Effects of Training Examples on Student Understanding of Force and Motion

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Introduction / Motivation

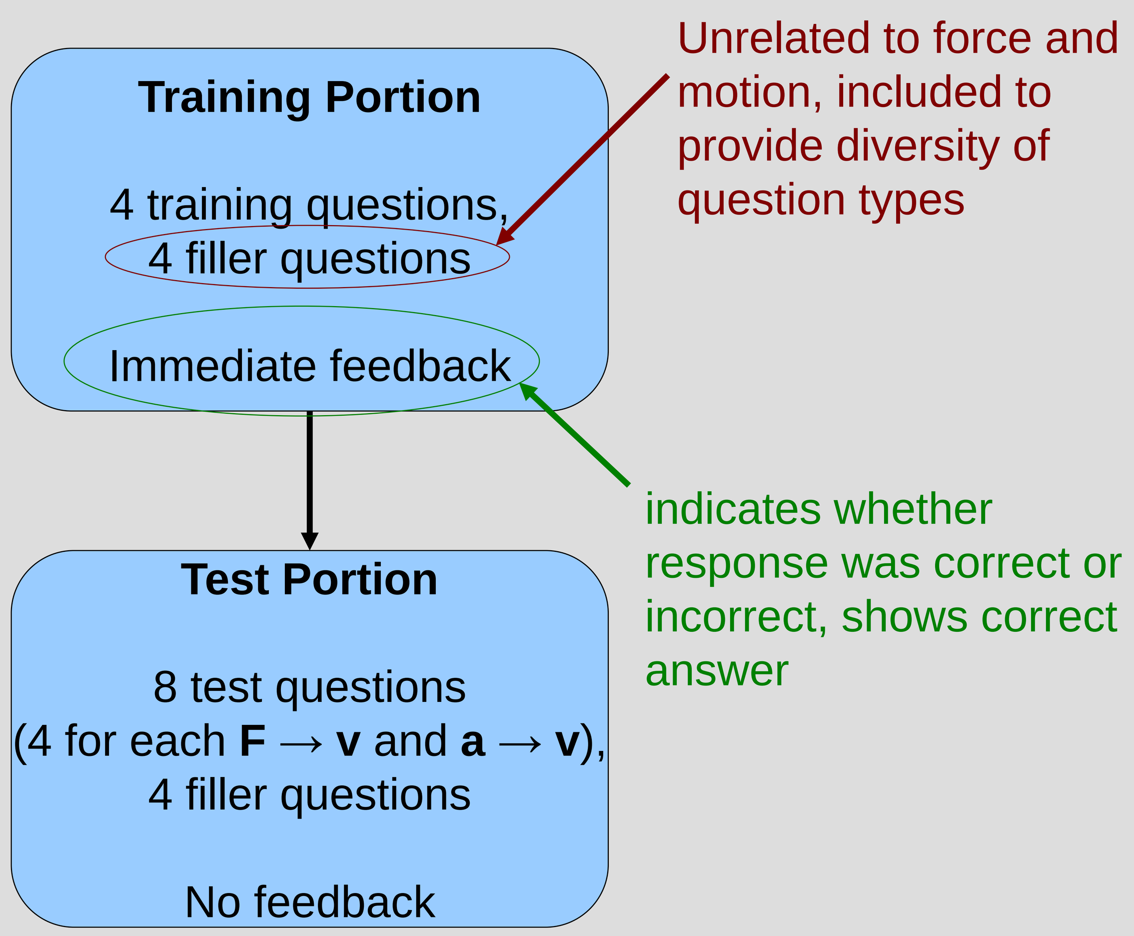
Force and motion are among the first topics students tend to encounter while studying physics and are equally important later in physics sequences for providing perspective and context for more advanced topics. Understanding force and motion is a vital component of educational goals for physics courses.

As studies continue to add detail to our understanding of student difficulties with force and motion, it is tempting to assume that the optimal instructional approaches with address student misconceptions head-on. However, we must remember that more efficient approaches may exist, as addressing some misconceptions may reduce the prevalence of other misconceptions (i.e., there may be hierarchies in student understanding), or observed misconceptions may be the result of traditional course structure and therefore require a more clever approach.

Rather than designing a course from theoretical principles of learning progression, we therefore find it necessary to study the effects of specific training strategies on student responses to force and motion questions. The results of such an empirical study stand to show how to get the greatest gains in student scores, which can also be integrated into existing theoretical frameworks to yield a more complete picture of student learning.

