

# When Physics Hurts: how to make learning more memorable

Caleb CLINKINGBEARD

*University of Arizona, 1209 E. 2<sup>nd</sup> Street, Tucson Az 85721*

**Abstract.** Attention and personal stake in an issue are the primary determiners of a student's quality of memory encoding and retrieval. Increasing both of those variables is a reasonable choice by educators in their pursuit of better pedagogy. Sometimes physics should hurt.

## **Students have bodies as well as brains**

Many of you will have seen a clip on various social media of a group of physics students sitting on desks while connected to a Van der Graaff generator. That's my class. After all students have been charged to somewhere around 500,000-volts, another student who is standing on the ground fist-bumps the last student in the line. This discharges most of the students at the end of the line and all jump while shouting. As physicists and physics teachers, you're already aware of the huge differences between voltage and amperage (and probably are able to reminisce about your own experimentation with sources of high voltage.). There is something fundamentally engaging about those real experiences. The research overwhelmingly shows that human learning takes place not to a disembodied brain, but to a whole human. Let's explore ways to make those bodies part of the learning process.

## **Pedagogical approaches to increase long-term learning**

I've joked that you tend to forget what you learn, but mental scars are forever. Embodied learning is not just another variety of hands-on learning; it assumes that students are not just their brains. From gut bacteria increasing one's impetus to exercise [1] to breathing routines designed to reduce cortisol levels [2], many body-to-brain feedback mechanisms have surfaced in the modern race to "lifehack" near every aspect of personhood. It behoves teachers to plan their lessons accordingly.

As such, I have kept a journal of the plentiful ways that my own students have benefited from using their bodies as they pursue understanding. I call it, "Testing on Humans."

What follows is absurdly anecdotal evidence that students who are actually doing things with their bodies learn more.

**Vocabulary Quizzes:** Freshman biology students were given quizzes on Latin prefixes and suffixes as part of their weekly routine. Every other week, however, they would know whether they were the control group or the experimental group... and then I would try to distract them. In ascending order, these are the type of distractions that were most deleterious on their scores: songs, smells, videos, videos on loop. This big question is whether those distractions decrease or increase their averages. The classes being distracted tended to perform better than those in the control group. (That doesn't apply for the video or olfactory distractions.) (This is evidence from the other side: that introducing non-congruent sensory input draws attention away from the "thing" being learned.)

**Napping:** existing literature [3] suggested that sleep had a major effect on memory. The specific takeaway was that students who study and then take a test perform worse than students who study then nap and then take a test. Of course we tried it. Students were sorted into napping vs. non-napping groups. It looked a bit odd to have freshmen all over campus asleep on the lawn, benches, or even tables. Yet again, the studies were supported. Those taking naps performed better on

average based on their own averages. (Trying to remove confounding variables from groups of freshman humans is rather difficult.)

Gravity: It was a fateful day in physics. My classes had slowly been gathering data about the time that it took to go down a long walkway between two of our buildings on campus... on an office chair. We were graphing the weight of the student vs. the time that it took. It is a vertical change of about 20-ft in a horizontal run of about 100-ft. That's a pretty good slope. Unfortunately, that path contained three small 90-degree shifts in which the walkway moved about 6-ft to the left. The first one was easily avoided by starting on the "up" side of the ramp. The second took a little bit of steering. If students began to feel that the office chair was not going to make it, they could simply stand up and leave the office chair to tumble down the ramp. It was sufficiently durable. Regardless, we were getting good data and it was leaving us with a mostly straight line reflecting the higher terminal velocity of heavier students. Two of my students, both girls, asked if they could go down the ramp together. That seemed like a strange outlier, but I said yes. I should not have.

They started their way down the ramp and dutifully avoided the first 90. They made it past the second, but they crashed into the third purely perpendicular to the metal pole. They went down. I ran down the ramp, entirely sure that at least one of them was broken. I had them go to the school nurse and began calling parents, administrators, and whomever else I could find, confessing my sins, my ignorance, and my deepest regrets.

About 30-minutes later, both girls came out of the lower building laughing and smiling. As someone who was just convinced that I gave two girls concussions, abrasions, and back issues for life, this was a surprise. They were both wearing new shorts.

As it turns out, when it became clear that they were going to hit that third pole, the girl sitting on the other's lap... peed... onto the girl below her. To this day, those two students come back to the school to visit and reminisce about the fateful day in physics.

More to our point, they and others remembered every detail.

Students who are doing things with their bodies learn more. Those same students can recall what they have learned better also. To take it past issues of encoding and retrieval, humans are not simply brains that happen to be wired to some inputs. Those inputs change the brain. They are part of being a whole human. A teacher's job is not just to educate, but to shape a human, their intellect, yes, but also their loves, their hates, their character, and every other aspect of being human. Let's not ignore the fact that these people are whole people. Let's educate them accordingly.

## References

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