BIOMECHANICS DONE BACKWARD

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There are several ways in which biomechanics can be done backward. For example, we can look at a movie of backward running and contrast that with a movie of forward running that has been reversed. Many of us can recognize the difference but it is more difficult to know exactly what we see that tips us off. In part this is due to the fact that our conscious, verbal minds are not the source of most of our knowledge about movement.

Backwards biomechanics can refer to looking backward at one's life and career in biomechanics. As I am embarking on a early retirement program, I have only 5 more chances to improve my biomechanics class. Consequently, I'm looking back to see which of the modifications that I have made over the years I want to keep or tweak. And I'm reading new material to find some new things to try. Both old and new ideas are presented here.

Another part of my reflection has been to look back at some of the experiences that have made a difference for me. For example, when I was 16, I aspired to excellence in basketball. I was fortunate to live in an area of Texas that had strong athletic programs for girls at a time that most girls in the U.S. were denied the chance to compete. One day in practice, as I was shooting free throws, Coach Tipton said to me that if I arched my shots more, I would make more. My first, typical teenage, reaction was to think that this was crazy. My second reaction was to recall Coach Tipton's success – 4 trips to state in 7 years – and surmise that maybe he did actually know something. My third reaction was that I had just been given a testable hypothesis -- and so I set off on my first biomechanics experiment: I tried more arch and more arch and more arch to see what would happen. Finally I realized that more arch was good, but too much [as in the snapshot] was not.

Then I had an epiphany – if I could adjust the path of projection much like I could turn the volume knob on a radio, there must be other knobs that I could turn as well. [As you see from this movie,] I figured out that range of motion -- in particular the starting position of the ball -- and balance -- in the form of how much to stagger my feet -- were also knobs that I could turn to good affect. For better and for worse, this experience has had a profound effect on the way that I relate to biomechanics.

Before I continue with other meanings of backward, I want to make a sideways detour. At times it may be helpful for us to change our perspective through the use of analogy. In particular, I think there are some instructive parallels between the development of skill in athletics (or physical activity) and the development of skill in academics, such as biomechanics. We'll return to this later.

Another meaning of backward is to look backward in review. As most of you know, our courses were initially called kinesiology courses. Not surprisingly there was a big emphasis on the study of movement in them. But there was also a strong sense of the mover as a person. When we

changed our course titles to biomechanics, we strengthened our science, but I think we have lost some of our focus on the mover and movement -- and I'd like to reclaim that. Thus I define biomechanics in my course as the study of movers and their movement and the mechanical factors that influence them.

Many of you know that the Biomechanics Academy of AAHPERD has developed and modified national guidelines and standards for teaching undergraduate biomechanics. The guidelines suggest 4 exit competencies as a goal. They are to:

- Observe and describe a movement technique accurately.
- Determine the anatomical and mechanical factors basic to the performance of an observed movement.
- Evaluate the suitability of a performer's technique with reference to the task at hand.
- Identify those factors that limit performance and establish a priority for change.

Plus there are several concrete suggestions as to the appropriate anatomical and mechanical content to reach these goals, such as:

- Explain the force-velocity and length-tension relationships.
- Explain the kinematic relationship between linear and angular motion.
- State the linear and angular forms of Newton's laws of motion.

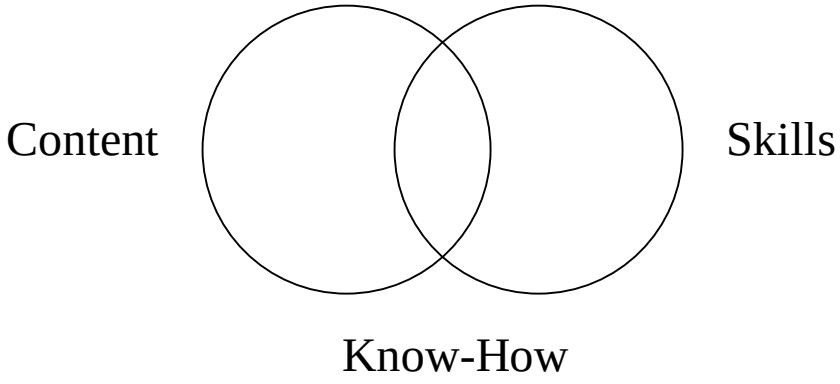
Finally the term backward can be applied to curriculum design when we start at the endpoint or goal and then plan backward. Although backward planning is not a new idea among pedagogy specialists, I was exposed to it when I read *Teaching as Leadership*. This book has come out of the Teach for America Program. If you are not familiar with it, recent college graduates, mostly from selective universities, agree to teach for 2 years in some of our most disadvantaged schools; most of their students are performing at well below grade level. As a rule, these teachers have not had any training in pedagogy until they enter the program. Then they get a crash course in what they need to know to not only teach the students, but also to help them make up much of their deficit. Program leaders have been studying their most successful teachers in order to distill what seems to matter most for student learning and then to infuse that knowledge into their crash courses. If, like me, you don't have much formal background in pedagogy, you might find some of their ideas and frameworks useful. I was particularly struck with their idea of reverse engineering their curricula so that exit competencies drive the content, and I want to spend some time on this.

