Crash Helmet Design, Prototyping, and Testing:
An Egg-Citing Physics and Engineering Design PBL

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"Learning to apply theoretical principles is much better done when given real problems and hands-on activities in projects" [*Shekar, 2014*]. As part of a schoolwide evolution towards authentic, project based learning (PBL), Adelson Upper School teaching teams are reimagining traditionally-taught content in the context of engaging and rigorous projects to be executed over several weeks. The Crash Helmet Design project, in which students create a device for protecting an "egg head" from a fall or crash injury, represents one such project. The project levels up the timeless egg drop challenge to instruct topics addressing multiple science and engineering standards.

Using an interdisciplinary approach, the project was conducted jointly by the science department and our Startup Incubator faculty. Content which had previously been delivered face-to-face via lectures, problem sets, and labs during the Mechanics phase of introductory, high school physics was reworked in a thematic, applied unit of study and formatted as a ten-day sequence of investigative and experimental activities. Throughout the redesign and implementation, the teaching team sought a retreat from the classic, teacher-centric instructional model and a migration towards "a collaborative culture for teachers and students," a key, fundamental best practice of successful PBL [*David, 2008*].

The evolved Crash Helmet Design project applied physics concepts consisting of linear kinematics, Newton's Laws, impulse, and elastic/inelastic collisions, teaching the basics of each concept "just in time" as applicable to the project. Simultaneously, students employed the Stanford d.school design thinking process – empathizing, defining, ideating, prototyping, and testing – to produce crash helmets for the purpose of protecting users from traumatic brain injury, using an egg to simulate a human head. Motivation for selecting the real-world problem of the crash helmet was derived, in part, from the age group of the target student audience: high school juniors and seniors who have recently received their driver's licenses. Students' new personal connections to a potential source of injury – car accidents which may result in traumatic brain injury (TBI) – fostered interest and stimulated investment in the first phase of the design thinking process, empathizing with the individuals affected by a specific problem. Each subsequent phase of the design thinking process hinged on the success of students' initial buy-in, and each posed its own implementation challenges with regard to instruction and evaluation.

Throughout the PBL (project based learning) unit, physics teacher Alexis Hilts and Director of Curriculum Innovations, Camille McCue, coached students in using a variety of technologies at various stages to construct and convey their learning. These included online research and graphical layout tools to create a TBI infographic; Google Sheets to record, analyze, and graph collected data; Quicktime to record a vlog; Coggle to create an ideation document; Tinkercad and Fusion 360 to design crash helmets for 3D printing; and Google Slides to construct final presentations following helmet drop testing.

Best practices for successful project implementation were sought from relevant literature, applied throughout the project, and enhanced by our own local experiences. Specific practices which proved critical to the success of the project included workspace planning, emphasizing reconfigurability of the work areas depending on the current design thinking phase; one-to-world technology access, including uninterrupted use of laptops and 3D printers; sufficient, at-school time-on-task, via block scheduling; formative evaluations, which required (for most tasks) transitioning to rubric-based authentic assessments in lieu of "right-or-wrong" problem sets; and instructional delivery methods, which ultimately took the form of flipped lessons, collaborative work sessions, and checkpoint meetings with instructors. Flipped lessons consisted of both original videos recorded by our instructional team and existing YouTube content, presented to students via our website (http://startupincubator.site/design-thinking.html). The flexibility afforded by flipped lessons and an effective online learning management system (Edsby) proved uniquely necessary due to a variety of daily schedule inconsistencies including sports event absences and multiple Jewish holidays. Working both synchronously and asynchronously, students successfully executed the Crash Helmet Design project, exhibiting mastery in physics content, the engineering design process, and soft skills including research, collaboration, pivoting, and presentation.

Like any egg crash project, the culminating "drop day" featured students strapping eggs into their 3D-printed helmets, then dropping them from successively higher altitudes until either the eggs cracked or the helmets failed. Student teams measured the success of their designs against the problem statements they had previously written during the design phase, determining whether their helmets met, beat, or did not meet specifications. After cleaning up the occasional gooey splat, teams then presented their design thinking process and discussed the iterative steps to improving and refining designs, considering what it would take to finalize an egg crash helmet for production and distribution.

Most significantly, the Crash Helmet Design project brought to life for our students something which typically lives only on paper for high school physics students: equations of motion and the impulse formula. Conducting their problem-solving in an applied context showed students that computing a final velocity or a "delta t" is not the end of a problem, but the beginning of a solution – the solution to protecting heads from crash injuries. And that's a real-world problem worth solving.

References

Shekar, A. (2014). *Project-based learning in engineering design education: Sharing best practices.* Retrieved from https://www.asee.org/public/conferences/32/papers/10806/download.

David, J. (2008). *What Research Says About Project-Based Learning.* Retrieved from http://www.ascd.org/publications/educational_leadership/feb08/vol65/num05/Project-Based_Learning.aspx