FLIPPED CLASSROOM FOR UNDERGRADUATE INTRODUCTORY BIOMECHANICS CLASS

ChengTu Hsieh

California State University, Chico, USA

The purpose of this exploratory study was to examine the effectiveness of flipped classroom teaching approach in an undergraduate introductory biomechanics class. A total of 28 students were recruited for the study. Students were required to watch short videos, study reading assigned, and complete pre-work assignments before each class. During class time, students were mainly engaged with problem-based learning. The biomechanics concept inventory (BCI) version 3 was used to determine learning improvement. The pre-, post-test, and survey were administered during the first and last two weeks of the semester. Students demonstrated significant learning improvement (d = 1.23, P < 0.05) with a 23% normalised learning gain. Most students (64%) indicated that the flipped classroom approach works well for their learning because it provides flexibility that they may review the course lesson anytime on their own.

KEYWORDS: BCI, learning, pedagogy, teaching, survey.

INTRODUCTION: Teaching is one of the major roles as professors/ instructors in higher education with the main goal of promoting student learning. To improve student learning in the field of biomechanics, several different organizations like the *International Society of Biomechanics in Sports*, *American Society of Biomechanics*, and the *American Kinesiology Association* have been providing professional opportunities through conferences, workshops, symposiums, etc. to share ideas and examples of teaching practice. Other than these initiatives, there are peer-reviewed research on teaching and learning in multiple disciplines providing evidence-based practice. Among these efforts, active learning (AL) has been the focus to promote student learning. AL is defined as any activity to engage students in learning meaningfully by doing and thinking about things they are doing in the classroom rather than passively listening to the lecture (Bonwell & Eisen, 1991; Prince, 2004). The effectiveness of the AL has been documented in multiple disciplines (e.g., Hake, 1998; Freeman et al., 2014; Springer et al., 1999). These examples all demonstrated significant improvement in students' learning when compared to traditional lecture. Although there is a vast body of research showing the effectiveness of AL in a variety of disciplines, there is limited direct evidence for all different types of AL strategies in the field of biomechanics.

To promote meaningful intellectual engagement, many different AL strategies have been studied from simple to complex. Recent studies in the field of sports biomechanics focused on the effectiveness of a few AL strategies on students' learning in the undergraduate introductory class such as Just in Time Teaching (JiTT), problem-based learning (PBL), and low-tech active learning. Riskowski (2015) shared that JiTT effectively enhanced learning by 30 to 40%, while low-tech AL strategies resulted in learning improvement by 15-22% (Knudson & Wallace, 2019). Wallace et al. (2020) implemented PBL in three undergraduate introductory biomechanics classes and reported a 25% of normalized learning improvement.

The application of these AL strategies provided encouraging student learning outcomes; however, there are limited studies on the implementation of a particular complex AL strategy, flipped classroom, in biomechanics learning. A flipped classroom is structured around the idea that class time can be better used than simply lecture. In this approach, students encounter information before class, freeing class time for activities that involve higher-order thinking. It provides a balance of the "sage on the stage" and the "guide on the side" philosophies. A few studies from related areas such as biomedical engineering and mechanical engineering implemented flipped classroom approach and reported 38.1% of normalized learning improvement or better class performance when compared to traditional lecture classes, respectively (Cho et al., 2021; Wille & Chesler, 2019).

Despite overwhelming evidence to support the effectiveness of active learning, studies still consistently report the resistance of students to be engaged in active learning environments worldwide and across disciplines. The resistance simply comes from two sources. An active learning approach may require students to change their learning style. Also, in some models such as the flipped classroom, students may be required to complete additional work before each class (Boevé et al., 2017; Tolman & Kremling, 2017). Although there is a vast body of studies showing the effectiveness of AL, there are only about 10 to 41% of the biomechanics

instructors who utilize any AL strategies in class (Garceauet al. 2012; Breen & Knudson, 2022). Therefore, the purposes of this exploratory study were to examine 1) if the flipped classroom approach would also enhance students' biomechanics learning in exercise physiology and kinesiology majors as the studies indicated in other fields and 2) students' perception of the design of the flipped classroom. It was hypothesized that the students would have a significant enhancement in learning that was assessed by using Biomechanics Concept Inventory (BCI version 3; Knudson, 2006). More students would have negative perception about flipped classroom approach.

