I've chosen to entitle my part of this program "A Recovering Schizophrenic's Perspectives on Biomechanics." Perhaps I should start by explaining what I mean by this title: In addition to addressing some questions from the members of our academy, I was invited to give my perspective on undergraduate instruction. But like any good schizophrenic, I have more than one perspective. And like any bad schizophrenic, I am often troubled by this. So in the interest of sanity, I have been trying over the years to get some of my perspectives reconciled with each other. Although I believe that I have made progress, I still consider myself to be in the process of recovery. Since the recovery process is inherently reflective, I'll be sharing some of the thoughts I've had along the way and using that as a backdrop for responding to your questions. Hopefully you have not been as tormented as I have been. And just in case you think my opinions might be unhealthy, let me assure you that most of the opinions I will be offering today are grounded in the reading that I have been doing in pragmatic philosophy, cognitive science, pedagogical physics, the sociology of science, art instruction, and golf. And one final caveat: Most of the visuals you will be seeing were either done by or of students using free software. So you should be heartened that you could do a better job at no cost.

Biomechanics Bodies of Knowledge

The essence of my schizophrenia is rooted in the fact that I have four perspectives on biomechanics. For argument I will call these perspectives "biomechanics bodies of knowledge."

Embodied Biomechanics

When I was growing up, my goal in life was nearly synonymous with the basketball goal on my parents' driveway. I spent hundreds and hundreds of hours trying to become a good shooter. Part of my time was spent observing better players and trying to adopt elements of their technique. Part of my time was in unfocused trial and error with the obvious feedback of whether the shot scored or not. Little did I realize that through action and observation I was building a knowledge base of embodied biomechanics. When I was about 15, my coach told me that there was a positive relationship between arch and success in free throw shooting. Somehow, in the manner of a teenager, I realized that that statement was a testable hypothesis.
Research-Based Biomechanics

With my coach's statement in mind, I began a very subjective form of experimentation. At first I tested the basic truth of the statement. That led to an awareness of non-linearity and conditional truth. (I.e., some arch is good, but too much is not.) Next I tried to determine which path of projection worked best for me. Eventually I realized that my balance and range of motion also affected my success. And since the combination that worked on one day did not necessarily work another day, I developed a calibration system to use during warm-up. In short, I was a young citizen-scientist using simple research to extend my embodied biomechanics. For the most part it was private and non-verbal, but it was also rich and effective – by my junior year of college I was hitting 90% of my free throws.

Instructional Biomechanics

In my senior year of college, as a math major, I elected to take anatomically- and mechanically-based biomechanics courses. In my mechanical course my term project consisted of filming and analyzing skilled and unskilled free throw shooters. Although I enjoyed these courses, they were not particularly fulfilling. So I began a master's program in biomechanics the next year. As with most graduate programs at the time, there was less emphasis on the content of biomechanics and more emphasis on the methods. But I was excited to begin my formal research work. And as you might guess, my thesis was on skill in free throw shooting.

Applied Biomechanics

The next year I was hired to be the softball coach at Penn State. But mostly that job consisted of teaching a diverse assortment of activity classes to 750 women who had not benefited from Title IX. This was a stiff challenge for a math major. I had not taken any classes in how to teach activity classes. And I was teaching sports where my embodied knowledge was scant: I was assigned to teach tennis and bowling even though I had grown up in a town without a tennis court or a bowling alley. I had to construct an applied biomechanics in a hurry. Only later did I realize that the majority of what I used came from my embodied biomechanics instead of my instructional biomechanics. Nevertheless I managed to be relatively effective because range of motion, balance, and path of projection were relevant to tennis players and bowlers as well as basketball players.

Integration of Biomechanics Bodies of Knowledge

Thus in the context of activity teaching, I had begun to develop an applied biomechanics that was integrated with my embodied biomechanics. In addition, it
seems that most of my formal and informal research questions have arisen from
the conjunction of my embodied experience and my interest in application.

The knowledge base that was an outlier for me was instructional
biomechanics (see Figure 1). Since I began teaching
biomechanics in 1974 I have
tried to teach the typical
content (as per our guide-
lines) in my classes at six
rather different universities.
But to some extent
instructional biomechanics
has always seemed like a
foreign language to me
because it was too remote
from my other three (more
native) biomechanics bodies
of knowledge.

Indeed, this gap with instructional biomechanics has been the main source of
my schizophrenia. (And I suspect that more than a few students suffer from
similar schizoid tendencies.) Finally, in the interest of harmony, one of my aims
has been to bring what I teach in biomechanics classes closer to what I do when I
am moving or working with movers. In this regard, I have tried to take a
problem solving approach.