But first I'll mention a few other ideas from this program: They make the point that we, as a culture, are depriving students of their liberty when we place them in underperforming schools where they do not learn sound academics. I would add -- by looking through our sideways lens -- that we also deprive students of their liberty when we don't help them gain the skills to avoid clumsy or sedentary lives. As they study their most successful teachers, they have seen how academic achievement is uniquely powerful in expanding life opportunities. This, I presume, is somewhat analogous to what it feels like when we learn how to ride a bicycle. They also state that the key is for teachers to have high expectations of their students and to know how to help

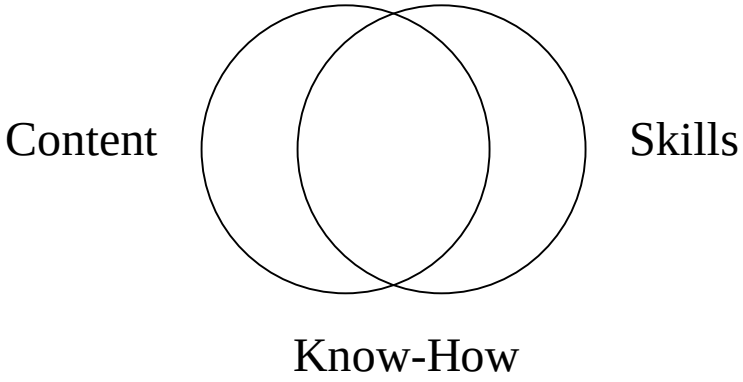
learners reach them. In fact, they say that their best teachers "awaken dreams, breathe life into them, and arouse the belief that we can achieve something grand."

So how would we reverse engineer a biomechanics course? How do we orchestrate learning such that it is equivalent to learning how to ride a bike? [movie] What do we want our students to know and to DO? In my view, the exit competencies of the national guidelines are a good goal for us to aim for. I like to think of these competencies collectively as what a responsible agent of change would do. And I think that most of our anatomical and mechanical competencies from our guidelines will be needed in some form. But this is not enough.

In addition to our content, change agents need some skills. Some of these skills are biomechanical, such as how to observe and describe a movement as per our guidelines. Ideally this skill would overlap with our content knowledge. I call this area of overlap know-how. This is the domain of the change agent and includes our exit competencies.



As we reverse engineer our curriculum, we would do well to expand the areas that overlap. Eventually, if we continue to have elements in our courses that fall outside the area of know-how, we might want to rethink why we continue to include those elements in our courses.



Now let us return again to the area of skills. Not only do we need biomechanical skills such as observation, but we also need some collateral skills. For example, many of my students do not seem to be very good at synthesis. And this hampers their ability to become change agents. Would it make a difference if our material were reconfigured to make it easier to connect with, especially in terms of our students' past experiences, their present lives, and their future ambitions? What if the students were explicitly shown connections that seem too obvious to the teacher? And what if the students were asked to demonstrate their awareness of connections in a variety of settings?

Another collateral skill for the change agent is an awareness or appreciation of context. Too many of the students who enter my biomechanics class seem to believe that there are one-size-fits-all solutions to challenges in movement. In other words, they think that there is a correct way to throw and deviations from that are faults that ought to be corrected.

As an illustration, consider this movie from a middle school physical education class. Many people would consider the athletic-looking boy to have mediocre throwing skill unless they recognize the role that context is playing here. That is, the gym was crowded and the boy's target was relatively close by; thus he did not need to use much range or speed of motion to reach his target. Had the target been farther away, I expect that his technique would have looked a good bit more skilled.

