



Effects of Image-Based and Text-Based Exercises on Student Learning Outcomes in a Musculoskeletal Anatomy Course



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Introduction

Research on the benefits of visual learning has relied primarily on lecture-based pedagogy, not accounting for the processing time students need to make sense of both visual and verbal material (Tangen et al., 2011). Recently, the use of clickers and other active learning exercises has been shown to increase learning and performance in STEM courses (Barr, 2014; Freeman et al., 2014), and an increasing number of instructors have been using these active learning pedagogies, also sometimes in conjunction with images. However, the role of images in enhancing student learning in STEM classrooms – whether through lecture-based pedagogy or active learning – is unclear.

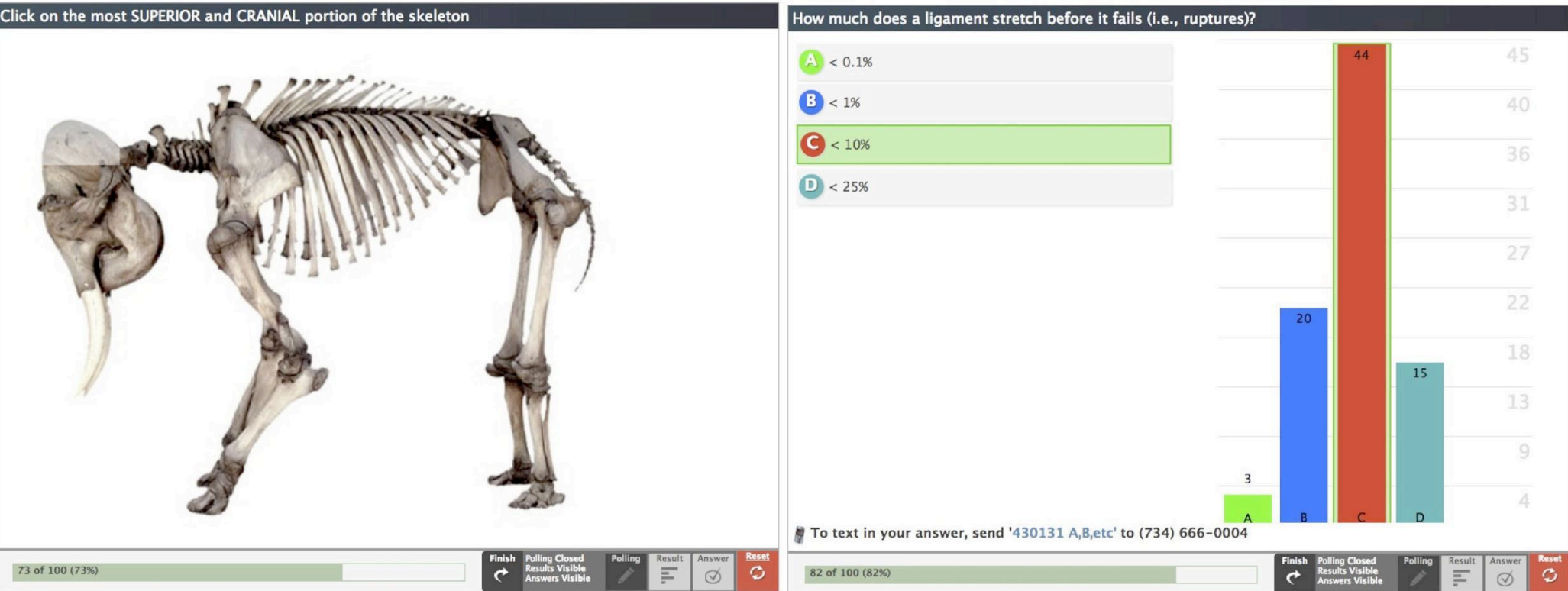
The purpose of this study was to investigate the potential differential effects of text-based and image-based active learning exercises on student learning outcomes in an undergraduate functional anatomy course.

Methods

The study analyzed data from an intermediate level course, Human Musculoskeletal Anatomy, which is required for all students majoring in Movement Science, over two terms. The course averages 100 students per term, comprising about half majors, with most at the sophomore level.

Active learning exercises. Each class session consisted of lecture segments punctuated with active learning exercises in which students answered interactive questions asked through LectureTools, an interactive presentation software.

Text-based exercises consisted of a written question and multiple-choice answers. Image-based exercises consisted of either a question associated with a particular image (and multiple-choice answers) or an image map where students clicked on the image to answer the question.



Analysis. Overall, the analyses examined students' participation and performance in 259 in-class active learning exercises over the two terms. Performance on exams also was tracked.