Framework for Reflective/Scientific Thinking

Drawing from pragmatic philosophy, John Dewey (1910) has postulated a
framework for reflective or scientific thinking. This is also his framework for
purposeful action or problem solving. It starts with the specification of a
problem/question or alternatively the goal/end (see Figure 2). Next one designs a
potential path or the means to connect the problem to the goal or solution.
Then come experimentation, observation, and evaluation. In the process there are key questions to ask:

<table>
<thead>
<tr>
<th>Are we on target and if not</th>
</tr>
</thead>
<tbody>
<tr>
<td>Should we modify the problem statement?</td>
</tr>
<tr>
<td>Should we modify the path?</td>
</tr>
<tr>
<td>Is our pursuit of the solution in balance and if not</td>
</tr>
<tr>
<td>Is it slowing our progress?</td>
</tr>
<tr>
<td>Is it taking us off the path?</td>
</tr>
</tbody>
</table>

**Balance**

As you see, the concept of balance was important to Dewey. And it's important to me, so please permit me to digress for a moment to say something more about it: In my view, balance does not mean that two opposing qualities need to be equal. Rather, as seen in Figure 3, balance can be described as the harmonious and contextually appropriate interplay of opposing qualities. In this context – with biomechanical balance as a goal – the performers are of different sizes and in different postures, yet the combination is harmonious and the goal is achieved.

![Figure 3. Depiction of balance from New York Times Magazine.](image)

**The Problem of Biomechanics Instruction**

Now let us return to the issue of instructional biomechanics. The basic problem for me in teaching undergraduate biomechanics is this: How do we prepare responsible agents of change for skillful and safe movement?
The Problem:
How do we prepare responsible agents of change for skillful and safe movement?

To a large extent this is just a restatement of what we have been saying in our guidelines for more than 20 years:

Exit Competency:
The student should be able to evaluate the suitability of a performer's technique and establish a priority for change in those factors most likely to lead to an improvement in performance.

NASPE, Guidelines & Standards, 1980

My dirty little secret is that for twentysomething years I have not managed to get my students to this level. In terms of Dewey's (1910) model, I don't think the problem is with the goal. I still think our students need to be equipped to be change agents. Obviously they could benefit from additional professional preparation that reinforces what they learn from us, and they should continue to learn on the job. But I think our original guidelines were wise in that they only say that our students should have a basic level of competence in using a systematic approach to applied biomechanics.

If the problem is not with the goal, then it may be with the path or the degree of balance in pursuing the path. Regardless of the adequacy of our path, it seems to me that typical biomechanics instruction may not be very balanced. Therefore I think it behooves us to consider the balance issue, in this case by looking at juxtaposed pairs of terms – one of which I think we emphasize and the other we don't.

ANALYSIS vs. Synthesis

Analysis seems to have a rather broad meaning in our culture and in our academy; for today's purposes, I'll begin by using the term primarily as it is specified in Bloom's Taxonomy (1956). That is, analysis is the separation of a whole into component parts. In this sense, the focus in analysis is on the details. However, according to Dewey (1910), all details should not be considered equally relevant. Instead, the emphasis should be put on details or components that matter or have significance. In effect, this requires us to ask and answer the question, What matters? In modern biomechanics, analysis has always had its place, but it
has become increasingly prominent in the last 25 years. For example, Hay (1978) accentuated the analysis of sports techniques. From my view, we have done a better job of breaking technique down in the Bloom sense than in identifying the significant factors in the Dewey sense. Would changing our balance in this area help us reach our goal?

<table>
<thead>
<tr>
<th>ANALYSIS</th>
<th>Synthesis</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Separation of a whole into component parts; details</td>
<td>• Combination of ideas to form a new whole; relationships; prediction</td>
</tr>
<tr>
<td>• Emphasis – what matters? what is significant?</td>
<td>• Placing the significant in context – why does it matter?</td>
</tr>
<tr>
<td>• Hay (1978) – [our] concern is the analysis of techniques employed in sports</td>
<td>• Broer (1960) – there are many common elements which [apply] regardless of the activity</td>
</tr>
</tbody>
</table>

In contrast to analysis, synthesis is the combination of ideas to form a new whole (Bloom, 1956). Here the focus is on relationships and predicting from what is known. With synthesis we can take the significant components of analysis and place them in context (Dewey, 1910). We do this by asking and answering the question, Why does it matter? For some reason the use of synthesis in biomechanics has waned as the use of analysis has waxed. Once upon a time (1960), Broer emphasized the significance of relationships with her statement that there are common elements with broad application in many contexts.

In my opinion, instructional biomechanics – as it is currently practiced – is quite out of balance in favor of analysis (and a skewed form of analysis at that). At least we seem to have good company historically. In 1910 Dewey lamented, "In some subjects, students are immersed in details; their minds are loaded with disconnected items . . . only when relationships are held in view does learning become more than a miscellaneous scrap bag." As Dewey suggested, the remedy for too much analysis is not necessarily less analysis but more synthesis. Rather than framing the issue as either analysis or synthesis, why not use both analysis and synthesis. In particular, we might benefit from identifying what matters (analysis [of the significant sort]) and connecting that to why it matters and what can be done with it (synthesis).
This tension between analysis and synthesis appears to motivate the question of Monique Butcher: "How do we get students to think about movement comprehensively when we teach in fragments (i.e., 1/3 anatomy, 1/3 biomechanics, 1/3 qualitative analysis)?"

