P01-16 ID37

GENDER DIFFERENCES OF LEARNING BIOMECHANICAL CONCEPTS

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The purpose of the current study was to compare the learning gains of biomechanical concepts between male and female students. A total of 49 students were recruited (26 female and 23 male) from an introductory biomechanics class. The Biomechanics Concept Inventory (BCI) was given during the first and final weeks of a 15-week semester to determine the students' learning. The results indicated that there was no significant difference in pre-test (P = 0.11) and absolute gain (P = .05) between genders but significant differences were found in post-test and normalized learning gains. The female students learned better as evidenced by higher post-test score than male students in this group with similar baseline knowledge of biomechanics. The findings support recent studies which found that the gender gap in scientific achievement is narrowing.

KEY WORDS: BCI, gender differences, learning pedagogy.

INTRODUCTION: There is a vast body of studies related to learning and teaching in science with variety of perspective such as the factors related to students' learning, learning styles, theory of teaching in different approaches, etc. (e.g., Champagne, Klopfer, & Anderson, 1980; Hsieh & Knudson, 2008; Hsieh, Smith, Bohne, & Knudson, 2012). One of the factors that has been frequently scrutinized is gender differences in learning science. Several large-scale studies have reported gender gaps on scientific achievement since 1970s such as the International Association for the Evaluation of Educational Achievement (IEA, 1988), the National Assessment of Educational Progress (NAEP, 1970-1986) (Mullis & Jenkins, 1988), the British Columbia Science Assessments (Bateson & Parsons-Chatman, 1989), the College Entrance Examination Board (Wilder & Powell, 1989), and the Educational Testing Service (Cole, 1997). These reports often showed that women underperform men in many different standardized tests in the scientific areas.

Biomechanics is a major core course of the Kinesiology major in North America. The competency areas of Biomechanics include four prerequisites and eight major competencies according to the guidelines and standards of the Kinesiology Academy in North America (Kinesiology Academy, 1992). These competency areas mainly consist of function of musculoskeletal system, neuromuscular system, kinematics and kinetics of human movement, and application of these competencies in human movement. Studies from related disciplines found that male students outperform female students in many different standardized tests such as Force Concept Inventory (FCI), Force and Motion Concept Evaluation (FMCE), and Medical College Admission Test 2009-2011 (MCAT) (AAMC, 2012; Lorenzo, Crouch, & Mazur, 2006; McCullough, 2004; Thornton & Sokoloff, 1998).

Standardized test results usually are poor indicators for students' learning from class. In other words, the results merely represent student achievement in the content area not how much this student learned from the class. This is because not every student has the same incoming knowledge on the subject when they enroll to take the class. Therefore, students' learning has been assessed with normalized gain (Hake, 1998) which includes the assessment of pre- and post-tests. Studies using normalized learning disclosed lower learning gains for female students than male students on the FCI (Hake, 2002; Lorenzo et al., 2006). Although there is a gap between the genders on scientific test performance, there is limited research investigating baseline knowledge, outcome of learning, and normalized learning gain of acquisition of biomechanical concepts between men and women. Therefore, the aim of this study was to investigate the gender differences on learning biomechanics. The hypothesis was that male students would score higher on the pre- and post-tests, exhibit greater absolute learning and normalized gains than female students.

METHODS: Forty-nine students (26 female, age = 22.77 ± 2.37 years; 23 male, 22.61 ± 3.33 years) majoring in kinesiology department were recruited from an introductory biomechanics in fall semester. All policies and procedures for the use of human subjects were followed and approved by the university Institutional Review Board. The original Biomechanics Concept Inventory (BCI; Knudson et al., 2003) was given during the first and last weeks of the semester. The data from two students were excluded due to lack of compliance according to the result of the post-test (decrease from pre-test for more than 4 questions). This 4% of non-compliance rate was in the range of the previous studies (1.67 – 7.5%) using similar inventories (Henderson, 2002; Hsieh, Smith, Bohne, & Knudson, 2012; Hsieh & Knudson, 2008; Knudson et al., 2003).

Students' learning was calculated by normalizing the gain (G) variable (g = (post-test score – pre-test score) / (maximum possible score – pre-test score)) (Hake, 1998). Since normalized gain may be skewed due to the pre-test (Brogt, Sabers, Prather, Deming, Hufnagel, & Slater, 2007), the absolute gain (post-test – pre-test) was also calculated and compared. Paired t-test was performed to determine the improvement of the post-test for both male and female students. The two-sample t-tests were applied on pre-, post-test, absolute gain, and g to verify if there is significant difference between genders. The effect size was also calculated. In order to control Type I error, the Holm's correction was performed to calculate new statistical significance level.

