ACTIVE LEARNING: REVIEW OF EVIDENCE AND EXAMPLES

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The aim of this paper was to review the evidence regarding the effectiveness of active learning in the sciences. Numerous research provide strong empirical evidence supporting the claim that interactive engagement with course material is vital to student learning, especially in areas such as physics, biology, chemistry, and physiology. In addition, common active learning techniques were discussed. Four active learning methods were described regarding their application to introductory biomechanics courses. This set of strategies is relatively easy to implement in a variety of classroom settings which increase overall student learning without requiring major curriculum change.

KEY WORDS: active learning, biomechanics, pedagogical strategies.

INTRODUCTION: Meaningful learning represents the ability of students to internalize abstract ideas so that students' learning is promoted beyond course requirements and useful skills can be acquired and applied to real-world situations. Unfortunately, meaningful learning is not easily achieved with traditional lecture methods (Smith et al., 2005). Therefore, learning has been a major research topic for many different scientific disciplines such as engineering, physics, medicine, etc. Research found that in order to promote students' learning, one of the most effective learning approaches is active learning (e.g., Crouch & Mazur, 2001; Deslauriers Schelew, & Wieman, 2011; Haak, HilleRisLambers, Pitre, & Freeman, 2011; Hake, 1998a,b; Naiz, Aguilera, Maza, & Liendo, 2002; Nehm & Reilly, 2007;).

There is no universally agreed upon definition for active learning, though many researchers agree that it includes students engaging in talking and listening, writing, reading, and/or reflecting. Bonwell and Eison (1991) identified active learning as any approach or technique which "involves students in doing things and thinking about the things they are doing" (p. 2). Students who experience active learning usually exhibit greater knowledge and understanding of course content (Chickering & Gamson, 1987; Ruiz-Primo, Briggs, Iverson, Talbot, & Shepard, 2011). In contrast, passive learning occurs during the traditional lecture approach where instructors deliver rehearsed information that result in less efficient student learning (Chickering & Gamson, 1987; Faust & Paulson, 1998; McKeachie, Pintrich, Lin, Smith, & Sharma, 1990; National Research Council [NRC], 1997; National Science Foundation [NSF], 1996).

There are reasons that passive learning persists in the classroom. Lecture is the default teaching method for many faculty as they struggle to balance multiple role expectations of research, teaching, and service (McKeachie, 1999). Instructors tend to have difficulties implementing effective practice of new approaches such as active learning in the curriculum as a result of time constraints (Allen & Tanner, 2005; Andrews, Leonard, Colgrove, & Kalinowski, 2011). Therefore, the traditional lecture format is perceived by many as the most efficient, predictable, and comfortable way to convey course content, especially when teaching a class with large enrollment (McKeachie et al., 1990; Smith et al., 2005).

For science teaching and learning, especially biomechanics, some theories and concepts have to be delivered before active learning can be engaged (Roselli & Brophy, 2006). Due to complexity of the subject matter, biomechanics faculty members often find themselves introducing and explaining concepts for a substantial portion of class time. Additionally, if students come unprepared with insufficient prerequisite knowledge foundation (e.g., anatomy, physiology, basic physics, etc.), instructors are required to spend even more class time familiarizing students with basic concepts before moving on to more active learning activities. Consequently, after theory and concepts have been presented, there is a lack of time to devote toward active learning.

Therefore, the major purpose of this paper was to provide examples of active learning strategies applied toward teaching introductory biomechanics in in lecture and laboratory settings. In the following section, several common examples of active learning techniques are described and the evidence of their effectiveness in related fields is provided. Finally, the applications of these techniques in biomechanics are presented.