Training / Testing Approach

We provided students with brief electronic training routines followed immediately by a test. Each training group received a different type of question during training (determined by their training condition), but each student received the same test.



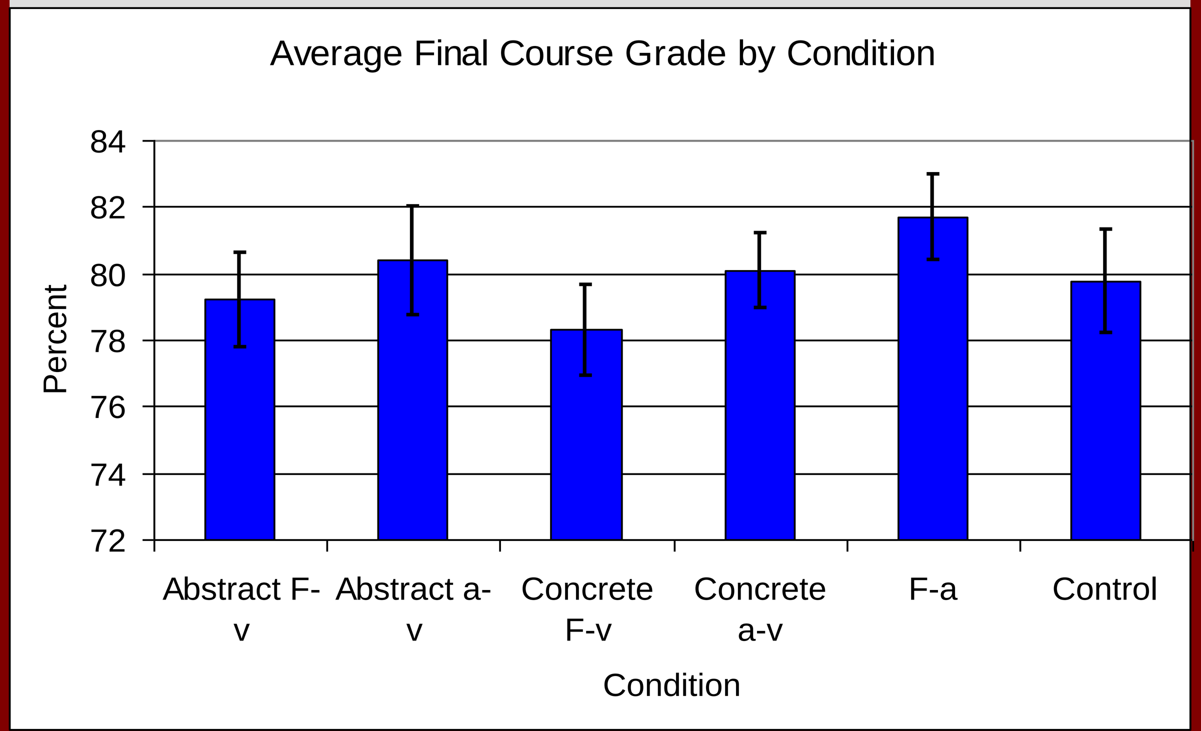
Training Conditions

Force and motion questions were restricted to relations between the directions between net force, velocity, and acceleration. A question of type "**x** → **y**" indicates the direction of quantity **x** and asks for the direction of quantity **y**. We also varied the context for each question type, including abstract, which uses general language only, referring to "particles" and "the positive direction," and concrete, which includes superfluous contextual information.

Training Condition	Number of Students
Abstract **F** → **v**	46
Abstract **a** → **v**	46
Concrete **F** → **v**	46
Concrete **a** → **v**	46
F → **a**	45
Control	45

Population

Students received course credit for participation in their introductory calculus-based electricity and magnetism course. They were randomly assigned to a training condition. There are no significant differences in average course grade between groups, lending credence to the idea that they were, in fact, representative samples of the population.