METHODS: This study was approved by the Institutional Review Board and all policies and regulations related to human subjects were followed. A total of twenty-eight students were recruited from a sixteen-week undergraduate introductory biomechanics class in 2022. The students' learning improvement was determined by using BCI v3 which was administered in the lab session (in-person) during the first and last week of the semester as pre- and post-tests. The BCI provides an unbiased measure of student learning on core concepts of the introductory biomechanics course (Knudson et al., 2003; Hsieh, Mache, & Knudson, 2012). Students were allowed 30 minutes to complete these tests, which consisted of 24 multiple-choice questions based on biomechanical concepts.

In addition to the tests, a six-item survey (Table 1) regarding the perception of the flipped classroom was conducted during the last week of the semester. A 5-point Likert scale was used to obtain students' agreement on the videos created and flipped classroom approach (items 1 and 5). Items 2 to 4 and 6 were to obtain qualitative feedback on their performance in the class. Two students who had more than 4 points of decreased score from pre- to post-test were excluded from the study. This non-compliance rate (7.1%) was within the range of previous similar studies (Henderson, 2002; Hsieh & Knudson, 2008; Hsieh et al., 2012; Knudson et al., 2003; Knudson & Wallace, 2019).

Table 1: Survey questions to obtain students' perceptions about the flipped classroom. Items 1 and 5 are based on a 5-point Likert scale where 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, and 5 = Strongly Agree.

Items
1. Are the videos for the class content clear and easy to follow so that you can answer the pre-work assignment questions?
2. How much have you watched the videos prepared? Express it by using percentages.
3. In the previous question, if you could not complete the videos at least once (100%), could you please share the reason for it?
4. As you reflect on your learning, which part of the class is the most challenging task for you to complete? Why?
5. The current mode of the flipped classroom approach works great for you (watch class videos before the class and work on the problem in class).
6. Please describe the best teaching/learning mode for you. For example, watching videos before the class and working on a problem during the class work fine, or purely lecturing the class with PowerPoint Slides and working on the problem after the class would be better, what else?

Students' engagement with the flipped classroom was organized into pre- and in-class portions with multiple AL strategies. The pre-class portion consisted of the materials that students needed to complete before the face-to-face class started (Table 2). The textbook readings were assigned with specific page numbers about the content covered for the following week. For the pre-class portion, students were also required to watch five to eight short videos created that depended on the length of content. Each video was about three to five minutes long. Before the class, students were all required to complete pre-work quizzes consisting of 20-30 questions to ensure they watched the videos and read the textbook assigned as well as to check their understanding of the content. There were two 75-minute in-person class sessions per week. Each class began with five to ten minutes of review and quizzes incorporating a think-pair-share activity to double-check the understanding of the content and followed by ten to fifteen minutes of clarification based on the outcome of the review. In some weeks, this activity was replaced by a small group discussion on the questions posted. The problem-based learning was the main portion of the class where students worked in small groups of two or three students while the instructor walked around to answer questions and provide hints/guides to solve the problem. Two separate problem-based learning scenarios were designed each week to align with students' emphasis areas. One was designed for physical education or coaching emphasis while the other was designed

for excise physiology emphasis. Each problem was based on a real-world scenario and data were extracted from peer-reviewed manuscripts when available. All main problems consisted of seven to ten sub-guided questions to solve the main problem.

Table 2: Flipped classroom design for pre- and during-class content.