Although there may be several pathways to resolution of this issue, I believe that any good pathway is likely to have a reasonable balance between analysis and synthesis. Moreover, any economical pathway is apt to feature selective analysis. For what it is worth, I will share the general approach that I am now taking in regard to this problem: In terms of analysis, I break the content of my course into three areas – the force field, the mover, and the movement (see Figure 4). Each of those areas are further broken down to include the material that I think matters most as well as the material that has been historically listed in our guidelines. (N.b., there is only modest congruence between what I think matters most and what has been specified in our guidelines.) Thus we cover kinetic foundations by studying external forces in the force field and internal forces in the mover, kinematic foundations by studying the movement, and anatomical foundations by studying the mover. From the beginning we try to synthesize our material within and across areas by keeping relationships in view. Among other things, that allows us to consider the mover as a whole and to integrate much of our anatomical and mechanical content. It also affords the opportunity to discuss movement as something that emerges from the mover's characteristics and circumstances (see dashed arrow in Figure 4). From there we can begin to predict what sorts of movement outcomes are likely to happen when one modifies the environment or the mover's profile (see arched arrows in Figure 4). In addition, we consider how changes in skill are somewhat predictable. By emphasizing the things that matter and can be modified and adding some tools of measurement, application is infused throughout our course.

**PRECISE vs. Sufficient**

Another characteristic of our field is that we tend to be very precise. This probably stems from our training. After all, we've taken many science and math courses, we've spent countless hours using high-tech equipment, and we've written dissertations and published data-based research. If asked to analyze the movement depicted in Figure 5, most of us would instinctively make precise measurements of the joint angles. Yet this is likely to be overkill for almost any practical situation. Most of the time a less precise answer would be sufficient for determining whether or not to recommend a change to a mover. And this is fortunate because sufficient – as opposed to precise – answers are more attainable with our students' budgets and abilities. Although there are reasons to retain some precise methods in our courses, a contextually appropriate balance between precise
and sufficient methods may be our best approach. For example, I have had some success using the five-inch-line and tick-mark approach shown on the right of Figure 5. Then, by making precise, quantitative measurements (as per the left side of Figure 5), the students are able to validate their qualitative observations.

<table>
<thead>
<tr>
<th>PRECISE</th>
<th>Sufficient</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Trunk Inclination</strong> = 47.2 degrees</td>
<td><strong>Trunk Inclination</strong></td>
</tr>
<tr>
<td><strong>Knee Flexion</strong> = 90.9 degrees</td>
<td><strong>Knee Flexion</strong></td>
</tr>
</tbody>
</table>

Figure 4. Free body diagram.

Figure 5. PRECISE and Sufficient measurement.
From the questions and comments that were submitted to this panel, it appears that this issue is a major concern for many – though the interrogators tended to use different terms. Duane Knudson asked, "What is the appropriate balance of qualitative analysis to quantitative analysis in the introductory biomechanics course?" Monique Butcher asked, "How much instrumentation is 'enough' for students to be exposed to?" And Jim Dowling asked, "Is it necessary to minimize or even eliminate the use of mathematical tools (equations and techniques) in order to deliver biomechanical content to kinesiology and physical education college students?" Similarly, Kevin Carlson was troubled by our "increasing focus on . . . quantitative/laboratory issues as opposed to qualitative/field based issues."

Finding a contextually appropriate balance point between precise/sufficient, quantitative/qualitative, and high-tech/low-tech may be a perpetual challenge for each of us. While I think it is paramount that our students gain a basic competence with sufficient/qualitative/low-tech methods, the paradox is that this end may be well served by incorporating some precise/quantitative/high-tech methods. For example, I believe that facility in making qualitative measurements is improved by making certain quantitative measurements. My rationale is that the need to be precise typically focuses one's attention in a way that then can be transferred to subsequent situations where sufficient answers are sought. Also, by developing some standard exemplars with precise answers, it would be relatively easy to give feedback to students who give sufficient answers on a continuum (such as a five-inch scale). As for instrumentation, it can help students to obtain precise answers for their comparisons, and it can provide a sense of "where numbers come from." But caution is warranted lest the use of instrumentation devolve into a "black box" experience or a blatant commercial for the elitism of research. Likewise, the use of equations and reasonable, round numbers can be beneficial to add depth of understanding with difficult material. Exposing the infrastructure may not be our most important role, but it may inspire some confidence in what is being learned. As most of us know, expecting students to solve word problems can be deadly to one's popularity. Yet, if we think this is important, we should be able to "sell" it with sound reasons, realistic expectations, and sensible proportions. I have found that most students appreciate opportunities to enhance their abilities to think procedurally as long as there is a safety net in place.

VERBAL vs. Visual

As with most academic areas, we tend to emphasize a verbal (or mathematical) approach to our material. This seems to be true in many cases where a visual approach might be particularly illuminating. Of course, we don't
entirely shun the visual domain, but our efforts there seem skewed as well: We are much more likely to resort to isolated pictures or other static depictions of movement rather than to employ movies or illustrations that convey the dynamic nature of movement. It is astonishing to me that a field that was once called kinesiology (i.e., the study of movement) finds itself relatively fixed in this position.

