

# What I Learned in 25 Years of Teaching Introductory Biomechanics\*

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*This paper presents observations and insights obtained during two and one-half decades of teaching introductory biomechanics. These observations fall into two categories: those concerning the subject matter itself and those concerned with teaching the material. Conclusions and recommendations are given. For the subject matter, biomechanics is divided into three major areas: performance, injury (or illness), and rehabilitation (or health care). The procedures employed include modeling, analysis, validation, and experimentation. Regarding instruction, it is recommended that the subject be taught simultaneously in three areas: (1) an overview discussing broad applications, (2) accelerated remediation in mechanics, and (3) basic biomechanics itself.*

## INTRODUCTION

RECENTLY, scientists, engineers, and science/engineering administrators and planners have predicted that biosciences will dominate research and development at the turn of the millennium. Based upon employment projections [1], biosciences are believed to take on the status of a national initiative. Going back to the 1960s, we have had space, energy, environment, computer science, and communications. Biosciences, or health sciences, are expected to be next.

Anticipating lucrative professional opportunities, students are increasingly looking for biotype courses. They have three principal objectives: (1) satisfying curiosity, wanting to know what bioengineering is all about; (2) determining what the professional and research opportunities might be; and (3) determining what might be required via preparation to enter the bioengineering field.

Students interested in biocourses come from various disciplines of engineering and even from science areas outside of engineering. The students thus have various backgrounds and various levels of preparation. Consequently the students have varying interests and varying expectations from the biocourses.

The varying student backgrounds and interests are creating increasing pressure to make biocourses more interdisciplinary and more accommodating to variegated classes. Also, the subject matter itself is by its nature interdisciplinary—particularly in its application.

In this paper I present some views on these issues as they relate to teaching introductory biomechanics courses—specifically, a three-quarter elective course sequence at the senior-beginning

graduate student level. The courses are titled 'Intro. to biomechanics,' 'Tissue biomechanics,' and 'Human body dynamics.' I try to identify approaches for accommodating the student needs and for optimizing the pedagogical/educational benefits.

The balance of the paper is divided into three parts with the following part providing an outline of the subject area. The next part presents a pedagogical discussion. The final part contains recommendation and concluding remarks.

## BIOMECHANIC DISCIPLINES

At the core of studies in biomedical engineering are courses in biomechanics. Upon entering an introductory course in biomechanics, many students either think or orally ask: 'What is biomechanics?' The insightful answer is that biomechanics is simply *mechanics* applied with living systems. Therein, however, is a basic difficulty: historically, mechanics courses have not been popular or easy-to-master courses. Indeed, most students find mechanics courses difficult and obscure. There are difficulties in understanding and mastering the fundamental concepts (the basic physics), the modeling and analysis concepts, and even the terminology.

Unfortunately, as with mathematics courses, mechanics courses are 'building block' courses where an understanding of what has gone before is needed to understand what follows. Therefore, a weak background in mechanics creates difficulties in attempting applications in mechanics; so too in biomechanics. Aggravating this is that many students entering a biomechanics course may not have studied mechanics for two to three years. As a result the students may have forgotten some of the basic mechanics principles and techniques.

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On the positive side, students entering biomechanics courses are generally bright and academically more mature than underclass students. They are usually quite capable of mastering mechanics principles. Indeed, if they are sufficiently motivated by biomedical applications they will often learn, or relearn, and master the underlying mechanics principles.

What distinguishes biomechanics from mechanics is, of course, the applications. There are three major application areas: (1) performance; (2) injury; and (3) rehabilitation. All three of these are major areas of research and study.

Performance involves routine daily activities such as walking (gait analysis), sitting, standing and lifting. Performance also includes workplace activities (including ergonomics) and workplace design. Finally, performance includes sport—a major area of high interest.

Injuries involve a failure that keeps a biosystem (e.g. the human body) from functioning as normally expected. Injury can arise from trauma, as in an accident, but loss of function can also arise from illness and disease. The study of injury-causing forces and the thresholds of human tolerance is becoming increasingly popular. Knowledge of injury causation is the basis for the design of protection devices (e.g. helmets, padding, seatbelts, air bags, guards, and warnings). As a parallel, the study of disease mechanics and disease progression (e.g. cancer/cell growth) is receiving increasing interest—an area often referred to as ‘microbiomechanics’.