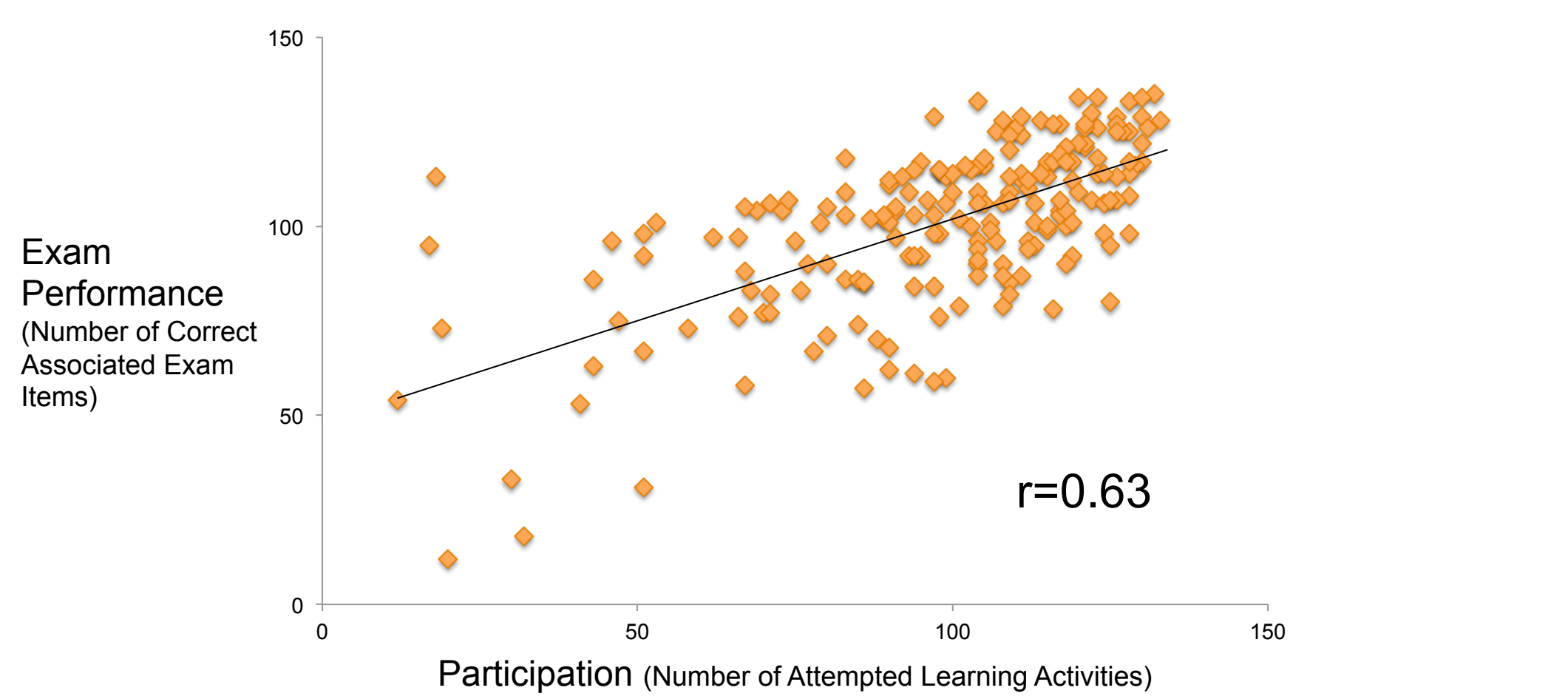
Linear multivariate regression analyses were used to look for correlations between performance on exam questions associated with the learning exercises and participation in these exercises, controlling for gender, URM status and prior GPA, as they have been found to be key predictors of STEM performance and educational achievement.

Finally, students were asked to participate in an end-of-semester survey, which asked them to reflect on the in-class exercises (75% response rate).

