STUDENTS' LEARNING OF SPECIFIC BIOMECHANICAL COMPETENCIES

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The purpose of this study was to examine student learning in various competency areas of undergraduate biomechanical concepts based on the North American guidelines. A total of 173 students were recruited from introductory biomechanics classes from two state universities. The third version of Biomechanics Concept Inventory (BCI3) was given during the first and last two weeks of the sessions to measure student learning in six competency areas. Data from the 162 students who completed the study protocol showed that performance on items requiring prerequisite skills remained consistent between pre- and post-test. Overall, post-test scores significantly improved by 17 percent from pre-test values. Furthermore, the students demonstrated significant learning progress on neuromuscular and kinetics competencies.

KEY WORDS: BCI, biomechanics learning, learning competency.

INTRODUCTION: Several studies have examined various factors such as learning styles and teaching methods (e.g., Champagne, Klopfer, & Anderson, 1980; Hsieh & Knudson, 2008; Hsieh, Smith, Bohne, & Knudson, 2012) related to student learning mechanics and biomechanics concepts. Though biomechanics is a difficult subject for many students to master (Knudson et al., 2003), several studies have documented significant increases in learning biomechanical concepts from students taking an introductory biomechanics class (e.g., Hsieh & Knudson, 2008; Hsieh et al., 2012; Knudson et al., 2003; Knudson, 2004; Knudson, 2006; Riskowski, 2013). However, these studies have not reported learning values in specific biomechanical concepts, so it is difficult to identify areas that require enhanced teaching and support for more efficient learning and mastery of biomechanics.
According to the 2003 guidelines from the Kinesiology Academy of the National Association of Sport and Physical Education (NASPE), there are a total of 12 different competency areas students should be proficient in upon the completion of an introductory biomechanics course for Kinesiology/Exercise Science (KES) majors in North America. Four of the 12 competency areas address pre-requisite biomechanical skills including algebra, interpreting graphs, anatomy, and muscular anatomical concepts. Knudson et al. (2003) identified that a national sample of KES students exhibited weak performance in 3 of the 4 (anatomy excluded) pre-requisite skills when they enter introductory biomechanics. This observation is supported by faculty reports of challenges when teaching undergraduate biomechanics (Garceau, Ebben, & Knudson, 2012).

The remaining eight competencies consist of functional musculoskeletal system, neuromuscular system, kinematics and kinetics of human movement, fluid mechanics and application to human movement. Previously, significant improvements in overall biomechanics knowledge (17 – 37% of pre-test values), based on BCI results have been reported (Hsieh & Knudson, 2008; Hsieh et al., 2012; Knudson et al., 2003; Knudson, 2004; Knudson, 2006). Unfortunately, these previous studies did not report details of improvement in specific course competencies. Therefore, the primary purpose of this study was to document student pre- and post-test performance in the pre-requisite course competency areas, and the eight skill areas as defined in the NASPE (2003) guidelines. The second purpose was to examine the trends in performance of students with positive improvement. The present results could provide a better understanding of students' baseline knowledge, ease and/or difficulty of learning certain biomechanics concepts according to the NASPE competency areas, and assist instructors with the design and preparation of appropriate and effective curriculum materials and teaching strategies.

METHODS: All study methods were approved by the Institutional Review Board for the use of human subjects. Over 200 students who were enrolled in five different introductory biomechanics classes in the fall 2013 at two public state universities in North America were invited to participate. Review of the instructor syllabi revealed that most of the NASPE competency areas were covered in the respective courses; however, algebra and graph interpretation were not directly covered. The actual time spent on each competency area was not provided by the instructors. A total of 173 students completed the study protocol, however data from 11 students were omitted due to a non-compliance standard of a decrease in performance of more than 4 questions on the post-test. This 6.4% non-compliance rate is similar to previous studies (1.7 – 7.5%) using similar inventories (Henderson, 2002; Hsieh et al., 2012; Hsieh & Knudson, 2008; Knudson et al., 2003).
The third version of Biomechanics Concept Inventory (BCI3; Knudson, 2006) was provided to participants through an online system during the first and last two weeks of the academic term, respectively. Student learning performance was analyzed in two different ways: 1) overall student performance on the pre-test compared to the post-test in each competency area, and 2) students were grouped into one of two groups based on their improvement in performance from pre- to post-test, group one included students who had positive improvement (post-test – pre-test ≥ 1question) and no improvement in post-test (post-test – pre-test ≤ 0 to -3 questions). A normalizing gain (G) variable (g = (post-test score – pre-test score) / (maximum possible score – pre-test score)) was used to indicate students' normalized learning (Hake, 1998). In order to evaluate improvement in student learning from pre- to post-test, a paired t-test was performed. Standard t-tests were performed to examine differences between the improvement group and no improvement group on both the pre- and post-tests. Holm's correction was applied to control type I error with new the significance level based on the number of comparisons.
Due to small number of questions for each competency area, these 24 questions were clustered into six major competency areas for the purposes of the present analysis: basic muscular anatomical concepts (MAC), algebra and graph reading skills (ALG), neuromuscular function concept (NFC), kinematics (KIM), kinetics (KIN), and fluid mechanics and application skills (FLA). Chi square test was used to determine the distribution difference between the pre- and post-test in each competency area.

