Math of OK Go

MiKyla Jean Harjamaki, Playful Learning Lab

MiKyla is an undergraduate student studying mechanical engineering and math and the University of St. Thomas. She is also a student researcher in the Playful Learning Lab.

Dr. AnnMarie Thomas, University of St. Thomas

AnnMarie Thomas is a professor in the School of Engineering and the Opus Colluege of Business at the University of St. Thomas where she is the director of the UST Center for Engineering Education. Her research group, the Playful Learning Lab, focuses on engineering and design education for learners of all ages.

Ms. Krista Schumacher, University of St. Thomas

Krista is an undergraduate Elementary Education and STEM Education major at the University of St. Thomas.

Abby Bensen, University of St. Thomas
Ms. Emma Michelle Monson, University of St. Thomas

Emma Monson is an undergraduate studying Elementary Education with a STEM co-major at the University of St. Thomas.

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Introduction

Grammy Award-winning rock band OK Go places mathematics concepts at the heart of its exciting music videos. Through the OK Go Sandbox project, the band has partnered with the Playful Learning Lab at the University of St. Thomas to create several education guides, based on Common Core standards, that explore topics including parabolas, spreadsheets, and frame rates in engaging ways. OK Go Sandbox is a resource for teachers to access and implement in their classrooms. These guides and videos introduce educational topics, then allow students to practice and develop an understanding of them by replicating the processes used within the music videos. These topics are explored first in an inquiry phase, in which the students find connections between the topic and the music video and other supplementary videos created by OK Go Sandbox. The second phase is a challenge phase, where students have the opportunity to apply what they have learned about a topic to engineer a solution to the present challenge. The videos, activities, and educator support materials are designed for middle school and high school students and are tested in the classroom by teachers that work closely with the Sandbox team during the early stages of curriculum development. This paper will discuss the strategies used for revealing the mathematical principles behind the engineering feats shown in the music videos and show how STEAM (science, technology, engineering, art, and math) concepts can be taught in ways that promote real-world application of concepts and increase student engagement with mathematics and engineering.

Who is OK Go?

OK Go is a Grammy Award-winning rock band known for its elaborate music videos that incorporate math, science, and art in exciting ways. Past videos have featured choreographed treadmill dances, massive Rube Goldberg machines, and stop motion animation using laser cut toast. This paper will focus on engineering education materials and applications for two of the band's videos:

- "The One Moment" music video incorporates high speed photography, projectile, and flip books to make a four-minute music video out of 4.2 seconds of footage.
- "Upside Down & Inside Out" music video was filmed while simulating the effects of microgravity through parabolic flight (see Figure 1).

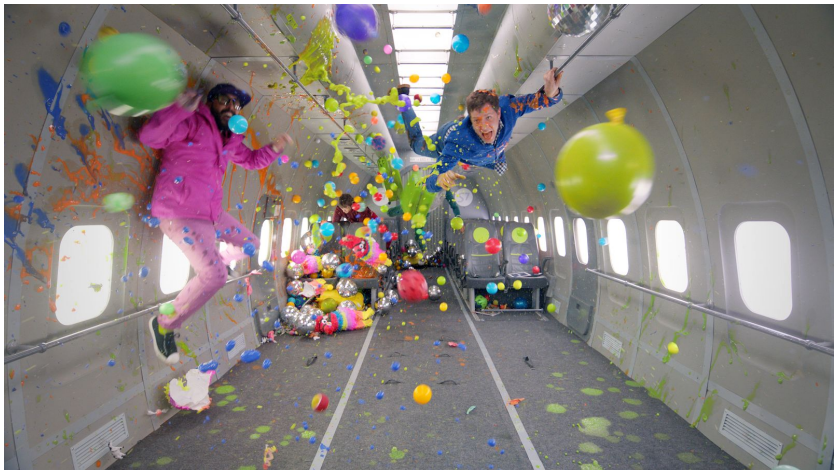

Figure 1: "Upside Down & Inside Out" music video includes members of OK Go in microgravity.

What is OK Go Sandbox?

Because of the creative integration of STEAM into these videos, for years teachers have told the band that they were showing these videos in the classroom and using them to inspire

students. In partnership with the Playful Learning Lab at the University of St. Thomas, OK Go created an online resource for educators called OK Go Sandbox. Using OK Go's music videos as inspiration, OK Go Sandbox creates new videos, activities, and challenges that can be integrated into the K-12 classroom to teach a variety of STEAM concepts.

Why Math?

OK Go's lead singer, Damian Kulash, has often spoken about the importance of math in the creation of their music videos. While discussing "The One Moment" music video, he states, *"The dance we were trying to choreograph, all these beautiful slow-motion things, it's basically a giant math problem. But you could also kind of see it as a way of traveling kind of, right? Because we never get to live at that time scale, we never get to see that stuff and through math we actually can kind of get these handles in a universe that we don't otherwise have access to, so it's also kind of like an insane sci-fi trip."* Thus, it was decided that some of the resources created by OK Go Sandbox would be designed to highlight the math used by the band and their teams in a way that allows kids to experiment with it. By utilizing the videos to teach math concepts, students are able to understand the way engineers approached the problems that needed to be solved to create the music videos.

