Above: Active learning in small groups. Photo Courtesy of Texas State University.

Active learning - Tools for overcoming Biomechanics anxiety

Dr. Duane Knudson highlights research on improved learning of biomechanical concepts and discusses tools that can be used by all sport and exercise science professionals.

Introduction

Biomechanics provides essential knowledge about exercise and movement technique for the sport and exercise scientist. As important as technique is to effective and safe movement, many students have difficulties with this important subject. The purpose of this article is to discuss active learning in Biomechanics and tools that can be used to enhance learning.

Teaching and learning in Biomechanics

Like the parent field of physics, biomechanics is difficult for students because many have misconceptions about motion and its causes, and preconceived fears/dislike of the subject. This in addition to anxiety about maths! Research has shown that conceptual difficulties with mechanics concepts are not remediated by solving numerous (sometimes thousands in some studies) quantitative word problems. Another example of instructional disconnect, are recent studies that report that, sometimes surprising and spectacular demonstrations, common with physics faculty, are not effective unless preceded by rounds of hypothesis and discussion. Laboratory experiences are also seen to be more effective for student learning the more they require student hypothesis and exploration, and less focus on finding the right answer or rediscovering/demonstrating Somebody's Law.

It is also ironic that in the past, physics faculty have often developed curriculum and problems using the physics of sports to stimulate interest. Biomechanics faculty know from painful experience that numerous sport and exercise examples of the application of biomechanical concepts, however, still feel just like a distasteful physics class to many students. Fortunately, over four decades of physics education and two decades of biomechanics education research is beginning to make progress in improving student learning of mechanics. This research on learning within a specific field/discipline, often referred to as Scholarship of Teaching and Learning (SoTL), is now published in numerous discipline-specific SoTL journals (e.g., Advances in Physiology Education) and disciplinary journals (e.g., Sports Biomechanics).

One key to learning that should be obvious to sport and exercise science students is the need for systematic study/practice, perhaps not 10,000 hours per course, but a personal commitment to construct their own understanding of the conceptual knowledge structure that the professor claims is so beautiful and important. The job for educators is to find ways to keep students focused on the real-world movements and problems they are passionate about in communicating the importance and relevance of biomechanics and exercise science.

Active learning

The instructional strategy that formalise some of this "practice" in class is interactive engagement or active learning. Active learning has been defined as an interactive and engaging process for students that may be implemented through the employment of strategies that involve metacognition, discussion, group work, formative assessment, practicing core competencies, live-action visuals, conceptual class design, worksheets, and/or games (Driessen *et al.*, 2020). The success of active learning in physics/biomechanics is not a surprise to education researchers who pioneered this discovery decades earlier. Numerous versions of the learning pyramid (Fig. 1) are available showing how greater engagement allows students to recall/learn when tested later time. A perfect example are recent studies that report that, sometimes surprising and spectacular, demonstrations common with physics faculty are not effective unless preceded by rounds of hypothesis and discussion. Laboratory experiences are also more effective in promoting student learning the more they require student exploration and less the focus is on finding the right answer or rediscovering/demonstrating a theory or law.

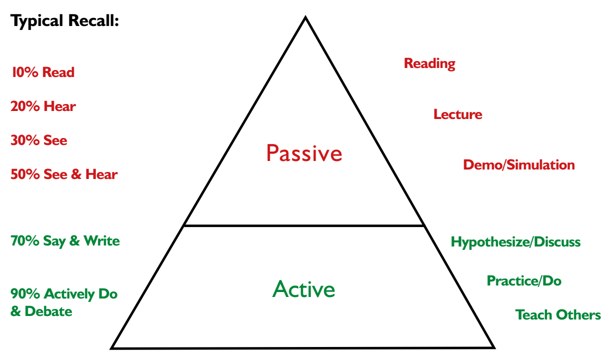

Figure 1. Passive to active continuum/pyramid of teaching and learning (Adapted from Dale, 1969)

But even in biomechanics?

Engaging students in solving small real-world problems with active learning in physics and biomechanics courses can double mean learning of course concepts compared to lecture alone (Hake 1998; Knudson *et al.*, 2009) with similar results in other sciences and fields (Freeman *et al.*, 2014). Learning in these studies is measured by improvement (post-pre) standardised tests like the Force Concept

Inventory or the Biomechanics Concept Inventory. The good news is that instructors need not 'flip' a class (off-load all reading and lecture out of class time) and use 100% of class time in active learning. Small amounts, low-tech, and high-tech active learning are all effective in improving mean learning. Several studies of active learning in biomechanics indicate a few low-tech active learning experiences can approach this doubled learning and even be successfully implemented in online courses (Wallace & Knudson, 2020). McConnell *et al.* (2017) has reviewed the utility and efficacy of eleven active learning strategies. A few examples of low-tech active learning experiences are highlighted later. In some primarily didactic courses, active learning exercises might be sprinkled in to leverage the effectiveness of active learning but also provide a change/activity break from following an instructor's presentation of a lecture.