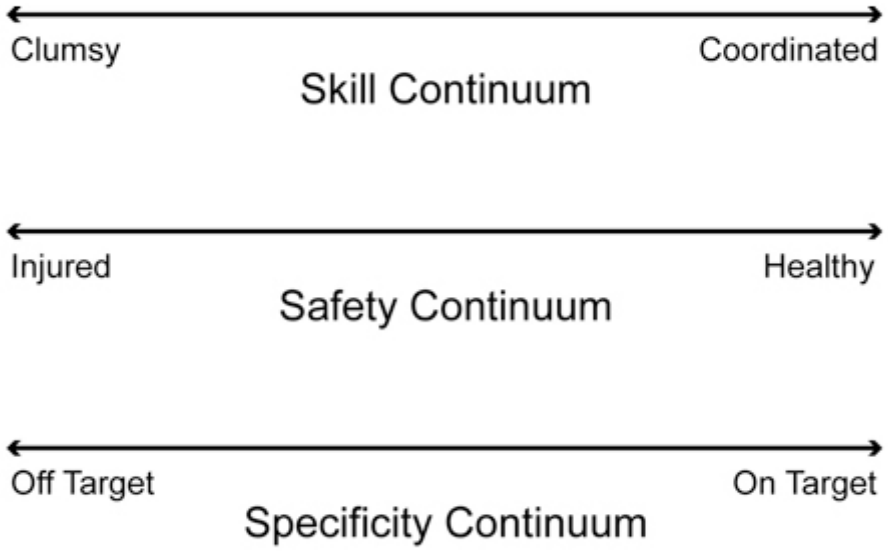
Now let's look at another situation in which context matters. We have three students on their first day of badminton class who are trying to hit a smash. All the students are athletic and have had previous experience tracking falling balls. Given the different drop characteristics of a badminton bird, they are having perceptual difficulties as they overcome their negative transfer of learning. Two of the students sacrifice skill in order to maximize the chance of contact. The other student initially maintains skill but consistently misses the bird. After several misses, he too compromises skill. Until their perceptual abilities improve, it is premature to critique their technique.

In addition to the collateral skills of synthesis and context awareness, many students would benefit from being stronger in analysis and the use of procedures. And for those students who tend to see the world in terms of black and white or right and wrong, becoming a change agent may be particularly challenging.

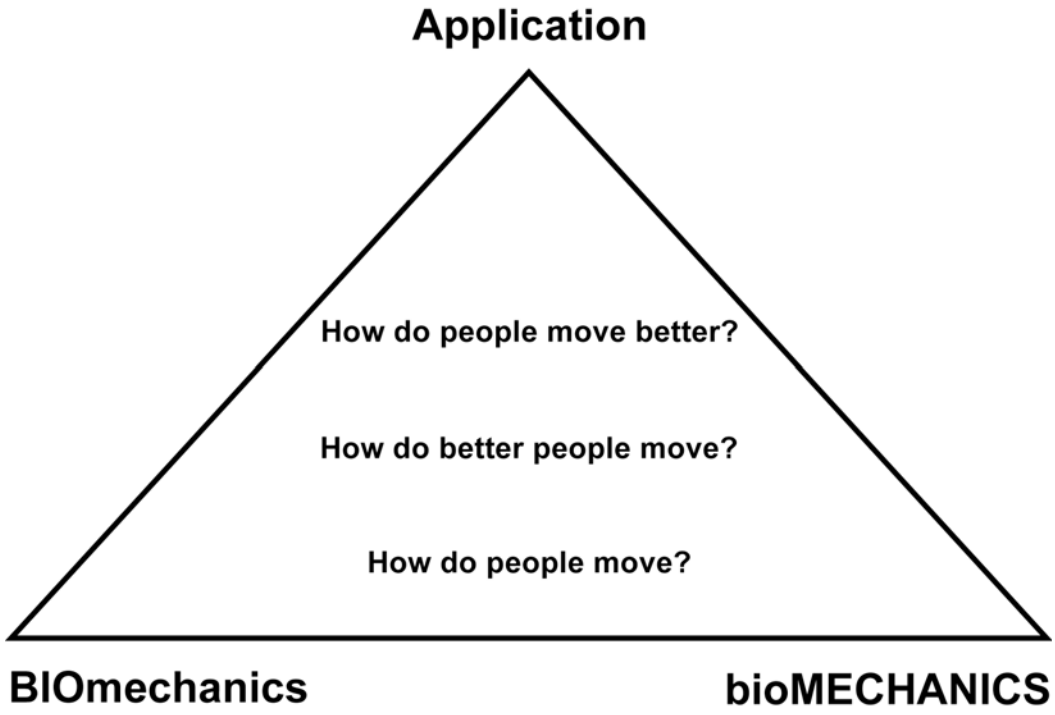
In sum, we will likely need to pay attention to the skills of critical thinking if our students are to exit our courses as change agents for movement. The question is, can we develop these skills at the same time that we are teaching content and the more explicitly biomechanical skills? I am betting that we can.