ACTIVE LEARNING EVIDENCE: The main tenets for effective science teaching and learning were adeptly summarized by Michael (2006) and Prince (2004). First, students must be actively engaged in constructing their understanding of facts, ideas, and skills/competencies presented by the instructor (Chickering & Gamson, 1987; Faust & Paulson, 1998; NRC, 1997; NSF, 1996). Second, instruction must differ to meet the distinctive learning pathways for declarative and procedural knowledge (Thomas & Thomas, 1994). Third, some subject matters are more generalizeable than others and it is important for instructors to learn how to foster or facilitate information transfer (Modell, 2000). Fourth, group learning has been found to be more powerful than learning alone (Johnson, Johnson, & Stanne, 2000). Lastly, self-explanations have been positively correlated with learning and overall retention of content (Calin-Jageman & Ratner, 2005). Thus, these key findings should be embedded into pedagogical strategies for active learning of science concepts.

As previously mentioned, active learning has been studied extensively across multiple disciplines and the vast body of research has identified a variety of approaches to enhance teaching and learning in the classroom. However, each discipline utilizes slightly different terminology to describe similar pedagogical approaches thus intensifying the confusion when determining which active learning strategy to implement. The most common in-class methods are described in Table 1.

Table 1
Description of common active learning techniques

Active Learning Technique	Description
Cooperative Learning	Students work together toward common goal and being evaluated individually (Dougherty, Bower, Berger, Rees, Mellon, & Pulliam, 1995)
Collaborative Learning	Students work together toward common goal (Lumpe & Staver, 1995)
Problem-Based Learning	Problems are introduced at beginning of the instruction and motivate students' learning followed (Dochy, Sergers, Van den Bossche, & Gijbels, 2003)
Discovery/Inquiry-Based learning	Exposing students to situations, questions, or tasks that allow discovery of intended concepts (Wilke & Straits, 2001)
Challenge-Based	An extension of Problem-Based Learning, students are presented with a scenario in which they work towards a solution with others (Roselli & Brophy, 2006)
Concept Mapping	A visual aid that is constructed by students to organize concepts through hierarchial order and possible relationships (Briscoe & LaMaster, 1991; Novak, 1990)

All areas of science face one mutual challenge: altering students' misconceptions about fundamental concepts in science (Chi, 2005; Michael, 2006; Smith, deSessa, & Roschelle, 1993). Though some misconstructions tend to be more robust than others, active learning techniques can assist students in fostering a stronger and more accurate foundation for deeper learning and generalizable science knowledge (Chi, 2005). The paradigm shift toward engaging students in their own learning has continued to gain momentum in the last decade. Recent research revealed when students are exposed to active learning techniques, significant learning improvements were evident in the hard sciences areas such as physics (e.g., Deslauriers et al., 2011; Hake, 1998a,b; Redish & Steinberg, 1999), chemistry (e.g., Dougherty et al., 1995; Jones-Wilson, 2005; Paulson, 1999), biology (e.g., Andrews et al., 2011; Haak et al., 2011; Lumpe & Staver, 1995), and physiology (e.g., Modell, 2000; Rao & DiCarlo, 2000; Wilke, 2003).

Improvements in academic achievement are only one positive result of using interactive and engaging approaches. Braxton, Milem, and Sullivan (2000) and Prince (2004) reported that a positive correlation between active learning behavior and social integration, the relationships between peers as well as faculty (Severiens & Wolff, 2008). That is, the techniques of active learning improved the overall quality of interactions of those involved in the learning process. The level of social integration, in turn, influenced sense of belongingness, which is related to both persistence and retention, especially among ethnic minorities (Zea, Reisen, Beil, & Caplan, 1997).

APPLICATION TO BIOMECHANICS INSTRUCTION: In an effort to minimize passive learning in undergraduate, introductory biomechanics classes, the author advocates that active learning should be targeted in both lecture and lab. The choice of strategies will depend on: the size of the class, the class objective(s), and the amount of available class time. The techniques presented below minimize major changes in course curricula while emphasizing easy-to-use in class pedagogical strategies to boost students' learning in the lecture setting.

The traditional teaching model can cultivate active learning through the integration of fairly simple techniques. Interest level of students can be understood in two ways. First, the content of any subject can be customized to match students' interests. This information can be obtained effortlessly through informal interviews conducted at the beginning of the course or short survey. Thus, their professional pursuits can be used as a platform to construct appealing examples. Second, the attention span of the average student is less than 20 minutes (Bonwell & Eison, 1991; Frederick, 1986; Ruhl, Hughes, & Schloss, 1987). Therefore, embedding one active learning strategy every 15-20 minutes assists students in maintaining a high level of focus.