RESULTS: Students (n = 162) performed significantly better on the post-test when compared to the pre-test (g = 0.11; $P < 0.01$). Figure 1 shows the percentage of questions answered correctly on the BCI3 for all students and the positive improvement students in six competency areas for both pre- and post-tests. Pre-test scores from the positive improvement group (n =101) did not differ ($P = 0.11$) from those of the no improvement group (n = 61), but the positive improvement group performed significantly better than the no

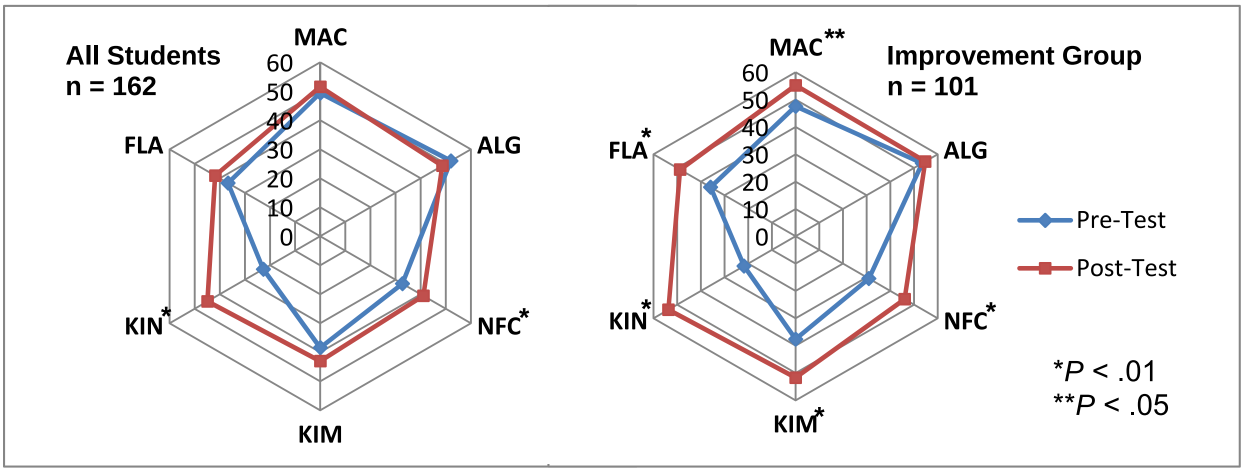

Figure1. Percentage of correct responses for all students (n = 162) and positive improvement students (n = 101) in pre- and post-tests by competency areas. See text above for competency abbreviations.

improvement group on the post-test ($P < 0.01$). Chi- square test (Table 1) showed that there were statistically more students who exhibited gains in the neuromuscular function ($P < 0.01$) and kinetics concepts ($P < 0.01$). When only the positive improvement group (n = 101) was analysed, there were statistically ($P < 0.05$) more students who gained in all competency areas, except algebra and graph reading skills (Table 2).

Table 1
Percentage of correct responses in competency areas for all students

n = 162	MAC	ALG	NFC	KIM	KIN	FLA
Pre-Test	49.4%	52.0%	32.7%	38.4%	22.7%	36.7%
Post-Test	51.5%	48.6%	41.1%	43.1%	44.9%	41.8%
***P*-value**	0.43	0.22	<.01	0.09	<.01	0.06

Note: See text for competency abbreviations.

Table 2
Percentage of correct responses in competency areas for positive improvement group

n = 101	MAC	ALG	NFC	KIM	KIN	FLA
Pre-Test	47.5%	53.5%	30.9%	37.6%	21.8%	35.9%
Post-Test	55.2%	54.7%	46.0%	51.7%	53.7%	48.8%
***P*-value**	<.05	0.72	<.01	<.01	<.01	<.01

Note: See text for competency abbreviations.

DISCUSSION: Consistent wtih previous studies (Hsieh & Knudson, 2008; Hsieh et al., 2012; Knudson et al., 2003; Knudson, 2004; Knudson, 2006) students in these introductory biomechanics classes exhibited a significant improvement (17% more from the pre-test) in the mastery of biomechanical concepts on the BCI3. However, questions such as "What exactly did students learn [in biomechanics]?" and "How well did they learn it?" are fundamental to the enhancement of pedagogical techniques, curriculum design, and ultimately, to any potential application of biomechanics by students. Although Knudson et al. (2003) suggested that the BCI instrument be used as an overall measure of learning in introductory biomechanics, the evaluation of student performance in specific competencies is a critical step to continue advancing teaching and learning in biomechanics.