As I have been revising my course over the last few years, I have added what I call the course in miniature at the start of the semester. This takes about 10% of our time, and it lays out the main themes of the semester. I place a lot of emphasis on showing the connections between various elements of our curriculum. In general, I conceive of our content as being laid out on several dimensions. For example, I start with the questions we ask, and in particular, the essential question of the change agent: "How do people move better?"

But what do we mean by moving better? In part, this depends on what we consider our objectives to be. I define these as skill, safety, and specificity, and then I show what better means in each of these areas with a continuum. By using the sliding scale, or shades of gray approach, the students are discouraged from thinking in black and white terms about movement.



Returning to our questions, we begin to realize that we cannot answer how to move better until we understand how better -- meaning more skillful or safe -- people move. And that answer depends on the more fundamental question of how people move.

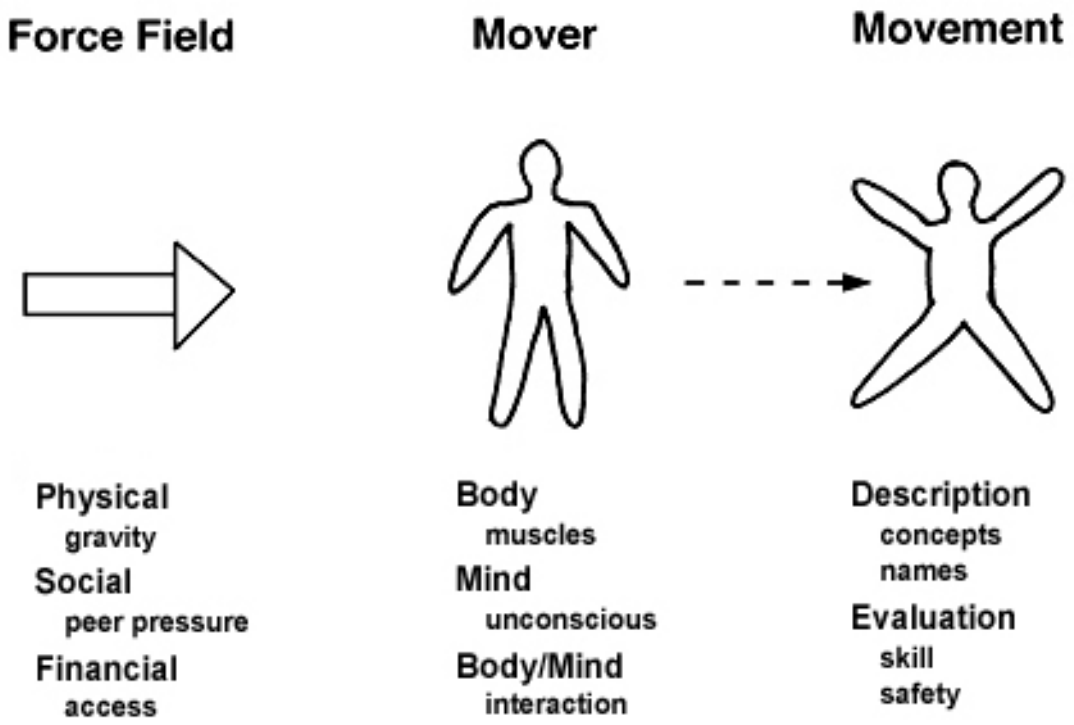


You will notice from this diagram that we have basic knowledge at the bottom of the triangle and applied knowledge at the top. The base of the triangle represents our content knowledge from the more anatomical on the left, which I have renamed BIOmechanics, to the more mechanical, which I have renamed bioMECHANICS. By using a continuum here, we imply that these areas are interrelated. And we can easily extend the base beyond our triangle to represent the related sciences of human anatomy and classical mechanics.

Next, there is a general-to-specific dimension to our material. I have illustrated that here by asking general and specific versions of each of our elemental questions.