Addressing this verbal-visual imbalance is not without cost. However, based on my recent experience with this issue, I think it is worth it. For example, a traditional, verbal description of translation is given on the left of Figure 6. Since I think that true translation is relatively rare in human movement, I sought to show how this concept could apply to ordinary activity. (Please keep in mind that a "squinty-eyed" or sufficient criterion of reality is quite useful in many circumstances). The home movie on the right of Figure 6 was taken by Kevin Zwetsloot of his father. I used iMovie, QuickTime, and the free version of PhotoShop to embellish it. (Apologies for the production values – shrinking this movie had the unintended effect of turning a red line into a lipstip-like smear.) After viewing this movie, most students seemed to understand how bodies as a whole could translate during activity. Mr. Zwetsloot also benefited from this movie: According to Kevin, his father was not aware until he saw this movie that he was "dipping his shoulder" (in compensation for arthritis); following a trip to the bowling alley to tweak this, he bowled a 300 game!

<table>
<thead>
<tr>
<th><strong>VERBAL</strong></th>
<th><strong>Visual</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Translation</strong></td>
<td><img src="image" alt="Visual Version" /></td>
</tr>
<tr>
<td>A body is translating if the parts move through the same distance in the same direction in the same time.</td>
<td><img src="image" alt="Visual Version" /></td>
</tr>
</tbody>
</table>

Figure 6. VERBAL and Visual versions of translation.
As you all know, the possibilities for us with digital video (DV) are manifold. To offer just one more example, we can combine selected frames from DV to convey a sense of movement in a single picture. With this in mind, I extracted and modified two snapshots of Mr. Zwetsloot to illustrate an important biomechanical concept (see Figure 7).

![Figure 7. Illustrations of range of motion.](image)

Kevin Carlson expressed concern about "the large amount of material that is recommended to be covered in one undergraduate course." I believe he speaks for many of us. Although I doubt that any single corrective for this exists, we might be able to save some time by replacing a few thousand words with pictures.

**OBJECTIVE vs. Subjective**

Another hallmark of biomechanists is that we tend to be very objective. For example, Bunn (1972) expressed this orientation through the use of the metaphor, "Man as machine" (see Figure 8). As this orientation has gained prominence, an earlier, more subjective orientation – expressed so eloquently by Wells in 1950 (see Figure 8) – has been obscured. Once again, I think we would benefit by increasing our subjectivity to counterbalance our objectivity.

This shift does not have to be difficult. Undergraduate students have got to be the most inherently subjective population on earth. Why not use their ready subjectivity to make connections with our material? The picture in Figure 9 illustrates a means that I have used with startling effect. During lab we filmed
<table>
<thead>
<tr>
<th><strong>OBJECTIVE</strong></th>
<th><strong>Subjective</strong></th>
</tr>
</thead>
</table>
| *Man is a machine.*  
*(Bunn, 1972, p. ix)* | *The student of kinesiology . . . can only stand in reverent wonder at the intricate mechanism of the body.*  
*(Wells, 1950, p. 1)* |

Figure 8. OBJECTIVE and Subjective orientations in biomechanics.

Each student as he or she was several yards from the end of a 50-yard sprint. At the same time other students were collecting stopwatch data at 10-yard intervals. As they ran, some students engaged subjectively due to the competition, and some were more tolerant than engaged. The first objective part of this assignment was to calculate and graph time vs. displacement, velocity, and acceleration. Most students were tolerant of the math – perhaps because they viewed it as a trade-off for the subjective benefit of being out of doors. Before the next lecture, I processed each movie to make a picture showing sequential take-off frames (and certain elements of technique). As the students received their pictures, there was a palpable spike in their interest in biomechanics. Using the embedded ruler and time data, they could calculate their own stride length and stride rate and compare it to classmates and experts if they wanted. Most could focus on the process rather
the product of their running for the first time. And many could make comparisons relative to size and have an epiphany that they were not inferior after all.

Figure 9. Example of combining objective and subjective approaches.

LEFT vs. Right

As a general rule, biomechanists don't look to the cognitive sciences for input on our problems. But I believe that we might benefit from some of the scholarship in embodied knowledge and brain laterality. For example, Lakoff and Johnson advance the following arguments in *Philosophy of the Flesh* (1999, pp. 3-4): "The mind is inherently embodied." "The same neural and cognitive mechanisms that allow us to perceive and move around also create our conceptual systems and modes of reason." Thus "reason [and the structure of our thoughts] arise from the nature of our brains, bodies, and bodily experience." In other words, "reason is shaped crucially by the peculiarities of our human bodies . . . and by the specifics of our everyday functioning in the world." "To understand reason, we must understand the details of our visual system [and] motor system." Also, "reason is . . . mostly unconscious . . . largely metaphorical and imaginative . . . [and] emotionally engaged." Therefore, it appears that we would do well to align the conceptual systems that we teach about movement with the ways that we
actually move. Moreover, working as we do in the discipline that studies human bodies and their movement, we seem to be uniquely positioned to construct knowledge that spans the body-mind dichotomy and transcends our discipline.