Finally, rehabilitation is currently the most active area of biomechanics and biomedical engineering study and research. It is directly related to the vast health care industry. Studies in rehabilitation range from physical therapy, to design of implants (e.g. artificial organs, artificial joints, and spine stabilizers), to the design of rehabilitation devices (e.g. crutches, wheelchairs, exercise machines, robot-assist devices and surgical instruments).

## PEDAGOGICAL CONSIDERATIONS

The principal objective in introductory biomechanics instruction is meeting the needs and perceived needs of the students in view of this vast and varied nature of the subject. More specifically, how can one instruct beginning students, albeit capable students, but students who often have inadequate preparation or poor recall in mechanics itself? In my opinion the answer is to develop the course to meet first the *perceived* needs of the students and then the *actual* needs of the students.

The general expectations of the students (the perceived needs) are: (1) to determine what the subject is ‘all about’ and (2) to develop some mastery of the subject enabling them to take advantage of professional opportunities. The

actual needs of the students are: (1) to obtain an appreciation of the vastness, the depth, and innate richness of the subject and (2) to acquire knowledge and develop skills (particularly in mechanics) which will enable them to engage in more serious and meaningful studies.

While these expectations and actual needs appear to be similar, they are in reality quite different. When the students want to know ‘what it’s all about,’ they expect biomechanics to be a relatively well-defined subject like statics, dynamics, strength of materials, or thermodynamics. When they discover how broad biomechanics is, they often become discouraged, losing enthusiasm. Going further, when the students discover that they need a sound background in mechanics for meaningful studies in biomechanics, they often give up aspirations they may have had for more advanced studies.

Aggravating all this is that with biomechanics being less well defined than traditional engineering subjects, there are relatively few textbooks available. Since students often find comfort in a text, they are further disheartened if there is no appropriate text for independent reading (References [2–11] are a few of the texts and supplementary references I have used.)

This raises two questions: What can be done to prevent the students from becoming overly discouraged? and How can the students best be brought into a position to engage in serious biomechanics studies? I believe the answers are found by taking a three-fold instructional approach:

- inspiring the students by exposing them to the richness of the subject and the corresponding professional and research opportunities;
- conducting an intense, accelerated review of mechanics fundamentals;
- undertaking an in-depth study of a specific area or application of biomechanics.

It happens that all three of these can occur simultaneously.

Providing inspiration can be relatively easy when one considers the breadth of biomechanics and the increasing number of professional and research opportunities. Also, many students will have an interest in biomechanics due to its fundamental role in sports and in accidents. Most students will themselves have experienced injuries or illnesses and have wondered about the biomechanical aspects of those injuries and illnesses.

My experience is that the first 15 to 20 min of an hour class can be effectively used for such instruction.

After the students are sufficiently ‘inspired,’ it is relatively easy to convince them about the utility of entering into a comprehensive review of the fundamentals of mechanics.

There are, however, other areas where the students usually need remedial instruction. These are basic anatomy, physiology, medical

terminology, measurement technology, modeling, and analysis methodologies. These areas need to be introduced and reviewed as well. My experience is that the students generally find these studies to be easier than a review of mechanics fundamentals.

Finally, the in-depth study of a specific area or application of biomechanics is ideally suited for directed self-study by the students. The acquired learning can be documented by having the students prepare a report or paper—typically ten to twenty pages with figures and references. To further document the self-study learning, the students may be asked to share their findings with the class in brief presentations. These student presentations, occurring in the last two to three weeks of the course, provide both the presenting students and the other students with in-depth learning and further inspiration for more advanced studies.

The subject matter for the in-depth studies consists of mutually agreed topics by myself and the individual students. Deciding upon a topic usually takes two to three weeks at the beginning of each quarter (individually, outside of class). I have found that the best topics appear to be aspects of sport mechanics and injury mechanics.

## CONCLUSIONS

In summary, after nearly 30 years of teaching an introductory biomechanics course to upperclass and beginning graduate engineering students, I discovered that the students have three basic needs:

- motivation;
- remedial work in mechanics fundamentals;
- learning in biomechanics itself.

These needs can be met in two ways: (1) by 'inspirational' in-class vignettes followed by accelerated reviews and studies, and (2) by guided independent studies by the students.

The accelerated in-class studies are divided into three parts:

- mechanics review;
- review of basic biomechanical terminology;
- study of basic biomechanics topics.

In the independent study, the students are focusing upon a specific topic of interest to them, gaining in-depth knowledge. They are also preparing a report, documenting their learning together with an in-class presentation.

A successful completion of these activities should prepare the students for more advanced study and research.

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