The "color response card" (CRC) system is an effective multi-functional tool which forms the basis of some in class active learning strategies presented. Each student receives a pack of CRC which allows them to participate in a variety of activities either individually or in a group setting (Figure 1). This approach reinforces each individual's engagement and avoids the domination of only a handful of students. In a large introductory biomechanics class, it is difficult to gage the level of student understanding. Instructors must carefully devise questions to examine comprehension and create answers to assess for common misunderstandings of concepts. By using the CRC, instructors will be able to obtain a general impression of the class response and immediately adjust instruction by providing additional support for the concept or if new material can be presented.

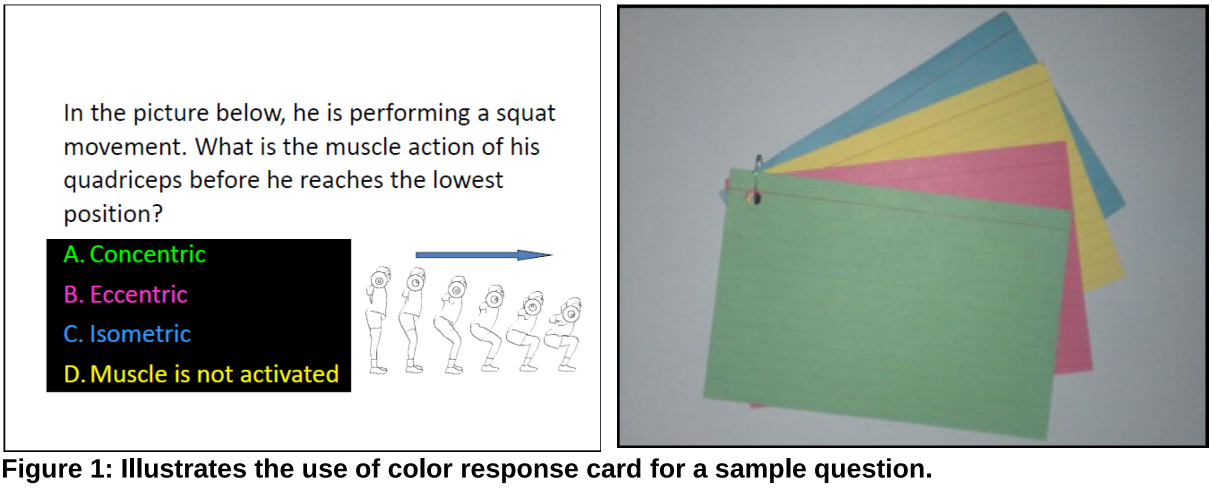

Figure 1: Illustrates the use of color response card for a sample question.

An advanced version of the think-pair-share strategy exemplifies cooperative and collaborative learning within the lecture setting (Rao & DiCarlo, 2000). This involves each student arriving at their own individual answer with CRC and then identifying a peer with a different answer. Not only does sharing occur, but the students will attempt to convince the other why their answer is correct. After this, the students will answer the question again so that the faculty member can ascertain whether more guidance is necessary.

Hands-on learning activities often involve both discovery-based and problem-based learning and are often utilized in lab (NRC, 1997). An abbreviated version can also be implemented in lecture in which students take part in a kinesthetic or physical experience, such as modified sumo wrestling, to understand the concept of balance. For this activity, students determine the best combination of base of support and location of center of mass to achieve mobility and/or stability. The use of CRC facilitates the instructor's assessment of the students' learning throughout the process.

The final technique is the one minute paper which compels the student to formulate short written responses conveying their familiarity with content presented (Stead, 2005). It can be employed at any time such as the end of class or activity. The instructor can pose a variety of questions to vary the activity slightly. In its origin format, students answered open-ended content questions. Various adaptations could be for undergraduates to communicate points that were ambiguous or most clear so that they can reflect on their own learning process and advocate for additional support if needed.

