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Work in Progress: Evaluation of Biomechanics Activities at a College-Wide Engineering Outreach Event

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Jason Franz is Assistant Professor in the Joint Department of Biomedical Engineering at the University of North Carolina at Chapel Hill and North Carolina State University, and Director of the UNC/NC State Applied Biomechanics Laboratory. He received B.S. (2004) and M.S. (2006) degrees in Engineering Mechanics from Virginia Tech and served for three years as a biomechanist in Physical Medicine & Rehabilitation at the University of Virginia. Dr. Franz then earned his Ph.D. in Integrative Physiology in 2012 from the University of Colorado Boulder. His primary research seeks to discover the musculoskeletal and sensorimotor adaptations that underlie a loss of independent mobility, and to introduce creative new approaches for preserving walking ability and preventing falls.

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Jarred Kaiser is a post-doctoral researcher at Boston University. He has previously earned degrees in Mechanical Engineering from the Ohio State University (B.S.) and University of Wisconsin - Madison (M.S., Ph.D.). His research focuses on imaging the multiscalar effects of altered mechanics due to injury/surgery on tissue health.

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Joseph Towles is a Faculty Associate in the Department of Biomedical Engineering at the University of Wisconsin-Madison. Joe completed his PhD in the Department of Mechanical Engineering at Stanford University and a research post-doctoral fellowship in the Sensory Motor Performance Program at the Rehabilitation Institute of Chicago and in the Department of Physical Medicine and Rehabilitation at Northwestern University. His teaching and research interests are in the areas of engineering education and neuromuscular biomechanics. With respect to engineering education, Joe focuses on assessment and evaluation of student learning; and innovation and research in approaches to enhance student learning. Concerning neuromuscular biomechanics, Joe's research interests are in translational studies aimed at elucidating the mechanics and control of the hand following neurologic and musculoskeletal injury with the goal of developing innovative rehabilitative and surgical interventions that improve grasp function. Computational and experimental approaches are used to investigate intrinsic characteristics of muscles, neuromuscular control and sensorimotor integration in the context of functional restoration of grasp.

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Introduction

In K-12 education, engineering provides a framework for integrating science, technology and math in a way that promotes student engagement and innovative thinking. Research around effective learning in K-12 classrooms demonstrates that an engineering approach to identifying and solving problems is valuable across all disciplines[1].

Collaborations among educational entities have resulted in the development of educational content for various settings for K-12 engineering[1]. The most promising programs are well-tested, comprehensive, and consistent with educational standards of governing bodies such as the American Society for Engineering Education (ASEE)[2] and the National Academy of Engineering (NAE)[3]. However, these programs are often implemented ad-hoc, without standardized professional development for teachers[4]. Consequently, students may be exposed to different types and levels of K-12 engineering curricula.

As college engineering programs become increasingly interdisciplinary, it is vital that students begin learning to integrate knowledge from across disciplines at the K-12 level. A relatable way to introduce integration would be to include biomechanics - a growing, highly interdisciplinary field[5] of engineering in K-12 science programs. The purpose of this study is to understand the educational and inspirational efficacy of various biomechanics activities among middle-grade students. To this end, we surveyed school groups before and after an engineering outreach event at the University of Wisconsin-Madison.

Methods

Activities

Four interactive biomechanics activities were developed at the University of Wisconsin-Madison to educate and inspire students attending a college-wide engineering outreach event. First, students used a Microsoft Kinect (Redmond, WA) to measure their jump height for comparison to professional athletes and animals. Next, students quantified their maximum mechanical power output on a stationary bicycle (Trek, Waterloo, WI). Then, students used signals from a Wii balance board (Nintendo, Redmond, WA) to assess their balance with and without inducing a reflex via tendon oscillators. Finally, they walked on a treadmill in a virtual hallway that provided either appropriate or inaccurate visual feedback.

Conceptual Questions:

1) Think about going to the doctor's office. Sometimes, the doctor hits your knee with a soft hammer. What usually happens?
2) When you stand up, is it easier to keep your balance when standing on one leg or both legs?
3) True/False: A backpack will make it easier for you to maintain your balance.
4) You and your friend want to find out who can jump higher. What tool can you use to accurately measure how high each of you jumps?
5) Think about standing in place. Which of your senses do you use to maintain your balance?
6) When engineers talk about "power", they mean the amount of energy used in a set amount of time. In sports, this feels like working harder. Which of these would require the most power?