RESULTS: Table 1 showed the descriptive statistics of pre-test, post-test, absolute gain, and normalized learning (g) for both male and female students. Students in both gender all showed a significant improvement from post- to pre-test ($P < .01$). There was no significant difference of pre-test ($P = .11$) and absolute gain ($P = .05$) between men and women. However, there were significant differences between gender on post-test and gain.

Table 1
Differences of learning variables between genders in biomechanics

Gender	Pre-test	Post-test*	Absolute Gain	Gain (g)*
Male**	8.30 ± 2.24	10.57 ± 3.26	2.26 ± 2.56	0.15 ± 0.17
Female**	9.23 ± 2.94	12.69 ± 3.00	3.46 ± 2.48	0.23 ± 0.16
Effect Size	0.14	0.35	0.19	0.52

Note: * indicates significant difference between genders for post-test and gain. ** indicates the significant difference between pre- and post-test in both genders.

DISCUSSION: There is extensive literature regarding the divergence of science achievement between males and females. Internationally, the gender gap has been well-documented in most scientific and technology related topics; physics, especially, continues to perpetuate the stereotype that males perform better in science than females (Ivie & Stowe, 2000, Perez-Felkner, McDonald, Schneider, & Grogan, 2012). In the current study where physics is the major underpinning of biomechanical concepts, the expectation was that males would outscore females. However, the findings of the present study showed that female students appear to learn better than male students with similar incoming baseline knowledge related to biomechanics competency areas, which contradicts the predominant stereotype of the previous older studies and aligns with more recent research indicating that gender gap is narrowing (Lorenzo et al., 2006; Sharma & Bewes, 2011).

With economists predicting the workforce majority will be women, it is especially important to ensure that women are well-represented in a variety of fields, and especially science (Haemmerlie & Montgomery, 2012). Unfortunately, two factors have arguably had lasting and devastating effects on women's achievement in science: 1) common socialization practices regarding the popular belief that science was an unsuitable topic or career for females (Eccles, 1994) which stemmed from 2) the substantial body of literature confirming that males could "do science" better than females. *Stereotype threat* represented the extent to which an individual's performance would be affected by the perceptions of one's ability in a particular area (Steele, 1997). Though these factors sound somewhat ominous, the findings of this study in which undergraduate female students outperformed male students in biomechanical concepts may indicate that the stereotype threat has at least in part been neutralized by efforts at various levels. Examples include fostering a strong "science identity" (Carlone, 2004) within females as well as the implementation of innovative pedagogical approaches in an attempt to equalize the classroom learning environment (Jovanovic, Solano-Flores, & Shavelson, 1994).

Studies in the 70's and early 80's indicated students' prior instructional experience influenced achievement which was related to gender bias (Brophy & Good, 1974; Eccles & Blumenfeld, 1985). Therefore, in the late 80's, the National Center for Improving Science Education developed new guidelines for science education (Shavelson, Baxter, & Pine, 1992) so that the instruction would be able to compensate for the disparities in student scientific experiences (Jenkins & MacDonald, 1989). For the pre-test results in the current study, it would appear that females have at least, if not better, prior experience and/or knowledge acquisition of basic science principles as males do. More recent literature indicated that active and interactive techniques are particularly helpful and valuable during science instruction (Hake, 1998). These methods are effective for learning in general; however, females seem to benefit more from these processes (Laws, Rosborough, & Poodry, 1999; Schneider, 2001). The material presented in the introductory biomechanics course for this study utilized active engagement and cooperative problem-solving methods in both lecture and lab components which may have facilitated female students' learning and achievement and resulted in higher post-test scores and normalized gain in biomechanical concepts.

The limitations of the current study are: 1) small sample size for both male and female students, 2) the gender difference in each competency area was not compared, and 3) intrinsic and extrinsic learning factors were not evaluated. It is obvious that other studies are needed to further explore this phenomenon.

CONCLUSIONS: The present study found that gender gap of scientific learning has been reduced. Female students have similar incoming baseline knowledge as male students. Women also have higher post-test scores and seem to learn better than men in this sample population. The findings of this current study suggest that with the application of innovative pedagogical approaches such as active and interactive learning, female students can learn as well as male students and possibly even better.

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