As we endeavor to understand and employ embodied concepts, we might gain some insights from the study of brain laterality. Forty years ago neurologists believed that the right side of the brain didn't do much of anything and that the left side of the brain was dominant by default. After all, a fully conscious patient could lose the entire right brain to surgery and not even realize it was missing! Over the past few decades, however, we are beginning to appreciate that the right brain uses a visual/tactile/spatial logic; apprehends things in a direct, immediate, holistic manner; operates in an instinctive, rather unconscious manner; activates when stimuli are rapid and/or complex; and perceives emotion. The right brain also appears to be skilled at synthesizing, but disinclined to comprehend reductions; to be content with approximate, evolving, sufficient solutions; to be visual rather than verbal; and to be more emotional. (Thomson, 1998) According to Edwards, who wrote *Drawing on the Right Side of the Brain* (1999), artists are successful to the extent that they can use the many talents of the right brain. Niednagel (1997) suggests that people who favor the right brain have an advantage in sports. And this is consistent with the EEG evidence: The brain waves of more successful golfers appear to localize in the right hemisphere before the ball is struck (Crews & Landers, 1993). The left brain has many, different talents as well. The talents of both hemispheres are summarized in Figure 10. If you will compare the left-brain list with the previously mentioned areas of emphasis in biomechanics, you will see why the case could be made that contemporary biomechanics is not in its right mind. As a field we seem to be similar to the lobotomized patient and the neurologists of 40 years ago. The question is, will we be able to recognize that we have right brains and realize that they hold the solutions to many of our most vexing problems?

In the following paragraphs I will highlight a few more areas in which I think instructional biomechanics is out of balance. And I will argue that we need a full-brain biomechanics if we are to reach our goal of educating responsible agents of change in movement.

**BORROWED vs. Built**

In 1950 Wells stated that kinesiology's "unique contribution is that it selects from other sciences those principles which are pertinent to human motion." (p. 1) More specifically we have borrowed the muscles of DaVinci, the math of Decartes, and the mechanics of Newton. In other words, we spent much of the twentieth century identifying material from the sixteenth-eighteenth centuries that
is relevant to human movement. As noted, we have spent much less time prioritizing those elements of our borrowed biomechanics that matter the most in improving movement. But the bigger problem, it seems to me, is that we have done even less to build a modern body of biomechanics knowledge that fits our purposes. If you disagree, I ask you: What is our paradigm of practical biomechanics? To date most of our applied research takes a rather ad hoc approach to the problems of movers and their movements. What could we accomplish if we extracted what we know in our right brains about movement, systematized this knowledge, and tested it for efficacy? I predict that the results of our research would be cohering in a manner that strengthens application, and our instruction would be recapitulating this.
BOOK KNOWLEDGE vs. Embodied Knowledge

Parallel to our continued reliance on borrowed knowledge, I think we have over-emphasized book knowledge in our left-brain-dominant biomechanics. We teach all about force couples and many other kinetic concepts that rarely enter either the left or right brains of people who are not enrolled in biomechanics. (And one could argue how well this book knowledge sticks in the left brains of people who are enrolled in biomechanics.)

Meanwhile all of us everyday are using an embodied biomechanics. We may not be conscious of it because most of this information may stay in our right brains as we make countless decisions about movement. For example, I believe that we make frequent decisions about how much range and speed of motion to use, how to maintain balance, and so on. Presumably the same conceptual circuitry is activated to some degree when we watch others move. Thus, through constancy of use, we seem to be virtually hard-wired for certain movement concepts. My list of core concepts is given in Table 2. Your list may vary.

<table>
<thead>
<tr>
<th>BOOK KNOWLEDGE</th>
<th>Embodied Knowledge</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Force couple, etc.</td>
<td>• Range of motion</td>
</tr>
<tr>
<td></td>
<td>• Speed of motion</td>
</tr>
<tr>
<td></td>
<td>• Number of segments</td>
</tr>
<tr>
<td></td>
<td>• Nature of segments</td>
</tr>
<tr>
<td></td>
<td>• Balance</td>
</tr>
<tr>
<td></td>
<td>• Coordination</td>
</tr>
<tr>
<td></td>
<td>• Compactness</td>
</tr>
<tr>
<td></td>
<td>• Extension at release</td>
</tr>
<tr>
<td></td>
<td>• Path of projection</td>
</tr>
<tr>
<td></td>
<td>• Spin</td>
</tr>
</tbody>
</table>

Based on my previously mentioned experiences, I believe that these (or similar) concepts have the potential to be integrated building blocks in a practical biomechanics. The first condition for this to happen is that the typical person must be able to connect the right- and left-brained – the verbal and visual – versions of these concepts. There is evidence from open-ended observation
research that both non-professionals and professionals in movement are inclined to do this (Bird & Hudson, 1990). In addition, my students have almost instantly made the connection in the manner expressed by Dewey (1910, p. 173): "Everyone has experienced how learning an appropriate name for what was dim and vague cleared up and crystallized the whole matter." The second condition for fulfilling the potential of core concepts in instruction is that we must build an appropriate body of knowledge about them.

