A Mathematical Approach to Designing Insulators

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EXECUTIVE SUMMARY

How do we keep hot drinks hot and cold drinks cold? Companies such as Tervis, YETI, and Thermos spend their time researching and designing products around that very question. In this lesson, students will discover, through mathematical modeling, which materials provide the best insulation and be tasked with designing their own insulator. This lesson has been designed at two different levels for students from grade three through high school with an optional extension activity for more advanced students. Students will use technology to explore the rate of change of the temperature of hot water over two minutes using different insulation materials. After this exploration, students will use the data they have collected to determine the best materials for designing their own insulator. This insulator will then be judged based on the ability to keep a hot drink hot and on the aesthetic value.

LITERATURE REVIEW

The history of insulated drinkware begins around 1896 when Sir James Dewar invented what would become the first Thermos. When Thermos began making bottles in the U.S. in 1907, it quickly gained popularity with famous users such as President Taft and the Wright Brothers (Insulated Bottle, 2006). It seemed as though everyone was looking for a way to keep their hot drinks hot and cold drinks cold!

The process for manufacturing commercial insulated drinkware is still very similar to what it was in the early 1900s. Most cups made for hot drinks are a vacuum, sealed between two walls of the same material. Most bottles for cold drinks are lined with a liquid foam that is allowed to harden (Insulated Bottle, 2006). Although this process began in the early 20th century, it hasn't kept people and companies from trying to perfect the insulated bottle. If one were to look up "insulated drinkware patents" on Google Scholar around 16,000 results would be returned. The search is never-ending to make consumers happy with their drink temperature.

When one thinks of insulated drinkware, the disposable coffee cup often comes to mind. These have become ubiquitous with the morning commute of many Americans. The history of the disposable coffee cup is riddled with controversy over the battle between material that is good at insulation (styrofoam) versus material that is better for the environment (paper). This argument was ultimately won by Howard Schultz, owner of Starbucks, in 1987 when he chose the paper cup. In order to insulate more like a foam cup, manufacturers have worked to develop paper cups with walls two or three times as thick as normal paper cups (Park, 2014).

However, the quality of the insulation is not the only consideration for disposable coffee cups anymore. A popular food blog, Eater.com, suggests that starting in about 2014, the visual design of the cups became incredibly important for consumers to feel like they are getting their money's worth for expensive coffee (Baird, 2015). In fact, unique designs of coffee cups have become immortalized on the internet by way of specialized Instagram accounts (Hargreaves, 2016), design blogs (Durso, 2014), and food culture websites (Hohenadel, 2014).

In this activity, students will explore the quality of insulation of different types of materials in order to make educated decisions about how to design an insulator that can compete with the best being manufactured. This is not a solved problem as over 350 of the patents for insulated drinkware on Google Scholar were filed as of 2016. Not only will teams of students have to think about the quality of their insulation, but they will have to consider the aesthetic design qualities as well.

CONTENT INFORMATION

This activity aligns with many national standards across several different subject areas. Most notably, this activity puts to use several standards from the Common Core State Standards for Mathematics (CCSSM). Certain questions in this activity are written at two different levels with an optional extension for students beyond the Algebra 2 level. The questions specifically written for grades 3-5 align with CCSSM standards related to differences and numerical comparisons such as 3.NBT.A.2, 4.NBT.A.2 and 4.NBT.B.4. The questions specifically written for grades 6-12 draw from standards about ratios and rate of change including 6.RP.A.3, 7.RP.A.3, 8.F.B.4, and HSA.CED.A.1. Finally, the optional extension activity relates to stan-

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