Example Question

The net force acting on a dog in a park points towards a small group of tulips at an instant in time. In what direction is the dog's velocity at that instant?

a. Towards the tulips

b. Away from the tulips

c. It is zero

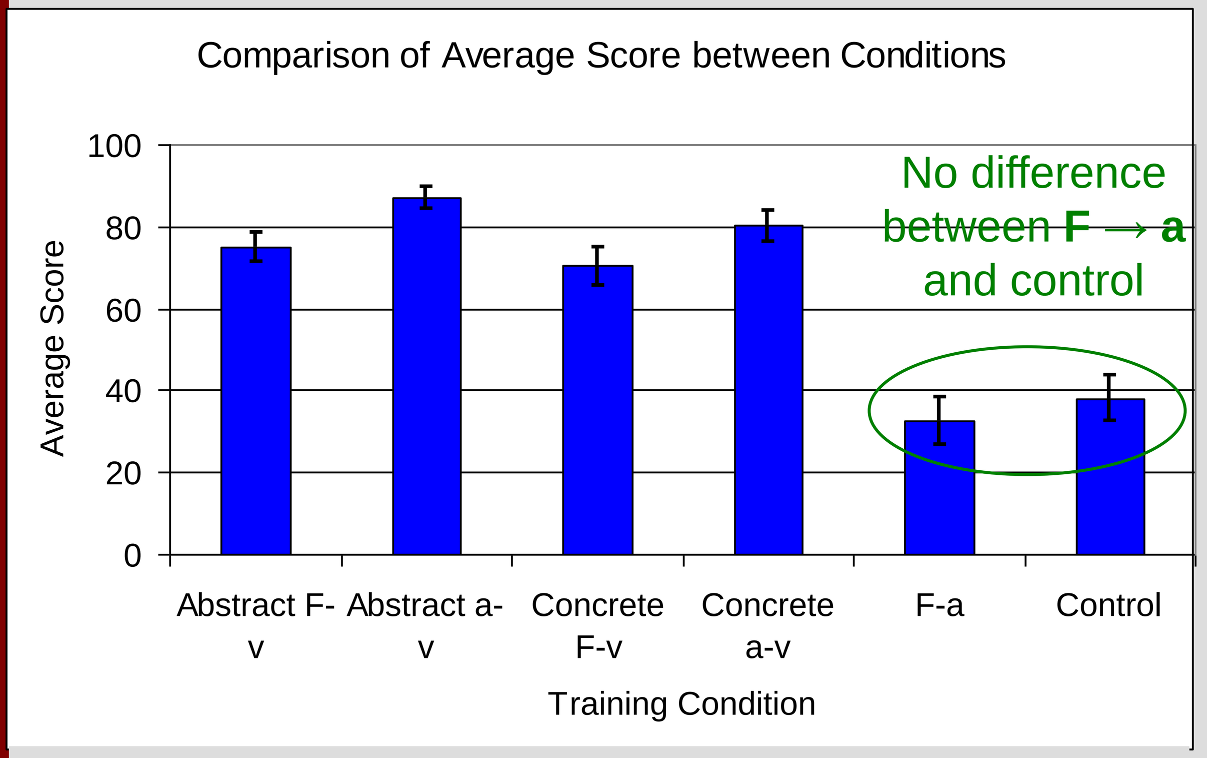
d. Both a and b are possible

e. Both a and c are possible

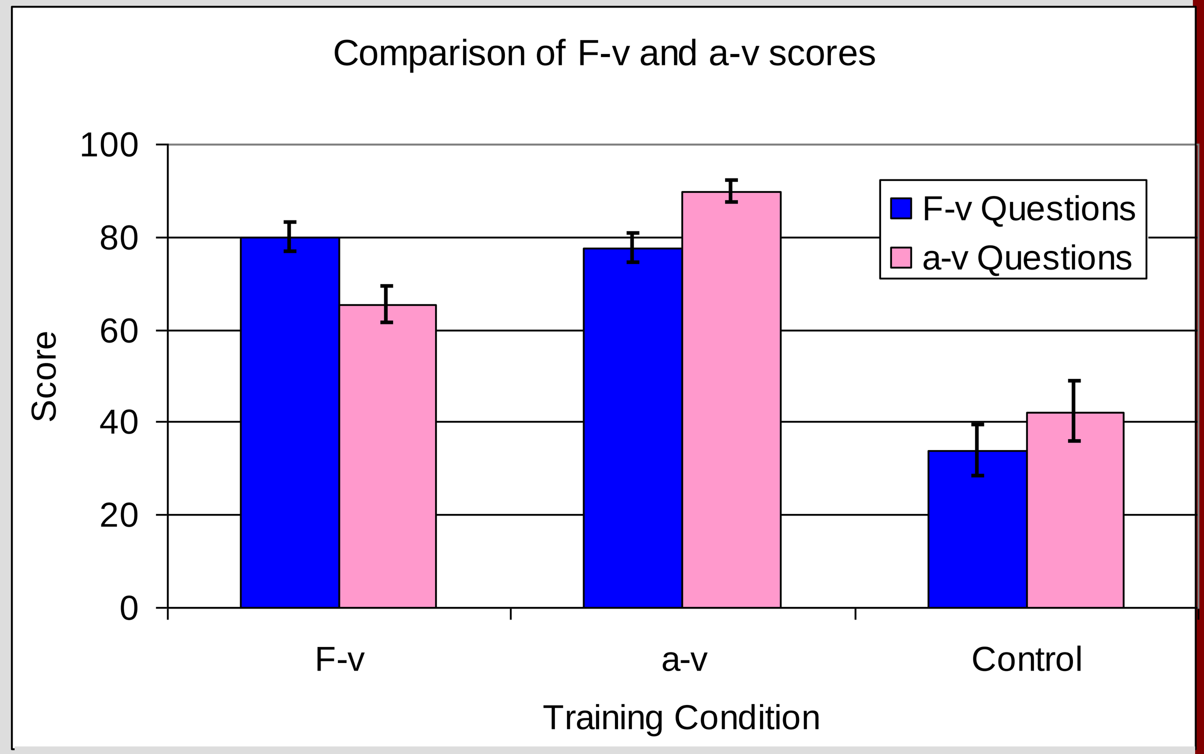
f. a, b, and c are all possible

(This question is "concrete **F** → **v**" test question)