SUMMARY: The efficacy regarding the use of active learning strategies in teaching science subjects has been strongly supported throughout the literature. The most common active learning methods found in the science research included cooperative learning, collaborative learning, problem-based learning, discovery/inquiry-based learning, and challenge-based learning. This paper explained how to modify these active learning strategies to supplement introductory biomechanics lecture and lab settings without major interruptions to teaching flow or excessively burdening the instructors with curriculum change.

REFERENCES:

Allen, D., & Tanner, K. (2005). Infusing active learning into the large-enrollment biology class: Seven strategies, from the simple to complex. *Cell Biology Education, 4*, 262–268.

Andrews, T. M., Leonard, M. J., Colgrove, C. A., & Kalniowski, S. T. (2011). Active learning not associated with student learning in a random sample of college biology courses. *Cellular Biology Education – Life Sciences Education, 10,* 394-405.

Bonwell, C.C., and Eisen, J.A. (1991). Creating Excitement in the Classroom (ASHE-ERIC Higher Education Report No. 1). Washington, DC: George Washington University, School of Education and Human Development.

Braxton, J. M., Milem, J. F., & Sullivan, A. S. (2000). The influence of active learning on the college student departure process: Torward a revision of Tinto's theory. *The Journal of Higher Education, 71*(5), 669-690.

Briscoe, C., & LaMaster, S.U. (1991). Meaningful learning in college biology through concept mapping. *The American Biology Teacher, 53,* 214–219.

Calin-Jageman, R., & Ratner, H. (2005). The role of encoding in the self-explanation effect. *Cognition and Instruction, 23(4)*, 523–543.

Chi, M. T. H. (2005). Commonsense concepts of emergent processes: Why some misconceptions are robust. *Journal of the Learning Science, 14*(2), 161–199.

Chickering, A. W., & Gamson, Z. F. (1987). Seven principles for good practice. *AAHE Bulletin, 39*, 3-7.

Crouch, C. H., & Mazur, E. (2001). Peer instruction: Ten years of experience and results. *American Journal of Physics*, *69,* 970-976.

Dougherty, R.C., Bower, C.W., Berger, T., Rees, W., Mellon, E.K., & Pulliam, E. (1995). Cooperative learning and enhanced communication: Effects on student performance, retention, and attitudes in general chemistry. *Journal of Chemical Education, 72*, 793–797.

Deslauriers, L., Schelew, E., & Wieman, C. (2011). Improved learning in a large-enrollment physics class. *Science, 332*, 862-864

Dochy, F., Sergers, M., Van den Bossche, P., & Gijbels, D. (2003). Effects of problem-based learning: A meta analysis. *Learning and Instruction*, *13*, 533-568.

Faust, J. & Paulson, D. (1998). Active learning in the college classroom. *Journal on Excellence in College Teaching, 9*(2), 3-24.

Frederick, P.J. (1986). The lively lecture-8 variations. *College Teaching*, *34*(2), 43-50.

Haak, D. C., HilleRisLambers, J., Pitre, E., & Freeman, S. (2011). Increased structure and active learning reduce the achievement gap in introductory biology. *Science, 332,* 1213-1216.

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

Hake, R. R. (1998b). Interactive engagement methods in introductory physics mechanics courses. *Retrieved from http://www.physics.indiana.edu/~sdi/IEM-2b.pdf*

Johnson, D. W., Johnson, R.T., & Stanne, M.B. (2000). *Cooperative learning methods: A meta-analysis. Retrieved at* http://www.tablelearning.com/uploads/File/EXHIBIT-B.pdf

Jones-Wilson, T. M. (2005). Teaching problem-solving skills without sacrificing course content: Marrying traditional lecture and active learning in an organic chemistry class. *Journal of College Science Teaching, 35*(1), 42-46.

Lumpe, A.T., & Staver, J.R. (1995). Peer collaboration and concept development: Learning about photosynthesis. *Journal of Research in Science Teaching, 3,*: 71–98.

