WHAT HAVE WE LEARNED FROM TEACHING CONFERENCES AND RESEARCH ON LEARNING IN BIOMECHANICS?

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A narrative review was conducted of biomechanics teaching/learning papers published in teaching conference proceedings and in journals since 1980. The majority of the papers published focused on course concepts and technology, rather than reporting data on student learning. Recent progress has been made in standardized tests of biomechanical concepts and identifying factors that are associated with learning these concepts. Future research should use these tests to focus on learning-related factors and active learning strategies from physics education research to improve student mastery of biomechanical concepts.

KEYWORDS: Instruction, kinesiology, pedagogy, physics, teaching.

INTRODUCTION: Teaching introductory biomechanics to most exercise science/kinesiology majors is a challenging task. Teaching biomechanics is difficult because the field integrates two difficult bodies of knowledge: the complexity of human anatomy with the mechanics of the body and the external forces it encounters. Add to this problem of non-linear, complex biomechanical systems, the fact that many kinesiology majors are not adequately prepared or interested in natural sciences like mechanics, and it is obvious why teaching introductory biomechanics is a challenging task for many faculty.

Biomechanics scholars have a long tradition of sharing teaching methods and materials to address this challenge. In fact, biomechanics faculty have organized five teaching conferences to discuss these issues since 1977 in North America. The purpose of this paper was to review the proceedings of these teaching conferences and the literature on teaching biomechanics to summarize the scholarship of teaching and learning (Boyer, 1990) in the discipline.

METHOD: The author reviewed the five published proceedings of the North American teaching conferences in biomechanics, as well as papers published on biomechanics of teaching and learning in journals since 1980. Papers in the five teaching proceedings (Dillman and Sears, 1978; Shapiro and Marrett, 1984; Wilkerson et al. 1991, 1997; Blackwell and Knudson, 2001), excluding summaries of discussion sessions, were classified into one of five categories based on the objectives and data in the papers: CCH-Course concepts and history, AOL-Activity or laboratory learning activity, TIP-Teaching idea or pedagogy, ETS-Equipment, technology or software, or STL-Scholarship of teaching and learning

Papers were considered STL if they reported data on student perceptions or learning outcomes from the instructional activities discussed. A review was also performed on papers identified by a search of several bibliographic databases for STL research in biomechanics. One hundred sixty-two teaching conference papers and twenty-one journal articles were reviewed.

RESULTS AND DISCUSSION: Forty-six papers were published in the proceedings of the first "national" conference on teaching "kinesiology" (Dillman & Sears, 1978). Two historical issues are important to note about this conference. First, the national conference, and the conferences that followed benefited from international participation (e.g. Canada, UK, Australia). Second, although many courses were still called "kinesiology" in 1977, the topic was really biomechanics and many of the papers focused on course content, technology, and teaching ideas. A young field was coming to grips with a lack of consistency in terminology and course content. Issues of contention were the balance of anatomy and mechanics content, qualitative and quantitative

analysis of human movement, as well as theory versus application. The several versions of the National Association for Sport and Physical Education (NASPE) Guidelines and Standards for Undergraduate Biomechanics were born from the discussions at the teaching conferences (Kinesiology Academy, 1980,1992; NASPE, 2003). The first two of three national surveys on instruction in biomechanics were presented at these conferences (Deutsch et al. 1978; Marett et al. 1984). Satern (1999) reported the most recent biomechanics teaching survey.
Subsequent teaching conferences had progressively fewer papers (40-35-24-17), even though the number of biomechanics programs and faculty expanded. While these teaching meetings have fostered collaboration and some consistency in this important core course. Relatively few papers published in the proceedings (Table 1) have presented actual data on student learning in biomechanics (STL), with the highest percentage of papers introducing technology (ETS) or sharing general concepts about teaching biomechanics (CCH).

Table 1. Kinds of Papers Presented at the National Conferences on Teaching Biomechanics

(Percentage)

Meeting	CCH	AOL	TIP	ETS	STL
1st	28	15	22	35	0
2nd	28	25	10	15	0
3rd	26	17	14	34	9
4th	21	25	8	42	1
5th	29	18	6	29	18

*CCH: Course Concepts/History, AOL: Activity or Lab, TIP: Teaching Idea/Pedagogy, EST: Equipment/Technology/Software, or STL: Scholarship of Teaching and Learning. STL involves the collection and reporting of student perceptions, interaction, or learning data that is peer-reviewed and shared with an external audience (Boyer, 1990).