Figure 1. Conceptual questions answered by students before and after the event.

Survey Questions

To evaluate the impact of the interactive biomechanics-related activities, three school groups (n=57) completed surveys before and after the event. We developed nine questions to assess student understanding of common concepts in biomechanics (Fig. 1), student interest (A, B, Fig. 2), and applicability to related professions (C, Fig. 2). Teachers from each group administered surveys via online software (Qualtrics, Provo, Utah) one to three days ahead of attending the event and two to three weeks after the event.

Interest and Inspiration Questions:

A) If you were going to start college tomorrow, how likely would you be to study engineering?

B) If you were going to start college tomorrow, how likely would you be to study biomechanics?

C) How much do you think the following jobs rely on understanding biomechanics?
   i) Dentist
   ii) Medical Doctor
   iii) Athlete
   iv) Physical Therapist
   v) Artist/Animator (e.g. Disney Films)
   vi) Designer of Running Shoes
   vii) Architect

Figure 2. Interest and inspiration questions answered by students before and after the

Data Analysis

Students were allowed to select one response per question even if multiple answers were correct. Educational effect was evaluated using differences between pre and post responses to questions 1-6. Inspirational effect was assessed using differences between pre and post responses on questions A-C. A one-way ANOVA was performed to evaluate pre-post changes in response to each type of question (conceptual, interest, and inspiration). Changes in response to specific questions were evaluated with t-tests. Statistical significance was defined as $p<0.05$, p-values less than 0.10 were considered a trend.

Results

On the initial survey, students answered the majority of conceptual questions correctly (77±15%) (Fig. 3). In regards to interest, students were largely neutral toward engineering or biomechanics as future educational pursuits (Fig. 4). They were also divided as to the applicability of biomechanics to various professions (Fig. 5). School group membership was a significant factor in survey responses when included in the ANOVA, hence analyses were done both overall and on a school group basis.

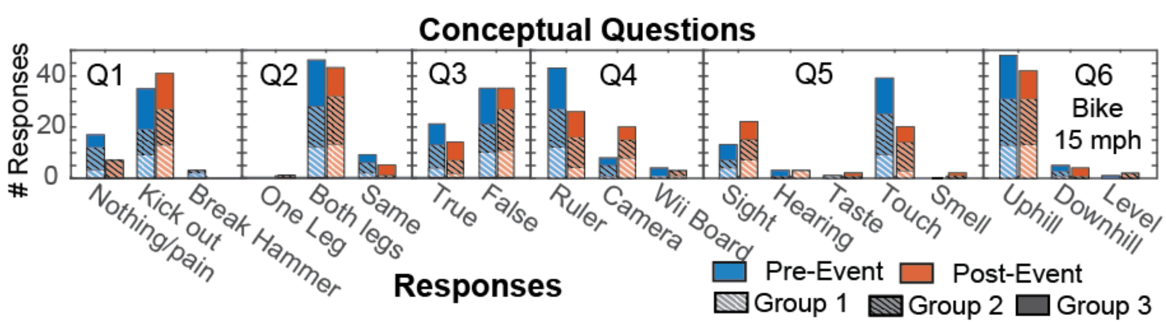

Figure 3. Student responses to conceptual questions before and after the event, shown by group.

Following the event, ANOVA's revealed no significant changes in the rate of correct student responses (post: 84±7%, ANOVA, $p=0.12$). Students did answer question 1 correctly more frequently at follow-up (t-test, $p=0.01$). Further, students were more likely to select camera instead of ruler on question 4 after the event (t-test, $p=0.047$). Similarly, students selected vision instead of touch more frequently on question 5 at follow-up (t-test, p=0.02). Group 1 had an increase in correct responses on question 1 (t-test, p=0.015) and changed responses on question 4 (t-test, p=0.02). Group 2 tended to respond differently on questions 4 and 5 than they had previously (t-tests, p=0.091, p=0.033, respectively). On average, Group 3 tended to answer more questions incorrectly (ANOVA, p=0.08), except for question 1, which they tended to answer more correctly in the follow-up (t-test, p=0.05).