Content	Duration	Class Materials
Pre-class	≅90 to 120 min of study/week	• Textbook reading (pages assigned) • Class content videos (5-8 short videos) • Pre-work quizzes (unlimited attempt)
During class	75 minutes/session	• 5-10 min review and quizzes • 10-15 min clarification • 40 min problem-based learning • 10 min wrap up with summary and hints

A paired t-test with a one-tailed test was performed to examine the improvement of the learning from the post-test to the pre-test. The effect size was also obtained to examine the magnitude of the difference. The statistical significance was set at 0.05. The normalized gain (Hake, 1998) in percentage was calculated. The median and mode of the agreement were reported. The students' perception of flipped classroom was organized and reported.

RESULTS: There was a significant learning improvement from the post- to pre-test (t_{25}= 6.65, $P < 0.05$) with an effect size of 1.23. The normalised gain for the learning improvement was 23% with a pre-test score of 9.2 ± 2.73 and a post-test score of 12.55 ± 2.98. The pre-test score was similar to the previous studies using BCI that ranged between 8.3 and 9.5 (Hsieh et al., 2012; Knudson et al., 2003; Knudson & Wallace, 2019). For survey item 1, students agreed that the videos for the class content were clear and easy to follow to answer the pre-work quizzes (average = 3.68 ± 0.98; median = 4; mode = 4). Students also agreed that the flipped classroom approach works well for them and do not like to change (average = 3.82 ± 0.94; median = 4; mode = 4). Table 3 shows the distribution of the students' agreement on the flipped classroom approach to their learning.

Table 3: Distribution of students' agreement on the flipped classroom approach (n = 28)

Items	Strongly Disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)
Item 1	3.57%	7.14%	25%	46.43%	17.86%
Item 5	3.57%	0	32.14%	39.29	25%

All students reported they have watched 99.78% of the videos posted with a range between 60 and 200% (watched the videos twice). The main reason students did not watch the videos at least once was due to time management issues (e.g., procrastination, occupied by other work, etc.). More than half of the students (64%) reported that they agree that flipped classroom was a great approach to learning as well as the design of the class videos because it provided flexibility for them to review class lessons and have more time in class to ask questions about the problems. About 40% of students reported the most difficult part of the class was applying what they learned from the pre-class materials to the PBL assignments. About 18% of the students shared the math portion of the PBL was difficult.

DISCUSSION: The flipped classroom is a complex AL strategy. In this example presented including the use of PBL, think-pair-share, and small group discussion. The current finding of significant and large improvement (d = 1.23) supports studies in other disciplines (Cho et al., 2021; Wille & Chesler, 2019) as well as the findings of other AL strategies in the field of biomechanics (Knudson & Wallace, 2019; Wallace et al., 2020). The normalized learning gain of 23% was lower than the JiTT AL strategy (30-40%, Riskowski, 2015) but slightly higher than the low-tech AL strategies (15-22%, Knudson & Wallace, 2019) and more than double of traditional lecture format (11%, Knudson et al., 2009).

Interestingly, more than half of the students (64%) agreed that the flipped classroom was a good learning mode for them. This positive attitude toward this complex AL strategy was aligned with the findings from Cho et al. (2021) and Wille and Chesler (2019). Students mainly reported that they liked the format to learn the content before the class and work on problems during the class since there are more times and opportunities to ask questions and interact with the instructor. This was achieved by a clear structure and constant reminders to help students preparing for the upcoming class. To ensure students' preparation, the pre-work quizzes were designed to align with readings and videos. The resource of each question was included for students to quickly review and check their understanding of the

concept. Students were allowed unlimited attempts to work on the pre-work quizzes as an encouragement to prepare for the class.

Despite the positive attitude toward the flipped classroom approach, 40% of students reported the challenge of applying the concept learned before the class to the PBL activity. It should be noted that PBL is to challenge students' problem-solving, critical thinking, and communication abilities. Therefore, it can be intimidating to some of the students. The instructor should carefully design the guided questions and hints to help students map out the steps to the solution. Last, the workload for the pre-class materials needs to be carefully assigned to help students balance their schedules and other commitments.