Literature Review

Math is often a subject that feels unapproachable to students and is seen as only being useful in limited fields. By using music videos to inspire the creation of challenges that help students learn math concepts, students are able to approach problems from a different perspective

and see how math is used in unexpected ways. A study done by Albertoni at St. Mary's college in California found that, although student engagement was not always high, those who were engaged had higher test scores. It was important to implement different types of interactive lessons to see if students would change their habits within their study of math. During the study, students were given pre-surveys and post-surveys about what teaching strategies helped them to learn math in the best ways possible. In the pre-survey, students generally chose textbook/worksheets and teacher explanation, as opposed to in the post-survey, when many students changed their answers to preferring hands-on instruction [1]. Children are being exposed to mathematics at young ages, but are not always engaged or enjoying this type of learning. If students are given opportunities to continue working with math more often, they will have increased success in their future years, even reaching into their high school years [2]. According to a study completed by Rowan-Kenyon, et al., regarding student engagement during math, "students at all grade levels preferred class activities that were visually or physically engaging, or that allowed them to collaborate with peers." When lessons were taught in a more appealing way, students responded positively and performed at higher rates than they had before [3]. Stan Yoshinobu has been working to implement inquiry-based instruction into college level math courses. To do this, he has proposed the idea to many professors, and aims at teaching students in a way that does not focus on lecture. Students are highly encouraged to find their own answers, and work through problems using their own problem solving skills, as opposed to be given answers by a teacher or professor [4]. While some students enjoy learning through the traditional math model, which may include lecture and worksheets, many kinesthetic learners may need different approaches. The use of manipulatives and visual aids are helpful in keeping

students engaged and working with the same math concepts, only in a different way. This can encourage learning through play or learning through experimentation, leading students to find new ways that they will choose to learn at a young age, as well as in later years [5].

Example One: The One Moment

"The One Moment" is a music video featuring a series of events, including exploding salt containers, a flipbook, and dropping paint-filled balls. These events were filmed in one take lasting 4.2 seconds. This footage was then slowed down to create a music video that lasts approximately four minutes. Through careful calculations, the events occur in ways that pair with the song playing. The OK Go Sandbox education team saw this music video as an opportunity to create education materials aimed at topics including frame rates and gravity. Through a series of videos and guides, teachers can lead students in exploring the spreadsheet that the band and its production team used to create the original music video. Students are then encouraged to design their own slow-motion video.

In "The One Moment of Math" video, which has become OK Go Sandbox's most watched video, Damian Kulash explains how he uses math to engineer the events using a spreadsheet. In this spreadsheet, he includes the events the band wanted to happen and the parameters that need to be met in order for each event to occur in time with the song. The parameters he emphasizes are the time the band wants something to occur and the speed the camera must be recording at. This spreadsheet is included in the guides paired with "The One Moment" music video in order to connect real-world use of mathematics to the classroom. This shows students that math is applicable in different careers, including the music industry. By

allowing students to approach math in this way, self-efficacy for students who feel less confident in their mathematical capabilities can increase [2].

The OK Go Sandbox educator and student guides that pair with “The One Moment” music video explore the topics of spreadsheets, analytical and theoretical data, frame rate, and slow motion. This guide is designed for students in grades 9-12 and covers the following standards.

CCSS.MATH.CONTENT.6.SP.B.5 [6]: Summarize numerical data sets in relation to their context, such as by:

- CCSS.MATH.CONTENT.6.SP.B.5.A: Reporting the number of observations.
- CCSS.MATH.CONTENT.6.SP.B.5.B: Describing the nature of the attribute under investigation, including how it was measured and its units of measurement.
- CCSS.MATH.CONTENT.6.SP.B.5.D: Relating the choice of measures of center and variability to the shape of the data distribution and the context in which the data were gathered.

ISTE Empowered Learner [7]

- 1c: Students use technology to seek feedback that informs and improves their practice and to demonstrate their learning in a variety of ways.

ISTE Computational Thinker [7]

- 5a: Students formulate problem definitions suited for technology-assisted methods such as data analysis, abstract models and algorithmic thinking in exploring and finding solutions.

- 5b: Students collect data or identify relevant data sets, use digital tools to analyze them, and represent data in various ways to facilitate problem-solving and decision-making.
- 5c: Students break problems into component parts, extract key information, and develop descriptive models to understand complex systems or facilitate problem-solving.

ISTE Creative Communicator [7]

- 6b: Students create original works or responsibly repurpose or remix digital resources into new creations.

ISTE Global Collaborator [7]

- 7c: Students contribute constructively to project teams, assuming various roles and responsibilities to work effectively toward a common goal.