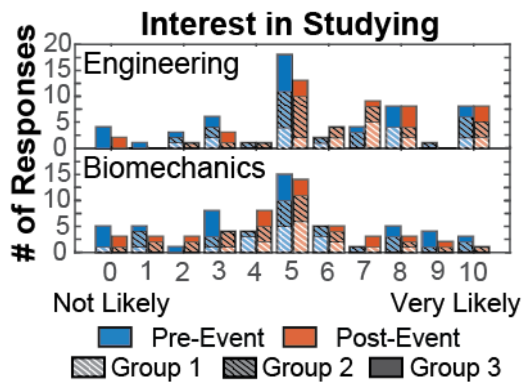

Figure 4. Student interest in engineering and biomechanics before and after the event, shown by group.

In evaluating student interest, an ANOVA revealed no significant overall change in interest in engineering and biomechanics (ANOVA, p=0.17) (Fig. 4). Group 1 tended to gain interest in both engineering and biomechanics (ANOVA, p<0.10; engineering, t-test, p=0.14; biomechanics, t-test, p=0.08), but Groups 2 and 3 showed no change. Overall, students' evaluation of the relevance of biomechanics to all listed professions did not change (ANOVA, p>0.7) (Fig. 5). However, students tended to say that biomechanics was more relevant to athletes following the event (t-test, p=0.076).

Conclusion

Questions 1, 4 and 5 generated changed responses following the event and were all clearly tied to specific activities during the event, suggesting that students learned from the activities. Questions 4 and 5 had multiple correct answers, thus changes primarily represented a shift in which correct response students chose. In both cases, responses shifted to more closely match activities at the event. Questions 2, 3 and 6 showed no change in response following the event. Question 3 was not directly tied to an activity, requiring students to extrapolate from their experiences. The other two questions (2 and 6) were answered correctly by more than 80% of students at the start.

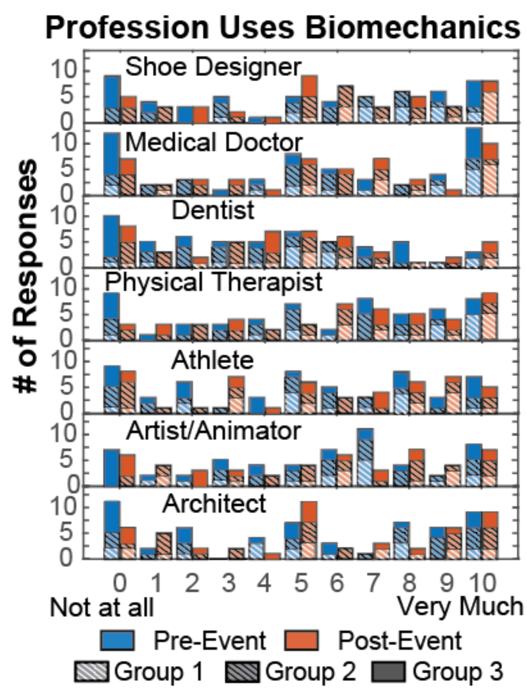

Figure 5. Student perception of applicability of biomechanics to various professions before and after the event.

Student inspiration is more difficult to track, in part because we did not link responses from specific students between surveys. Hence, the lack of significant change on these questions could represent a subset of students with increased interest and another subset with decreased interest, cancelling one another out. In relating biomechanics to careers, our activities may have communicated the relevance of biomechanics to athletics, but in the future we plan to create clearer links between biomechanics and additional career paths.

Differences between groups in this study were likely due to the demographics of the groups. Group 1 included students from grades 5-8 who traveled 2+ hours to reach the event. They were likely hand-selected to attend based on interest and/or proficiency in STEM topics. Groups 2 and 3 were 5th grade classes, both from an elementary school roughly 30 minutes away. Hence, these groups were likely more heterogeneous in terms of STEM interest and proficiency.

Because surveys were administered at students' schools, there was no guarantee that students completing surveys actually participated in our activities. Moving forward, we will re-structure the method of data collection to improve data tracking and quality. Specifically, during the next engineering outreach event, students will receive a paper with pre- and post- activity questions on opposite sides to be answered as they enter and exit the room, respectively. Further, in the next iteration of this study we plan to collect demographic information and the level of science preparation from students as a way to identify activities that are appealing, and in particular to groups that tend to lose interest in STEM disciplines after middle school – namely young women and minorities[6, 7]. Our goal is to build an online repository of well-tested, education standards-compliant biomechanics activities that are both educational and inspirational to a diverse group of middle grade students.

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