Surprisingly, twice as many students were able to answer kinetics (linear and angular) concepts questions correctly on the post-test than they were able to on the pre-test for the entire sample (n = 162) as well as the improvement group (n =101). On the other hand, students performed consistently from pre- to post-tests on basic muscular anatomical concepts, and algebra skills, and graph reading skills. This finding is comparable to Knudson's (2003) findings and confirms the documented concerns of faculty (Garceau et al., 2012). The lack of improvement in these areas could also be related to the fact these areas may not have been the focus of the instructors' curriculum.

When students were subsequently divided into two groups (i.e., positive improvement and no improvement), results indicated that the students in both groups shared similar background knowledge as they entered the introductory biomechanics class. In contrast, the positive improvement group displayed statistically greater post-test scores than the no improvement group by 36%. In the positive improvement group, the growth between pre- and post-test was significant in all of the content areas except for algebra and graph interpretation competency. Nearly 80% of students were able to correctly respond to the algebra questions; however, only 25% of the individuals demonstrated the ability to interpret graphs.

Despite the encouraging trend of score improvement from pre- to post-test, nearly half of the students continue to struggle in all content areas. If students are unable to master fundamental biomechanical concepts, higher order skills such as application will be lacking, which is troubling. Biomechanics does not exist in a vacuum; instead the goal of our field should be to train a new generation of scholars, researchers, and practitioners who are capable of applying biomechanical knowledge to real world situations. This practice will assist biomechanics as we continue to strive to flourish as a "mature" scientific field. The development and utilization of effective pedagogical techniques will strengthen the fundamental biomechanical concepts on which critical thinking and application are based. These are required for students to successfully meet the demands of a continuously evolving profession as well as to align with the trends of future industry.

The limitations of the current study were: 1) a small number of questions in each competency area in the BCI3 test, 2) the instructors may design their curriculum to focus on different competency areas, 3) mastery of pre-requisites may be different among students, and 4) although students may not willingly admit that they take an active role in the assessment of their achievement, the seriousness of students when completing the pre- and post-tests using an online format needs to be taken into consideration (Henderson, 2002). Future studies should correlate various concepts from the BCI to other assessment modes such as curriculum-embedded questions and course tests as well as student interviews (Knudson et al., 2003).

CONCLUSIONS: The current study confirms that biomechanics is a difficult subject for many KES students to master. Students performed consistently on the pre- and post-test in the algebra and graph interpretation competencies. The competency where student learning showed the greatest growth was kinetics. Even though overall results showed significant improvement in the post-test, less than 60% of the students demonstrated at least 50% competence in each of six competency areas.

REFERENCES:

Champagne, A.B ., Klopfer, L. E., & Anderson, J. H. (1980). Factors influencing the learning of classical mechanics. *American Journal of Physics*, *48*(12), 1074-1079.

Garceau, L. R., Ebben, W. P., & Knudson, D. V. (2012). Teaching practices of the undergraduate introductory biomechanics faculty: a North American survey. *Sports Biomechanics*, *11*(4), 542-558.

Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six thousand student survey of mechanics test data for introductory physics. *American Journal of Physics*, *66*(1), 64-74.

Henderson, C. (2002). Common concerns about the force concept inventory. *The Physics Teacher*, *40*(9), 542-547.

Hsieh, C., & Knudson, D. (2008). Students factors related to learning in biomechanics. *Sport Biomechanics*, *7*(3), 398-402.

Hsieh, C., Smith, J. D., Bohne, M., & Knudson, D. (2012). Factors related to students' learning of biomechanics concepts. *Journal of College Science Teaching*, *41*(4), 82-89.

Knudson, D. (2004). Biomechanics concept inventory: Version two. In Lamontagne, M., Robertson, D. G. E., & Sveistrup, H. (Eds). *Scientific Proceedings of the 22nd International Society of Biomechanics in Sports.* Ottawa, Canada: University of Ottawa.

Knudson, D. (2006). Biomechanics concept inventory. *Perceptual and Motor Skills*, 103, 81-82.

Knudson, D., Noffal, G., Bauer, J., McGinnis, P., Bird, M., Chow, J., Bahamonde, R., Blackwell, J., Strohmeyer, S., & Abendroth-Smith, J. (2003). Development and evaluation of a biomechanics concept inventory. *Sports Biomechanics*, *2*, 267–277.

NASPE. (2003). *Guidelines for Undergraduate Biomechanics*. Reston, VA: author. Retrieved December, 2013 from: http://www.aahperd.org/naspe/publications/teachingTools/upload/Guidelines-for-Undergraduate-Biomechanics-2003.pdf.

Riskowski, J.L. (2013). Teaching biomechanics for conceptual learning. In Shiang, T.Y., Ho, W.H., Huang, C.F., & Tsai, C.L. (Eds). *Scientific Proceedings of the 31st International Society of Biomechanics in Sports.* Taipei, Taiwan: National Taiwan Normal University.

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