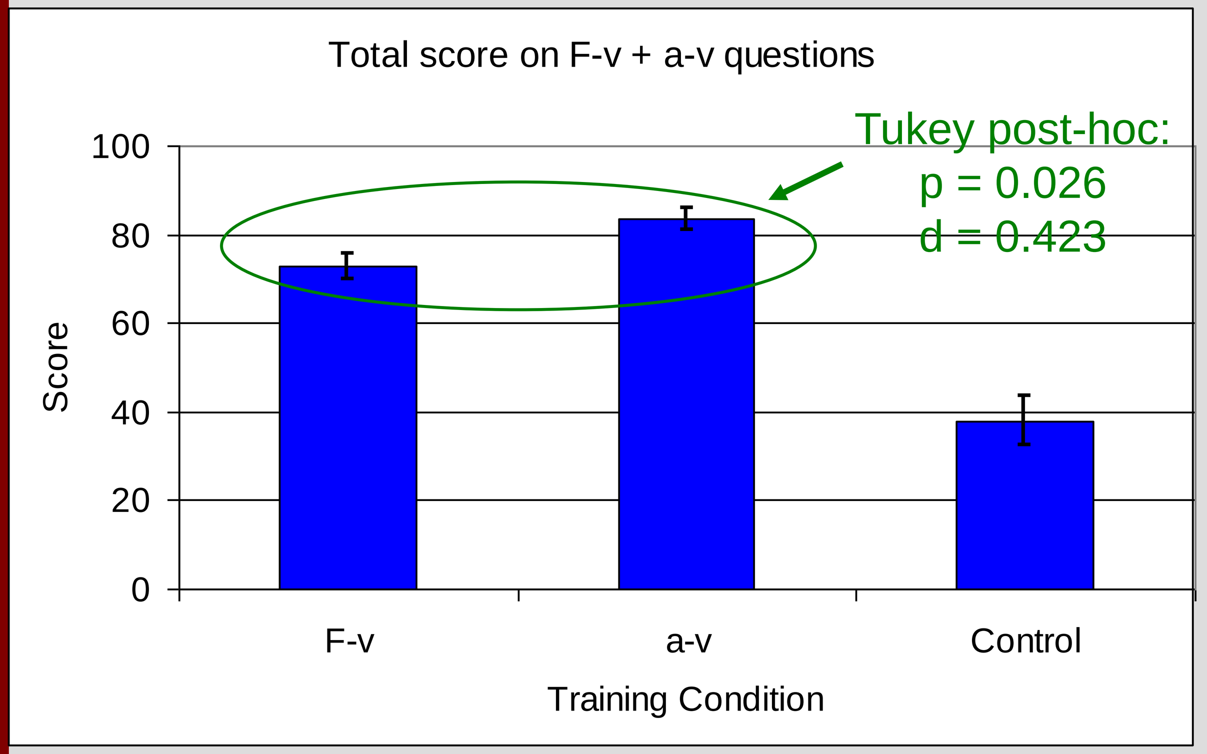
Results

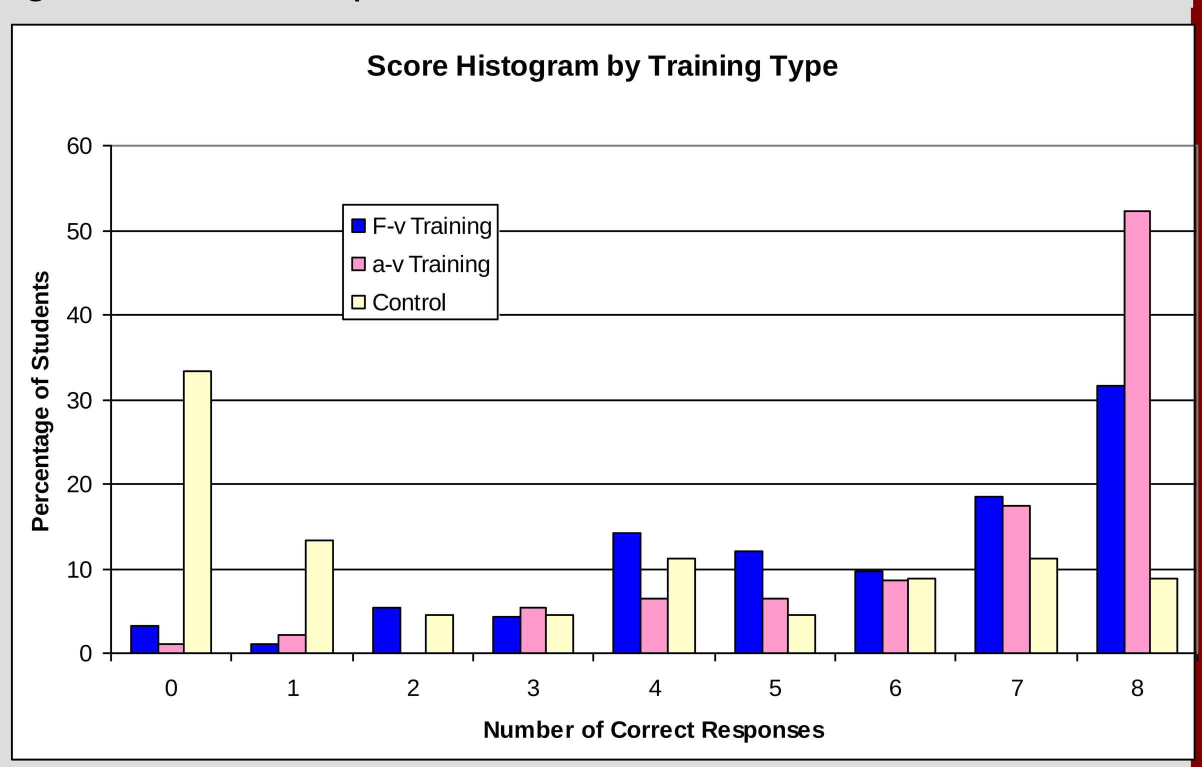


Two-way ANOVA analysis: training type significant (F(1,180) = 8.262, p = 0.005), but context is not.



Both types of training improve scores on both types of questions, but **a** → **v** training provides significantly larger gains on **a** → **v** questions.





Conclusions

We find that **a** → **v** training provides significantly larger gains in student scores than **F** → **v** training, which is consistent with previously observed learning progressions. We have therefore shown some evidence that these observed hierarchies are represented in the effects of instruction, albeit with very simple training examples.

We have *not*, however, shown that these increased scores will persist over time (i.e., that they have high retention rates) or what effect these training routines have on students *before* receiving instruction in force in motion in a traditional class.

Acknowledgments

Special thanks to the other members of the OSU PER group.

Selected References

Previous studies on force and motion:

Halloun and Hestenes, *American Journal of Physics*, 1985

Thornton and Sokoloff, *American Journal of Physics*, 1998

Clement, *American Journal of Physics*, 1982

Hestenes, Wells, and Swackhamer, *The Physics Teacher*, 1992

Rosenblatt and Heckler, *Physical Review Special Topics – PER*, 2011