McKeachie, W. J., Pintrich, P. R., Lin, Y-G, Smith, D. A. F., & Sharma, R. (1990). *Teaching and learning in the college classroom: A review of the research literature* (3rd ed.). Ann Arbor, MI: University of Michigan Press.

McKeachie, W. J. (1999). *Teaching tips: Strategies, Research, and theory for college and university teachers* (10th ed.)*.* Boston: Houghton Mifflin.

Michael, J. (2006). Where's the evidence that active learning works? *Advances in Physiology Education, 30,* 159-167.

Modell, H. I. (2000). How to help students understand physiology? Emphasize general models. *Advances in Physiology Education, 23,* 101–107.

Naiz, M., Aguilera, D., Maza, A., & Liendo, G. (2002). Arguments, contradictions, resistances, and conceptual change in students' understanding of atomic structure. *Science Education, 86,* 505-525.

National Research Council (NRC). (1997). *Science teaching reconsidered: A handbook.* Washington, DC: National Academies Press.

National Science Foundation (NSF). (1996). *Shaping the future: New experiences for undergraduate education in science, mathematics, engineering, and technology. Report of the Advisory Committee to the NSF Directorate for Education and Human Resources.* Washington, DC: Author.

Nehm, R. H., & Reilly, L. (2007). Biology majors' knowledge and misconceptions of natural selection. *BioScience, 57,* 263-272.

Novak, J. D., (1990). Concept mapping: A useful tool for science education. *Journal of Research in Science Teaching, 27*(10), 937-949.

Paulson, D. R. (1999). Active learning and cooperative learning in the organic chemistry lecture class. *Journal of Chemical Education, 76*(8), 1135-1140.

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

Redish, E.G., & Steinberg, R. N. (1999). Teaching physics: Figuring out what works. *Physics Today, 52*, 24-30.

Rao, S. P., & DiCarlo, S. E. (2000). Peer instruction improves performance on quizzes. *Advances in Physiology Education, 24,* 51-55.

Roselli, R.J., & Brophy, S.P. (2006). Effectiveness of challenge-based instruction in biomechanics. *Journal of Engineering Education*, 95(4), 311-324.

Ruhl, K. L., Hughes, C. A. & Schloss, P. J. (1987). Using the pause procedure to enhance lecture recall. *Teacher Education and Special Education*, *10*, 14-18.

Ruiz-Primo, M. A., Briggs, D., Iverson, H., Talbot, R., & Shepard, L. A. (2011). Impact of undergraduate science course innovations on learning. *Science, 331,* 1269-1270.

Severiens, S. E., & Wolff, R. (2008). A comparison of ethnic minority and majority students: Social and academic integration and quality of learning. *Studies in Higher Education, 33*(3), 253–266.

Smith, J. P. III, deSessa A. A., & Roschelle, J. (1993). Misconceptions reconceived: A constructivist analysis of knowledge in transition. *Journal of the Learning Science, 3*(2), 115–163.

Smith, A. C., Stewart, R., Shields, P., Hayes-Klosteridis, J., Robinson, P., & Yuan, R. (2005). Introductory biology courses: A framework to support active learning in large enrollment introductory science courses. *Cell Biology Education, 4*, 143–156.

Stead, D. R. (2005). A review of the one-minute paper. *Active Learning in Higher Education, 6*(2), 118-131.

Thomas, K. T., & Thomas, J. R. (1994). Developing expertise in sport: The relation of knowledge and performance. *International Journal of Sport Psychology, 25*(3), 295-312.

Wilke, R. R. (2003). The effect of active learning on student characteristics in a human physiology course for nonmajors. *Advances in Physiology Education, 27,* 207-223.

Wilke, R. R., & Straits, W. J. (2001). The effects of discovery learning in a lower-division biology course. *Advances in Physiology Education, 25,* 62–69.

Zea, M. C., Reisen, C. A., Beil, C., & Caplan, R. D. (1997). Predicting intention to remain in college among ethnic minority and nonminority students. *The Journal of Social Psychology, 137*(2), 149–160.