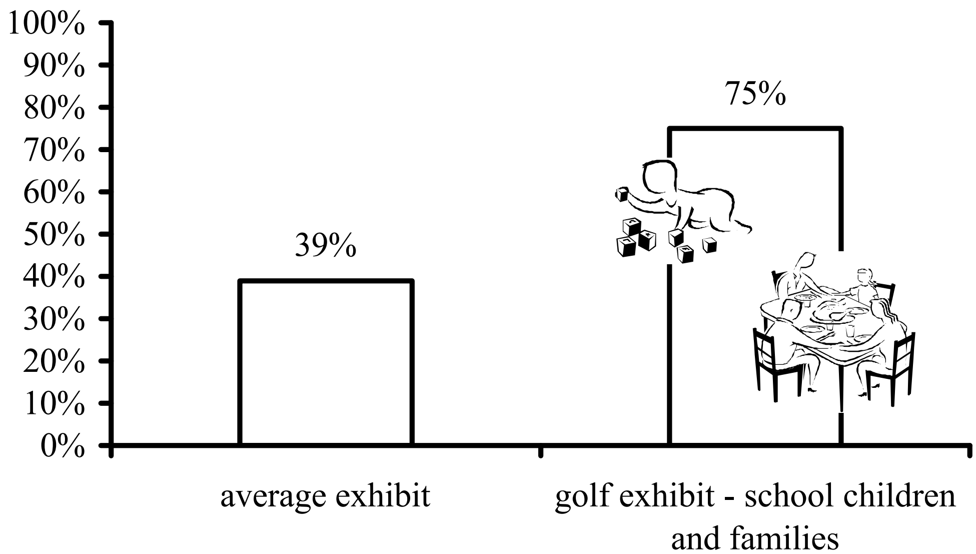



**Figure 5 - Equipment failures and Attracting Power.** Students recorded visitor behavior, including incidence of equipment failures and attracting power (shown above). This was defined as the percentage of visitors who walked by the exhibit and stopped for at least 3 seconds.

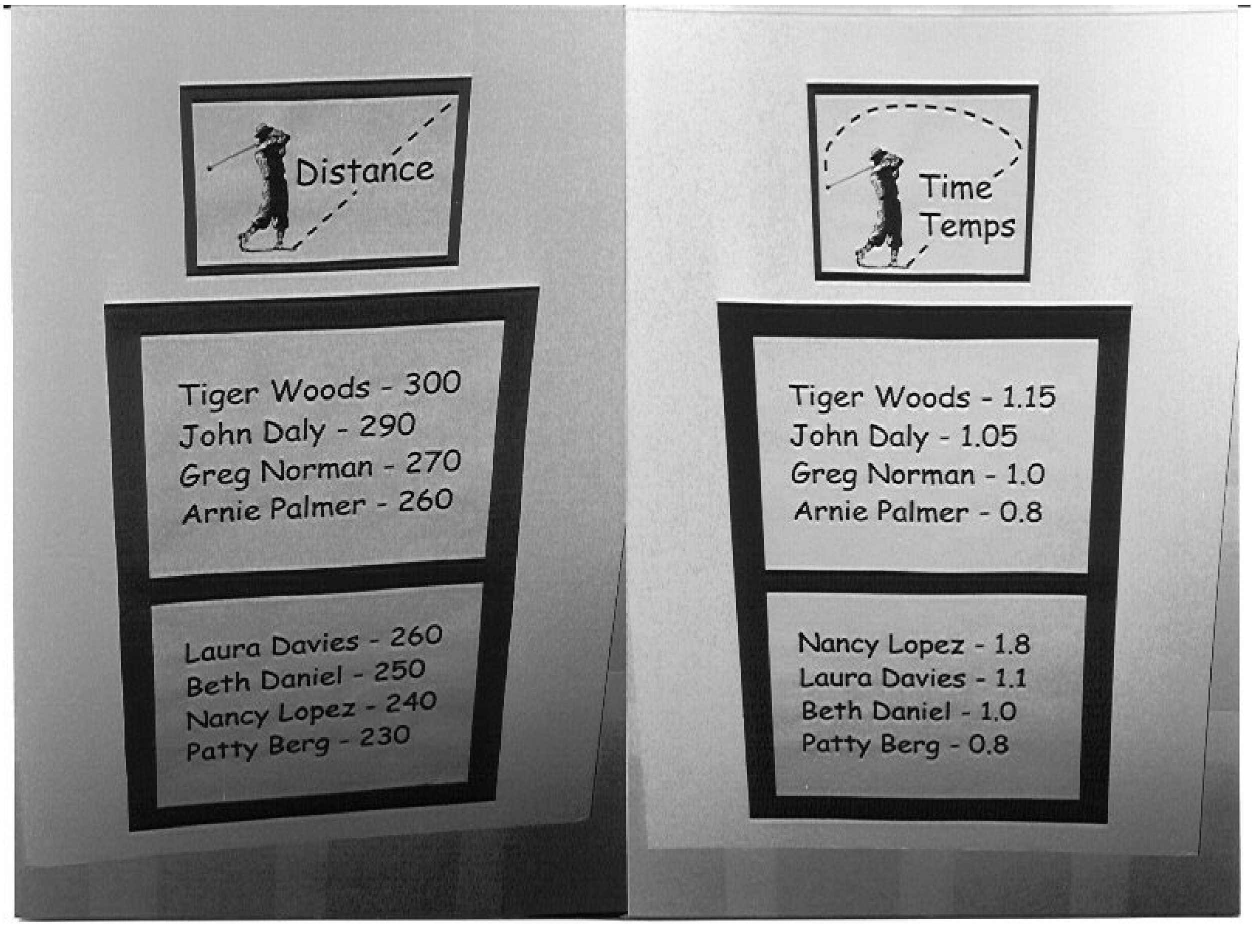



**Figure 6 - Simple Presentation of Statistical Data Worked Better.** Students found that communicating mean statistical quantities was best communicated as simply as possible in a bilingual environment.