Some of the earliest STL studies reporting learning data in biomechanics were reported at the 3rd national conference on teaching biomechanics. Knudson et al. (1991) used a pre- post-test design and found that traditional instruction in biomechanics did not automatically transfer to ability to qualitative analysis of sports skills, while Dedeyn (1991) reported retrospective data showing biomechanists with significantly better that visual movement analysis ability than teachers or undergraduate students. Other teaching conference STL papers have also utilized pre- and post-test measures of student learning. McPherson and Guthrie (1991) examined the addition of computer-assisted instruction (CAI) in introductory biomechanics. There was no significant effect of the additional CAI, even though the student attitudes about CAI were positive. Bird et al. (1997) reported preliminary data that instruction could improve mastery of NASPE standards from 18 to 74%. McGee, Fletcher and Bird (1997) used similar methodology and reported a 10% increase in learning of EMG concepts following hands-on EMG experiences compared to classroom instruction. Coleman (2001) integrated a standardized physics test (Force Concept Inventory) into the introductory biomechanics course at the University of Edinburgh and found that mastery of Newton’s Laws of motion improved from about 30% to 70%.

Knudson and colleagues (2003) implemented Coleman's suggestion to create a standardized test of biomechanical concepts. The Biomechanics Concept Inventory (BCI) is a 24 question test based on the NASPE standards (NASPE, 2003) validated with a national sample of classes. Research using the BCI test and subsequent versions has been remarkably consistent with the physics education research (PER) that improvement in mechanics knowledge falls short of instructor objectives. Typically, mean improvement is between 25 and 40%, which is equivalent to about 20% of individual maximum possible improvement. Dixon (2004) also reported a pre- post-test for biomechanics instruction in exercise science.

Research using the BCI has identified variables that are associated and are not associated with student learning of biomechanical concepts. Course and instructor characteristics account for much smaller variance (2-5%) in learning (Knudson et al. 2009) than student characteristics and behaviors (14 – 40%) do (Hsieh & Knudson, 2008; Hsieh et al. 2010). Another important observation was that increasing course credit hours from 3 to 4 with a laboratory (66% increase in contact hours) significantly improved (doubled) learning (Knudson et al. 2009). Knudson et al. (2009) also reported a weak inverse association ($r = -0.18$) between average spending on labs and learning. This was interpreted as a possible distraction effect of technology that has also been reported in hypermedia and visualization research (Chandler, 2009), and was also a caution about "black box" use of computers in biomechanics instruction noted by Miller (1997). Student learning of biomechanical concepts is primarily related to grade point average, and student's perception of career relevance, and their interest in the subject.

The papers on teaching biomechanics published in journals mirror the distribution of papers from the teaching conferences. Most papers have also focused on proposed applications of instructional technology (Carlton et al. 1999; Chow et al. 2000; Kirtley and Smith, 2001; Nicol and Liebscher, 1983) or lab activities (e.g. DiCarlo et al. 1998). There is little STL research on instruction using these technologies or other teaching methods to determine if these new tools and ideas increase learning beyond traditional instruction with biomechanics students.

Several biomechanics STL studies have been reported the biomedical engineering literature, focusing on using computer-assisted, active-learning or challenge-based instruction. These studies are based on several decades of PER reporting significant improvements in learning mechanical concepts with these pedagogies (Hake, 1998). Three studies reported no significant differences with these instructional innovations (Duncan and Lyons, 2008; Roselli and Brophy, 2006; Washington et al. 1999), while Pandy et al. (2004) reported significant improvements in learning with challenge-based instruction compared to traditional instruction for students within a class. These results highlight the difficulties in creating new active learning pedagogies in biomechanics. Good summaries of these active learning strategies in PER have been reported (Hake, 1998; Henderson and Dancy, 2009; Redish and Steinberg 1999) and the PER Central web site provides electronic access to some journals and research in this area (http://www.compadre.org/per/index.cfm).

CONCLUSION: Only a small percentage of papers from previous teaching conferences and journals report data-based research on student learning in biomechanics. Future research should focus on measures of student learning of biomechanics concepts and explore active learning strategies that have been effective in PER. Biomechanics-specific research supports the hypothesis that for new technologies or pedagogies be effective, they must be designed to accommodate student's abilities and be attentive to student attitudes toward biomechanics.

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