CONCLUSION: This study supported that flipped classroom can be implemented in undergraduate introductory biomechanics to result in significant learning improvement. With careful structure and consistent communication and reminders, the majority of students agreed that this type of learning approach is helpful and commented that they like the flexibility to review the lesson. However, a small group of students reported that it was difficult to complete all the required preparation each week due to other commitments.

REFERENCES

Boevé, A. J., Meijer, R. R., Bosker, R. J., Vugteveen, J., Hoekstra, R., & Albers, C. J. (2017). Implementing the flipped classroom: An exploration of study behaviour and student performance. *Higher Education: The International Journal of Higher Education Research*, *74*(6), 1015-1032.

Bonwell, C. C., & Eisen, J. A. (1991). *Active learning: Creating excitement in the classroom.* Washington, DC: George Washington University.

Breen, S., & Knudson, D. (2022): International survey of faculty teaching undergraduate introductory biomechanics. *Sports Biomechanics*, DOI: 10.1080/14763141.2022.2110933

Cho, H. J., Zhao, K., Lee, C. R., Runshe, D., & Krousgrill, C. (2021). Active learning through flipped classroom in mechanical engineering: improving students' perception of learning and performance. *International Journal of STEM Education*, *8* (46), https://doi.org/10.1186/s40594-021-00302-2

Freeman, S., Eddy, S., McDonough, M., Smith, M., Okoroafor, N., Jordt, H., & Wenderoth, M. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences*, *111*, 8410–8415.

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, DOI: 10.1080/14763141.2012.725764

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

Henderson, C. (2002). Common concerns about the force concept inventory. *Physics Teacher*, *30*, 542–547. doi:10.1119/1.1534822

Hsieh, C., & Knudson, D. (2008). Student factors related to learning in biomechanics. *Sports Biomechanics*, *7*, 398–402. doi:10.1080/14763140802233207

Hsieh, C., Smith, J., Bohne, M., & Knudson, D. (2012). Factors related to students' learning of biomechanics concepts. *Journal of College Science Teaching*, *41*, 83–89.

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

Knudson, D., Bauer, J., & Bahamonde, R. (2009). Correlates of student learning in introductory biomechanics. Perceptual and Motor Skills, 108, 499–504. doi:10.24.66/PMS.108.2.499-504

Knudson, D., Noffal, G., Bauer, J., McGinnis, P., Bird, M., Chow, J.,…, & Abendroth-Smith, J. (2003). Development and evaluation of a biomechanics concept inventory. *Sports Biomechanics*, *2*(2), 267-277. Doi.org/10.1080/14763140308522823

Knudson, D., & Wallace, B. (2019). Student perceptions of low-tech active learning and mastery of introductory biomechanics concepts. *Sports Biomechanics*, *24* (4), 458-468. Http://doi.org/10.1080/14763141.2019.1570322

Prince, M. (2004). Does active learning work? A review of research. *Journal of Engineering Education*, *93*(3), 223-231.

Riskowski, J. L. (2015). Teaching undergraduate biomechanics with just-in-time teaching. *Sports Biomechanics*, *14*, 168–179. doi:10.1080/14763141.2015.1030686

Springer, L., Stanne, M., & Donovan, S. (1999). Effects of small-group learning on undergraduates in science, mathematics, engineering and technology: A meta-analysis. *Review of Educational Research*, *69* (1), 1999, 21–52.

Tolman, A. O., & Kremling, J, (2017). *Why students resist learning?* Sterling: Stylus Publishing, LLC.

Wille, C. M., & Chesler, N. (2019, June). The teaching assistant's perspective on flipping an undergraduate biomechanics course. In 2019 ASEE Annual Conference & Exposition. *American Society for Engineering Education*. Extracted from: https://peer.asee.org/the-teaching-assistant-s-perspective-on-flipping-an-undergraduate-biomechanics-course