**BASIC BIOMECHANICS vs. Applied Biomechanics**

Given our penchant for borrowed, book biomechanics, basic – as opposed to applied – material seems to predominate in our guidelines and curricula. No one seems to doubt the necessity of covering such basic information as the force-velocity relationship (noted on the left of Figure 11). But we have much less to say about how our students will be able to apply this information. Although my curriculum is a work in progress, I make a point to show how certain (desirable and undesirable) movement outcomes are related to the force-velocity relationship. For example, the correspondence between force-velocity demands and range of motion (RoM) is shown in the schematic on the right of Figure 11.

<table>
<thead>
<tr>
<th>BASIC</th>
<th>Applied</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Force-velocity relationship</td>
<td></td>
</tr>
</tbody>
</table>

![Figure 11. Basic and applied knowledge.](image)
(For a given mover and maximum context, RoM can be predicted with a horizontal line connecting the force-velocity demand and the beginning and ending position scales.) To change the RoM, one may need to change the force-generating ability of the mover or the force requirements of the activity.

But there are other considerations besides force and velocity when considering RoM. For example, RoM could be restricted because the mover is inflexible. Alternatively, RoM could be restricted because the mover is not particularly skilled. Or, taking a much broader view of biomechanics/kinesiology, RoM could be restricted because of the cultural force field or the psychological state of the mover. Given these complexities, I think it is crucial for us to build an applied biomechanics that is connected to and consistent with what we know in basic biomechanics but that transcends basic biomechanics to be applicable to the movement problems of holistic movers in an ambiguous world.

Many of us seem to identify applied biomechanics as a problematic area. For example, Duane Knudson asked, "Should the application of biomechanics be taught using a few generic principles of biomechanics (e.g. Norman, 1975, Hudson, 1995, Knudson 2001)?" In keeping with Broer's (1960) advocacy of common elements, I assume that our students might be better able to understand some of the complexity of the world if we can use simplifying constructs. Plus, the use of simplifying constructs might help us deal with Kevin Carlson's issue of "the large amount of material that is recommended to be covered in one undergraduate course." So I certainly believe it is worth our while to explore in this direction. However, if our simple systems do not transcend basic biomechanics to be truly useful in the universe of application, then we have still fallen short of our goal of educating agents of change.

Our difficulties with applied biomechanics appear to be reflected in the complaint of Steve McCaw: "I am tired of having biomechanics be blown off by the pedagogy faculty. In my class, I emphasize the need to use biomechanics as the basis of skill analysis for learners of all ages, but then look at how students are taught in activity classes and I can see why they think biomechanics is irrelevant. There are limited, and often wrong, references to biomechanics principles." In my opinion, Steve is a very conscientious, committed, competent teacher, so I do not fault him for having this problem. Rather I commend him for articulating what may be the elephant in the biomechanics living room: Despite our best efforts, much of what we do is considered irrelevant. While I am not about to advocate an unprincipled approach, it seems that our principled approach is not connecting with our colleagues. That is, our colleagues, who have presumably had biomechanics courses, are showing with their actions that our instruction has had limited effect. (N.b., this is consistent with Hoffman's (1984) contention that
students in general are not learning what they need to in our classes.) In fact, one could argue that movement professionals who have not taken a class in biomechanics are not at a demonstrable disadvantage when compared to those who have. There are simply too many golf pros, such as Harvey Penick (1992, 1993, 1995, 1996), and other successful coaches who have not had biomechanics to say that our contemporary content is essential. Of course, I believe that most students are better off in many ways because they've had our classes, but I take this charge of irrelevancy very seriously.

What would it take for our classes to be widely seen as relevant, even essential? Predictably, my best guess is that we need to bridge the gulf between the embodied biomechanics that most movers possess and the basic biomechanics that we teach. If, after decades in the field, my default knowledge base is the embodied one, I suspect that most of our students may make a similar reversion when away from our classes. There is simply no evidence that our instructional biomechanics is more potent for most folks than their pre-existing embodied biomechanics. In response I say, If you can't beat them, join them. That is, I believe that anyone's embodied biomechanics can be strengthened and extended with proper instruction. Therefore, in my view, our challenge is to build and deliver an instructional biomechanics that integrates with and enhances embodied biomechanics. While this may sound daunting, it could be as simple as shifting our balance and engaging our right brains to access our own embodied knowledge.

**CONTENT vs. Skills**

As an academy we seem to be quite absorbed with our content. Witness the ongoing concern with our guidelines and standards. According to Ravetz (1971), it is common for scientists to focus on standards when their field is in an ambiguous, pre-paradigmatic state. So I would take our emphasis on content and standards to be a sign that we are discontented and in search of stability. Of course, working toward a more satisfying content is important. But we might improve our stability by getting a better balance between content and skills. For example, if our students are to become agents of change, they will need the skills of analysis, synthesis, and evaluation. Fortunately, these higher-order thinking skills can be developed to some extent in conjunction with content. In addition to these general skills, our students need the specific skill of observing/measuring movement as it happens with sufficient accuracy to make recommendations. Given the difficulty of this skill, progressive practice (ideally with prompt feedback) may be needed. But knowledge of content and thinking/observing skills by themselves are not enough. If our students are to be change agents, they need "know how" – and that only comes with experience in combining content and skills in context (see Figure 12). So I think it is incumbent on us to help our
students develop a fundamental level of know how; otherwise, our classes will fall
short of our goal. Needless to say, I don't think an unbalanced biomechanics will
get us there.