General	Elemental	Specific
• How can the mover or the movement change and what is the priority for change?	• How do people move better?	• What is the particular recommendation for change (and how is it implemented)?
• What can we predict about skilled movement or uninjured movers? (What is our model of better)?	• How do better people move?	• How does a particular mover or movement compare to our predictions about better movers and movement?
• How do movers generate movement? (What are the causes or mechanisms of movement?) • What are the consequences of movement to movers? • What movements are likely to emerge from the context of the mover and the environment?	• How do people move?	• What muscles are active during movement? • What exercises use a given muscle? • What movements are occurring as a mover moves?

Then I introduce a three-component model of the force field, the mover, and the movement. This is in keeping with my definition of biomechanics as the study of movers and their movement and the mechanical factors that influence them. I like that the mover is in the center because that suggests that all our decisions need to be appropriate for the mover or movers in question. From here we can flesh out some aspects of the components. For example, we can look at forces from a traditional biomechanical or physical perspective, but we can also think of our mover as a social creature who may be compelled to move by non-physical forces such as peer pressure. We can also pay attention to the mover's mind as well as body.



The unconscious mind, for example, is much more important to movement and biomechanics than most people realize. For starters, most of our choices about movement are made by our unconscious minds. Remember when you waved at me and made at least 4 choices that you had no conscious memory of making? Well those choices were likely made in your unconscious mind. In fact, there are a fascinating array of decisions, conceptualizations, and short-cuts that can be attributed to this aspect of mind. Most of our visual, kinesthetic and other sensory input about movement goes to our unconscious minds instead of our conscious minds. From early in our lives -- well before we are verbal -- we begin to build a rich store of embodied knowledge. Even a one-year-old child knows to enlarge the base of support in what seems like an unstable situation. [movie of child riding a large horse]

In addition, our colleagues in the physics education community are presenting persuasive accounts of how our embodied knowledge includes an intuitive sense of mechanism that we use to understand how things work, predict what is possible, and function in the world. In fact, it appears that a large portion of the people who have learned formal physics in school abandon most of this formal education in favor of their embodied sense of mechanism when away from the classroom. diSessa and others believe that the path to expertise in physics is to start with embodied knowledge and then refine it rather than replace it. With this in mind, I have reduced the amount of formal physics that I expect my students to do, and I have added a session where we make predictions and draw conclusions about forces. I do, however, still require working on some physics word problems because I think it helps to develop procedural thinking, and I don't want my students to be at a horrible disadvantage if they go on to an advanced course with a mechanical emphasis.

If you have not read it yet, I highly recommend the book *Blink* by Malcolm Gladwell. He presents a number of examples of how people engage their unconscious minds when the situation is too quick or complex or confusing for the conscious mind to be aware of or to grasp. When we do this, we take a relatively instinctive, holistic view of the situation to rapidly filter the information and discern patterns. For example, Gladwell talks about Tony Trabert, the tennis player and commentator, who can tell before the ball is struck if a server will hit a double fault or not. Unfortunately for Trabert, he and his team of biomechanics consultants cannot figure out consciously what Tony's unconscious mind knows. Here is a chance to test your ability on some tennis serves. The first movie is a second serve hit by Serena Williams at the recent Wimbledon championship. Now I am going to play 3 more second serves to see if you can tell which ones are good or double faults.

