Intro Slide

Good morning. I’m Mike Florek, a high school teacher out in Roanoke, Virginia. I teach science and math, but my own degrees are in civil engineering. This is what happens when you let a former engineer into a classroom.

This student project came to be when our anatomy teacher asked if I would like to collaborate on something about brains and collisions. I said yes, and here we are.

Brain Slide

Many of our students play extracurricular and team sports, so concussions were a natural focus. Many of our athletes (and a few others over the years) have personally had at least one concussion. In a concussion, your brain impacts the inside of your skull, damaging neurons and even bruising the tissue. You might have a headache, feel nauseous or fuzzy, or lose fine cognitive abilities.

Over time and many repeated concussions, tau protein builds up around the brain’s blood vessels, restricting blood flow, and eventually killing neurons, a condition called chronic traumatic encephalopathy, or CTE. CTE symptoms include severe memory loss, personality changes, irritability, aggression, and depression. Currently, there is no standard method for diagnosing CTE in a living person – it can only be confirmed by autopsy. The images here compare healthy and severely damaged brains.

Impulse Slide

The timing of our physics and anatomy curricula is purely coincidental. But having a convenient opening to discuss impulse and the conservation of linear momentum is priceless. In my classroom, we introduce kinematics, forces, and energy before starting momentum. For this project, our focus is on the time-dependent function – impulse = force times time. We have a discussion about economics of sports, looking at the variables available to manipulate and which are reasonable. Athletes are getting larger, faster, and stronger. We can add more points of contact, so that the forces are spread out and smaller, and we can increase the time of impact through cushioning. In past years, I’ve traded places with the anatomy teacher for a day – I do a crash-course in collision physics and they go over brain physiology.

Field Trip Slide

One of the perks of teaching in Roanoke is having a world-class laboratory just up the road. The Helmet Lab at Virginia Tech tests headgear from any sport you can imagine, ranging from the obvious football to equestrian sports to bicycle helmets. In the fall, I take my students for a short campus tour and a visit to Dr. Barry Miller. The pictures you see are this year’s students padding football helmets, which were tested by the Helmet Lab staff. The apparatus, not pictured, is a hinged metal post with a high-tech, thousands-of-dollars headform bolted to the end. The goal of the activity is to reduce the acceleration of the headform as low as possible.

Blueprint Slide

Students liked the first field trip so much, I scrapped together a budget version to do ourselves. The football coach gave us ten old helmets – they are required to replace equipment every few years, so these would have been trashed otherwise – and I save packing materials throughout the year just for this project. For blueprints, the picture has to represent the full-scale helmet. Some years, I switch it up and have each group design one helmet, but they build another team’s design.

The materials available this past year were bubble wrap, packing foam, and tape. Modern football helmets use gas pockets, foam, and connectors. The recycled materials are functionally similar to the real deal. The padding needs to be thick enough to affect the impulse, but still allow room for a model head.

Helmet Slide

With the blueprints drawn, construction begins. This is the most time-consuming part of the project. It takes a longer than you’d think – about two hours – to cut and assemble the padding. As a teacher, I enjoy hearing the timeless question, “What were you thinking?” This is a great introduction to technical communication. Takeaways include: instructions are broken into steps for a reason, pretending to measure doesn’t work, and cutting Styrofoam is harder than it looks.

Head Slide

For testing, I have been using Vernier GoDirect Acceleration Sensors and foam heads from the craft store. I carve a hole in the top of the head and slide the sensor in. They’re not quite the right volume and way under-massed, but for my budget they work just fine. Someday, I’ll find some real test-dummy heads. The heads fit into the helmets pretty well. Then we test. At our school, we have a foyer with a second floor balconly.

Testing Slide

Testing an empty helmet looks something like this:

Data Collection Slide

We collect two sets of data: linear acceleration in three major axes with is translated into a net acceleration, and rotational velocity around the three major axes, which is left alone. Here is where one of the major limitations of the project becomes apparent – without a neck and body to keep the head from spinning, the rotation is unrealistic. But it’s still interesting to look at, and it provides a gritty example of angular velocity. We compare the peak accelerations and see which group scored the lowest value. That helmet was the most effective.

Overall Impact

This has been a well-received project every year. This design-build project introduces technical drawing and communication, manual construction, graphing skills, and data analysis. My students love the field trip and the chance to do the experiment again at our own school. There are a couple barriers to entry for this project – getting helmets and sensors – but I think those can be overcome with some creativity.