Figure 12. Know how at the intersection of content and skills.

As we seek and share teaching practices that expedite our students' progress,
let us not overlook the use of tools to lighten some of the learning. For example,
I would rather that my students not spend time memorizing things that can be
looked up. In this regard, I provide laminated sheets for them to refer to at any
time including exams. These include drawings of muscles that reveal attachments;
matrices of muscles and actions; equations; and diagrams (such as that in Figure
11) that connect purpose and observation in skilled movement. The students seem
to appreciate these tool sheets, and there are even anecdotal reports of their use
outside of class.

Besides reducing memorization (and baiting students to use biomechanics in
their personal lives), tool sheets have other advantages. For example, Monique
Butcher asked, "How do we meet program certification requirements (i.e. Athletic
Training – they need origin, insertion, action, innervation) without compromising
what biomechanists want to teach (more mechanics?)?" In a better world, our
students would have very good prerequisite coursework in human anatomy, and
students who need to know attachments and the like would learn it there. More
realistically our students enter our classes with varied backgrounds in anatomy.
By using anatomical tool sheets, those with the poorest backgrounds can move
ahead without being too compromised. And those with the best backgrounds or
the greatest need to know anatomy can use tool sheets at a more refined level to
reinforce or extend their knowledge. Equation sheets can serve a similar purpose for students who have different backgrounds in math and physics. For what it's worth, I have not had any students who choose to ignore the tool sheets.

An Attempted Solution

In the fall of 2000 I received a local grant to incorporate digital video in my biomechanics class. As I was shifting the balance between verbal and visual material, I decided to redesign several other aspects of my class along the lines of what I have discussed today. There is much work still to do, but the response so far has been extremely encouraging. Exam scores have improved by several percent, and attitudes have ranged from solidly to shockingly positive. Sometimes I think I have been transported to Lake Wobegon – where all the students are above average.

So I am emboldened to share a brief outline of how I have tried to reach the target of educating responsible agents of change in movement. But please keep in mind that I am sharing a process more than a product. I am trying to find an appropriate interplay of ideas for my context, and I encourage you to try to do the same for yours.

Context

The situation at Chico State is thus: Our introductory biomechanics class is 4 credit hours with 3 one-hour lectures per week and a two-hour lab. All of our majors are required to take the class; those in exercise science take a second biomechanics class. There is a human anatomy prerequisite; entering knowledge varies considerably, in part because students tend to take the prerequisite at community colleges all over California. Most students have not had physics or trigonometry. Few of the students are varsity athletes, but most have had substantial experience in one or more movement forms. Career aspirations vary widely.

At present 3 different people teach biomechanics at Chico State. The students in my section have access to extensive lecture notes with illustrations, several brief movies (such as the one in Figure 6), self-tests and sample exams, plus a syllabus and course calendar on a university server. Most also buy printed copies of the illustrated notes. Toward the end of the semester the students get personal CD-ROMs containing movies of their movement during lab and for their term projects. Our exams are slanted toward problem solving in movement contexts; answers are often short essays that give a recommendation and a rationale related to course content. This takes time, so I give the first 2 of 3 exams during lab rather than lecture. The remaining labs are task-oriented;
typically there is a mini-lecture followed by some activity; students confer in small groups to complete worksheets based on the activity.

In some ways my curriculum is a throwback to the old kinesiology courses: I prefer to put the mover and the movement in the foreground instead of anatomical and mechanical content. As Wells (1950, pp. 1-2) said, "The study of kinesiology . . . has a dual purpose: on the one hand, the purpose of perfecting performance in motor skills, and, on the other, the purpose of perfecting the performer." It seems to me that all of our majors would do well to understand what the mover can do to move better and what the movement can do – both good and bad – to the mover. As a staunch integrationist, I like having mover and movement, anatomy and mechanics, foundations and applications, and students of all stripes in one course.

But your experience may vary. Steve McCaw asked, "What about the growing rift between the biomechanics needs of exercise science students vs. athletic training students vs. PE teaching students? I have noticed a great increase in the chasm between the interests of these groups over the past several years." Similarly Duane Knudson wondered, "Should specialized biomechanics courses be taught for physical education and exercise science/sports medicine majors?"

Alternatively, Kevin Carlson said, "Ultimately, I would like to see a refinement of the guidelines and standards that would allow for the inclusion of the standards in their entirety into one introductory undergraduate course. If there are other pieces of information that need to be addressed via a second course that would be fine with me." Like Kevin, at this point I favor a unified first course with specialized courses following if needed. But I have not been experiencing the friction that Duane and Steve identify. If you are sensing friction, then separation may be the answer for you.