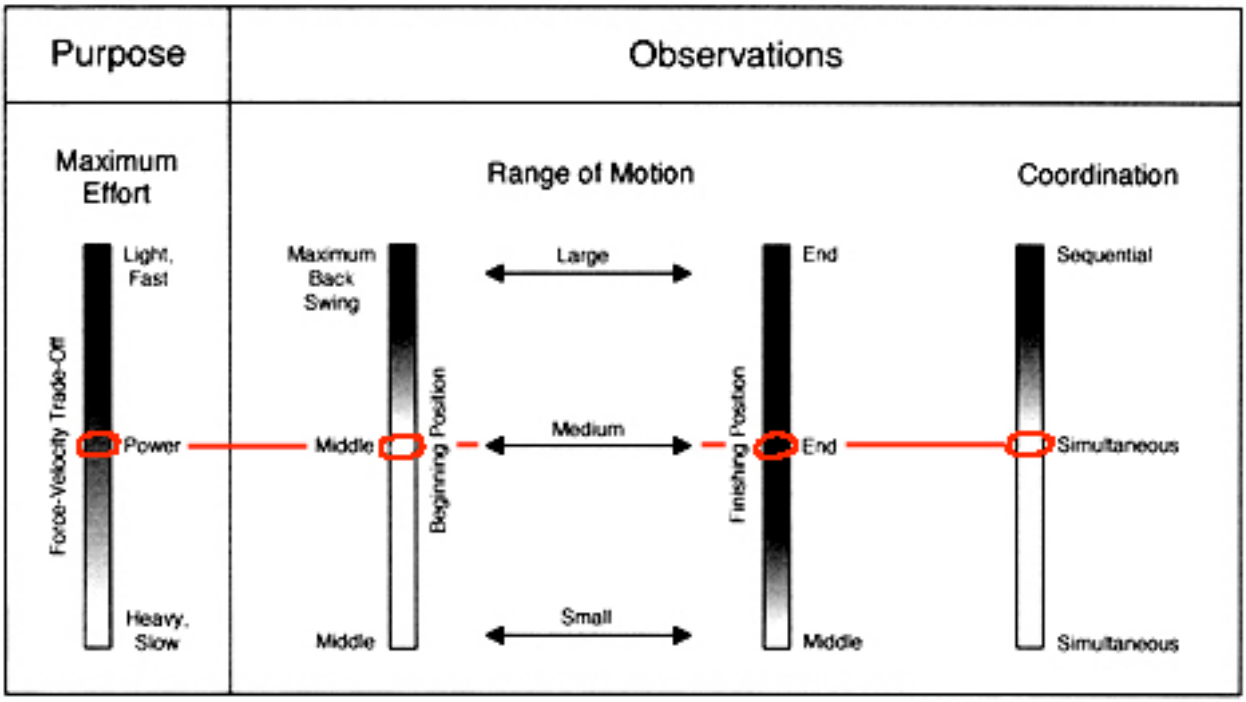
Gerd Gigerenzer is one of the scholars who provided foundation material for Gladwell. His book, *Gut Feelings*, is also an interesting read. Among other situations, he has studied how emergency room doctors make intuitive decisions. His contention is that we can develop a science by connecting the doctors' decisions with the available evidence and then using this to train medical students in a disciplined and informed way. It does not take a lot of projection to think that biomechanists might also be able to learn more about our intuitive decisions about movement that originate in our unconscious minds and then incorporate that in our preparation of change agents.

One of our challenges as change agents is to combine our body-based or embodied knowledge, with fresh observations from our unconscious minds, and appropriate verbal terms from our conscious minds. When we achieve this sort of resonance, we discover a source of genius.

So you might imagine that my students are both skeptical and excited when I tell them that they can be geniuses with regard to movement. To facilitate this I have put together a set of 10 concepts that seem to work with the body as well as with both the conscious and unconscious minds. In addition, they are concepts that matter to better movement, can be measured qualitatively with the naked eye, and can be manipulated by movers to achieve better movement. These concepts form what amounts to a visual vocabulary of movement. In fact, they become the primary thread that ties together most of the pieces of my curriculum. This includes a theoretical model that predicts how movement will change as the context changes and what changes are mostly likely to lead to an increase of expertise.

I presume that you will be familiar with most of these concepts: They are range of motion, speed of motion, balance, coordination, number of segments, nature (or plane) of segments, compactness, extension at release, path of projection, and spin. As you may recall, path of projection, range of motion, and balance were the concepts that I found so meaningful as a teenage basketball player. And I have used them and the other seven again and again when I operate as a change agent. Michael Bird and Scott Strohmeyer and I are developing movie clips to illustrate many of these concepts. Here are just a few.

Magnitude of Force I.



One other change that I am trying to incorporate is based on the work of John Dewey (e.g., *Experience and Education*). He contrasts the learning that accrues from a traditional model of education that is relatively disconnected from real life with the learning that arises when experiential activities are incorporated and theory and practice are woven together.

I certainly know that I have learned the most, in general, and in biomechanics, in particular, from my body-based experiences. Those of my students who have richer experience in movement seem to learn more and make greater strides toward becoming change agents than do the others. But why not make this more available to all of our students? I am betting that by incorporating more movement experiences in my class that my students will 1) be able to tap into their inner genius to become better observers, 2) use their present experiences to synthesize it with their pasts and their anticipated futures, 3) show more sophisticated understanding of our theoretical model because they can validate it with their experiences, 4) better appreciate the differences in movers and movements so that they become more aware of context, 5) build the confidence that comes from success, and 6) develop their abilities to be responsible agents of change for movement.

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