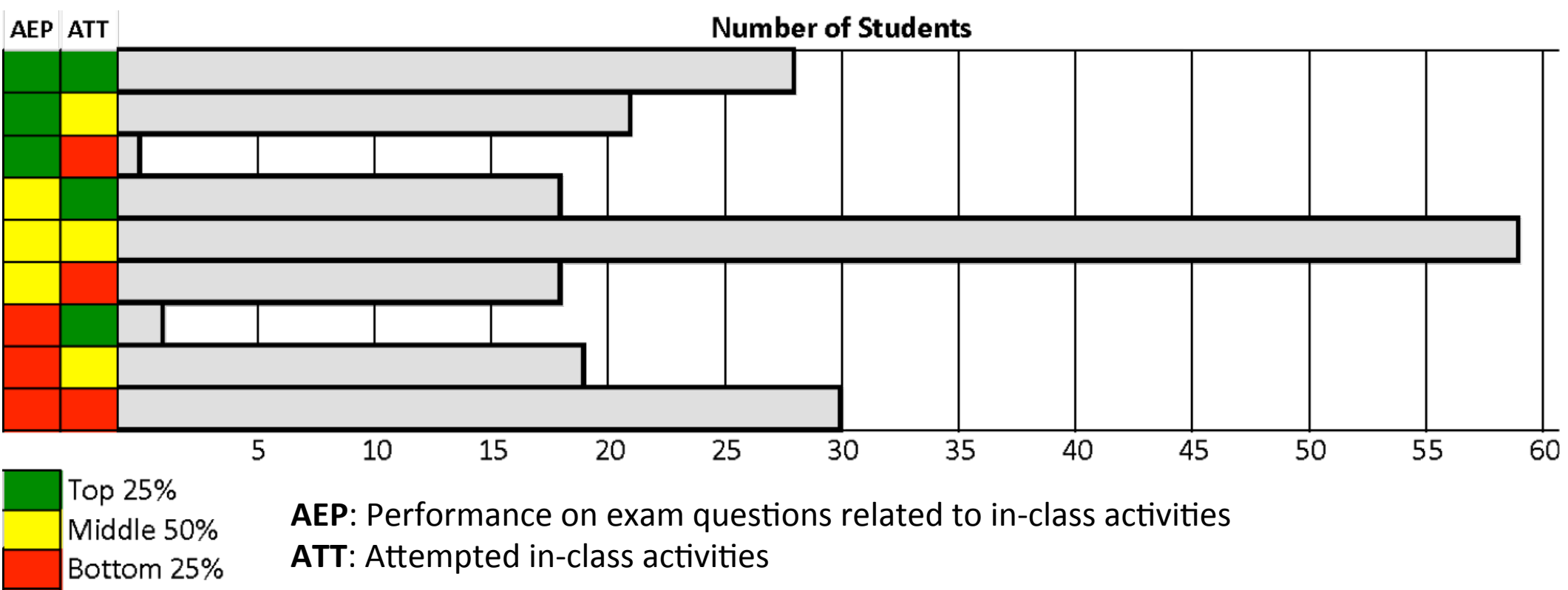
Results

Participation. On average, students participated in more image-based (58±14) than text-based (39±11) exercises. Students participated in 75% of all text-based and 74% of all image-based (74%) exercises.

Participation and exam performance. There was a strong relationship between participation and exam scores.



Students at the bottom (top) quartile of exam performance on exercise-related questions tended to also be at the bottom (top) for number of questions attempted.



Regression analysis. When predicting exam performance on image-based exam questions, participation in image-based active learning exercises and prior GPA had a statistically significant impact.

	Estim.	SE	β	p-value
Intercept	0.18	0.07		0.01
Image participation	0.42	0.11	0.51	<0.001
Text participation	0.05	0.10	0.07	0.62
URM status (non-URM coded 0)	0.03	0.03	0.05	0.37
Gender (Male coded 0)	-0.02	0.18	-0.73	0.23
GPA	0.75	0.02	0.24	<0.001

Alternatively, when predicting exam performance on text-based exam questions, again participation in image-based active learning exercises and GPA had a significant impact.

	Estim.	SE	β	p-value
Intercept	0.16	0.08		0.05
Image participation	0.32	0.13	0.33	0.01
Text participation	0.20	0.11	0.24	0.07
URM status (non-URM coded 0)	0.01	0.03	0.01	0.84
Gender (Male coded 0)	-0.03	0.02	-0.10	0.12
GPA	0.08	0.02	0.20	0.002

In summary, results for both regressions suggest that participation in image-based questions is associated with higher exam scores, while participation in text-based active learning is not. URM status and gender were not significantly correlated with exam performance in this class, holding other covariates constant, suggesting that this benefit holds for a diversity of students.

Student feedback. Overall, students found LectureTools exercises to be very helpful to their learning experiences, particularly for seeing images of key ideas and clarifying course concepts. Nearly all students (94%) agreed or strongly agreed that LectureTools learning exercises were helpful for "seeing images of key ideas in the course." As a respondent stated, "The questions on LectureTools really help you learn and think about what you are actually learning." Another student commented that the tool "provided pictures that were vital for comprehension."

Discussion

Our findings are consistent with the prediction that participation in learning exercises is positively correlated with student learning outcomes. Furthermore, our results suggest that participation in image-based learning exercises is more strongly correlated with exam performance than participation in text-based exercises, when controlling for key background characteristics.

In-class student learning exercises may be particularly valuable in helping students discern critical features in an image, learn how to "see" important elements in the image, and begin to construct the mental models that are necessary for advanced applications of their knowledge. In the active learning setting, students have more time to process information, thus reducing cognitive load and potentially increasing deeper learning, particularly with image-based exercises.

Lessons learned. The use of visual materials along with verbal cues has been shown to be particularly effective for low-knowledge learners (Kalyuga et al., 2000; Mayer, 2011), perhaps because students with less experience in a subject require additional information before generative processing can occur. Thus, the use of visual material may be particularly beneficial in introductory courses. Our finding about the positive impact of visuals when implemented during in-class exercises is significant for other STEM instructors who wish to design pictorially-based active learning exercises.

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