Like physics education research, biomechanics education research has shown that course and instructor variables are weakly associated with learning biomechanical concepts (Knudson *et al.*, 2009), but student characteristics and behaviors (GPA, interest, & perceived professional application) more strongly associated (Hsieh *et al.*, 2012). Active learning experiences leverage students' natural passion for exercise science and specific stories/problems to engage them. Biomechanics and exercise science instructors just need to let go of some of their explicit leadership, presentation, and rehearsal of course concepts. Some of class time with active learning is set aside for students to work in small groups on simple, real-world problems where the laws/principles/theories and data of exercise science are rehearsed and used. Instructors need to be willing to carefully plan these scenarios, guide student interactions, summarise answers, and reevaluate these activities given student success.

Example active learning tools

Here are a few examples of short (5-10 minute), low-tech (not requiring major space or electronic equipment) active learning exercises that can be inserted into a biomechanics course. These are ordered approximately by learning efficacy according to McConnell *et al.* (2017) but with also moderate implementation requirements (utility).

- **Teaching with Models:** Science if filled with physical and symbolic models of complex systems. Bringing or having students build simple physical models for students to manipulate and experience (see and feel) have powerful leaning benefits: Simple 2-segment rigid body models, track batons with different mass distributions, or different inertias (chains, elastic bands, masses). Passive dynamics (transfer of forces from a proximal segment to the distal segment) is vividly seen, felt, and its importance understood. A student who hypothesized a knee cannot extend or shoulder horizontally adduct without muscles crossing those joints, must reevaluate that hypothesis in the face of strong, personal evidence.

- **Concept Map:** Student groups could be tasked with creating their own structural model of the biomechanical concepts in a unit or section of lecture. This could be like assigning student create "sketchnotes" summarizing the key issues and relationships within a biomechanics topic (see Richardson, 2020).

- **Peer Instruction or Conceptests:** An active learning technique proposed by Mazur (1997) uses the whole class to respond to a conceptual multiple-choice question (conceptest) focused on a single key concept. Overall student responses (cards, clickers, paper, or 'biomechanical response' systems) tell the instructor what percentage of students understand. Students are assigned to discuss reasoning about answers with each other if the percentage correct is between 35 and 70%. Instructors remediate if fewer than 35% are correct and may move on with correct responses greater than 70%. Hint: Biomechanical responses are body motions (e.g., thumbs in different directions, actions like raised arms), however this technique can create problems as students sometimes answer based on other's responses not their true understanding).

- **Minute Paper:** Students write a brief reflection on course concepts. These are quite flexible in many ways: Timing (middle or end of class), identified or anonymous, and focusing on many things from the student's perspective (Most important point, surprising insight/application, muddiest/confusing point, or create exam question & answer).

- **Think-Pair-Share:** An activity that can be implemented at the beginning or the end of study of specific concepts to get students talking to each other about ideas. Instructors pose a question or ask students to respond to what a photograph/video may mean. Students use a few minutes to craft their answer, pair with a partner to create an integrated response, and potentially report back to the class in a whole-class discussion of the question.

An example of a longer but highly effective active learning exercise is a Problem/Case Study. Student groups are assigned or pick a carefully planned, real-world or simulated professional problem that requires their understanding and application of course concepts. This takes more in class time (usually more than an hour) where student groups must not only review course concepts but also read background research on the issue, person, and situational factors. Instructors spend class time helping guide student hypotheses, discussions, and sometimes dealing with group dynamics.

Take-home messages

- Correcting student mechanical misconceptions is difficult and not easily resolved in many students by traditional instruction (lecture, demonstrations, or multimedia);
- Biomechanics education research confirms that learning biomechanical concepts is difficult for most students;
- Learning of difficult concepts in all fields can be improved with carefully crafted active learning experiences based on student interests and professional application. These experiences need not be high-tech or use the majority of in class time;
- Think about how credible our emphasis of evidence-practice in exercise science if we do not utilise research-supported instructional strategies like active learning; and
- There is a need for more educational research or Scholarship of Teaching and Learning to identify the most effective instructional experiences for biomechanics and all exercise sciences. ■

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