**Course breakdown by time**

One of the new features in my curriculum is what I call the course in miniature. (The idea is a spin-off from Kline's (1988) *The Everyday Genius.*) We begin the semester by building a basic scaffold (see Figure 4) for the class. We flesh it out with several things that the students already know, and as we do, we make note of the interactions between the components. By including non-physical forces and the mind as well as the body of the mover in our discussion, the students are encouraged to see biomechanics in a more holistic way. We also leave some room to grow during the semester by putting a few space holders on the scaffold. Next we spend an hour or more in the movement section of the scaffold. Here I educe the core concepts (Table 2) from the students and connect that with the visual and verbal vocabulary that we will be using. Finally, we
spend an hour or so considering force with a special emphasis on embodied perspectives. (Johnson [1987] and diSessa [1993] provide the foundation for this.)

Table 3. Allocation by time.

<table>
<thead>
<tr>
<th>Time</th>
<th>Component</th>
</tr>
</thead>
<tbody>
<tr>
<td>10%</td>
<td>Course in miniature</td>
</tr>
<tr>
<td>35%</td>
<td>BIOmechanics</td>
</tr>
<tr>
<td>35%</td>
<td>bioMECHANICS – Kinematics</td>
</tr>
<tr>
<td>20%</td>
<td>bioMECHANICS – Kinetics</td>
</tr>
</tbody>
</table>

Once we have finished the course in miniature, we begin the anatomical section of the course, which I renamed BIOmechanics to emphasize integration. Although anatomical aspects of the mover are in the foreground, we connect this with several of the core concepts as well as our rudimentary understanding of force. As with each section of the course, we deal with content, skills/tools, application, and modification. The goal is for the students to understand how movement can be modified to help and not harm the mover. We work backward from that by selecting what matters most, addressing mechanisms, and analyzing relevant elements of movement.

The second and third major sections of the course are in bioMECHANICS. The integrated emphasis here is on the mechanics of humans. The core concepts are covered in greater detail in the kinematic section; the force field is covered in the kinetic section. Again, the goal is modification (i.e., how the mover can improve movement.) The time allotted to each area is given in Table 3. You will note that kinetics gets the least time. In part this is because forces in general were covered in the miniature course and internal forces were covered in BIOmechanics. It is also because I think kinematics is more important than kinetics for a practitioner.

Course breakdown by content

Although I try to make my course as seamless as possible, there are some topics that get more emphasis in either the BIOmechanics or the bioMECHANICS sections. These are outlined in Table 4. In BIOmechanics we appeal to vanity by discussing movers and their muscles. Most of my students, regardless of their
career aspirations, are habitués of the weight room, and they seem pleased to learn more about what is happening under the skin when they lift weights. So this seems to be a good place to spotlight slower, simpler, planar activities. And this fits with exercising for fitness and for rehabilitation. Unfortunately most of my students seem to have a history of injury and rehabilitation, so safety issues have broad interest and fit well in this part of the course.

Table 4. Emphases within Content Areas.

<table>
<thead>
<tr>
<th>BIOmechanics</th>
<th>bioMECHANICS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mover</td>
<td>Movement</td>
</tr>
<tr>
<td>Muscular</td>
<td>Mechanical</td>
</tr>
<tr>
<td>Safety</td>
<td>Skillfulness</td>
</tr>
<tr>
<td>Activities</td>
<td>Activities</td>
</tr>
<tr>
<td>• Fitness</td>
<td>• Sports</td>
</tr>
<tr>
<td>• Simple, planer</td>
<td>• Multiplaner</td>
</tr>
<tr>
<td>• Slower</td>
<td>• Faster</td>
</tr>
</tbody>
</table>

How does movement better humans? How do humans move better?

Most of my students have either felt clumsy when playing sports (or know someone who has). So the bioMECHANICAL section of the course deals with how people can move better. Sports and other fast, complex activities provide a fertile ground for examining skillfulness from a mechanical standpoint. During this unit I work one-on-one in slow-motion/stop-action with the students so they can appreciate some things that they are doing well as they move. Usually I can point out a thing or two that they might be able to do better. In this way I try to model the behavior that I would like for them to learn. Finally each student does a self-analysis/evaluation on an activity of choice. Although we do plenty of objective observation as well, it is in the subjective activities that I notice an emerging sense of personal power in most of my students. I think it comes from understanding skillful movement in body and mind.

**Conclusion**

Very few people in or outside our field would say that instructors of biomechanics are reaching our goal of preparing students to use a systematic
approach to applied biomechanics. In my view, the goal – though distant – is a good one. After quite a lot of observation, experimentation, and evaluation, I believe that our problem is poor balance. In many significant aspects of our instruction, we seem to be putting most of our weight on the left side. I don't know if that is skewing our path, but like the mover in the dark below (Figure 13), I'm pretty sure that it's slowing our progress. If you agree, I hope you'll consider ways that you can get some of your weight on the right side.

Figure 13. Not the best way to make progress.
References