The educator guide suggests that teachers show both the music video and "The One Moment of Math" video, which explains the spreadsheet, math, and engineering behind the music video. This is followed by inquiry-based learning (Kelly Field defines this as a method for students to learn by doing rather than by listening, so the teacher is guiding them to answer instead of giving them solutions [4]), in which students explore how spreadsheets can be used. Allowing students to view the actual spreadsheet used by OK Go gives them the opportunity to connect this math content to the creation of the music video. This is followed up by a challenge activity where students are asked to create their own short video in which 5 events occur (see Figure 2). These events will be determined by the students and can include things such as dropping a pencil or throwing an airplane. Using Microsoft Excel or Google Sheets, they will list their five events and the times at which they occur within the video they filmed. Students will then calculate the time between each key event shown in their video and find the average of these numbers, as well as

the maximum and minimum of the time between their events. Finally, students will explore what changes need to be made in order to make their video three times longer. They will find theoretical data through calculations for their slow-motion video. By using these calculated times, students will record their video again while attempting it to make it 3 times slower. During the recording, students will collect the data of the actual times the events occur. This data will then be compared with their spreadsheet. The challenge activity allows students to develop a deeper understanding of the material and its applications.

SPREADSHEET INVESTIGATION

ABOUT THIS CHALLENGE

In this challenge, students will investigate the spreadsheet of math that was used in the making of "The One Moment" music video. The spreadsheet provided is the actual spreadsheet used by the band to ensure that their high-speed video would match up with the song when played in slow motion. Your students will learn about statistics, rates of change, and additional concepts relating to filming within different frame rates.

CONTENT AREA

Grade Levels: 9-12

Content Area: Mathematics, Algebra, Statistics

Context for Learning: Before starting this lesson, students should be familiar with reading spreadsheets and have a general understanding of statistics and rates of change.

TOPICS		ACADEMIC LANGUAGE	
Statistics	Theoretical Data	Theoretical Data	Mean
Excel/Spreadsheet	Analytical Data	Analytical Data	Maximum
Frame Rate	Slow Motion	Column	Minimum
		Row	

Figure 2: “The One Moment” music video is accompanied by a classroom challenge.

Example Two: Upside Down & Inside Out

The “Upside Down & Inside Out” music video was filmed inside an airplane during parabolic flight. This created a microgravity environment in which OK Go and acrobrats performed stunts. While filming a video in this environment, they experimented with the way people, paint, and other objects behave in microgravity. This inspired the creation of educator content focused on parabolas.

This content includes two videos. One is titled “How Parabolas Work,” in which OK Go members Andy Ross and Damian Kulash explain how parabolic flights can be used to simulate microgravity. As the plane ascends the parabola, gravity is felt twice as strong. Microgravity is experienced as the parabola levels off, until double gravity returns when descending the parabola. The second video is “How We Did It” in which the band members discuss how they fit the song into cycles of 27 seconds of weightlessness. Because the microgravity sensation fades in and out as the plane moves around the parabola, this was a difficult process. The song was divided into 8 pieces, each being a single period of weightlessness. However, each portion of the song was 21 seconds and each microgravity period was 27 seconds, so the song was slowed down during filming. Paired with these videos are educator guides about parabolas for two different age ranges.

The General Parabolas Guide is intended for grades 3-5 and covers the following standards [6].

- CCSS.MATH.CONTENT.3.MD.B.4: Generate measurement data by measuring lengths using rulers marked with halves and fourths of an inch. Show the data by making a line

plot, where the horizontal scale is marked off in appropriate units-whole numbers, halves, or quarters.

- CCSS.MATH.CONTENT.5.G.A.2: Represent real world and mathematical problems by graphing points in the first quadrant of the coordinate plane, and interpret coordinate values of points in the context of the situation.

The activity begins with the inquiry phase about what a parabola is and how points can be plotted to show the path of travel of the plane during parabolic flight. Students will also find objects in the classroom that are shaped like parabolas. Following the inquiry activity, students will attempt the challenge activity (see Figure 3). Given two parabolic shaped objects, such as a bowl, they will measure the depth at 0.5 inch intervals and plot both objects's depths on graph paper. This offers an opportunity for teachers to introduce or expand upon graphing techniques and labeling axes. Following the completion of their graphs, students will compare their graphs with other students' and discuss how the axes interact and how time relates to altitude in OK Go's parabolic flight. This creates a unique setting in which students can translate their own classwork into genuine, real-world applications. Recognizing the similarities and differences in their parabolic object and OK Go's parabolic flight encourages further inquiry into the topics at hand and allows students to strengthen the connection between content and concrete knowledge.

GENERAL PARABOLAS

ABOUT THIS CHALLENGE

In this challenge, students will graph the process OK Go used to create parts of the video "Upside Down and Inside Out." Learners will discover the basics of parabolic shapes, finding and creating their own parabolas in the environment around them.

CONTENT AREA

Grade Levels: 3-5

Content Area: Math

Context for Learning: Before starting this lesson, students need to know how to measure with a ruler, record information in a table, and be able to plot a simple line graph.

TOPICS	ACADEMIC LANGUAGE
Plotting	Parabola
Graphing	x-axis
Measuring	y-axis
Parabolas	

Figure 3: OK Go Sandbox provides a grades 3-5 parabola challenge to pair with the music video "Upside Down & Inside Out."

The Advanced Parabolas Guide is intended for grades 9-12 and covers the following standards [6].

- CCSS.MATH.CONTENT.HSA.CED.A.1: Create equations and inequalities in one variable and use them to solve problems. *Include equations arising from linear and quadratic functions, and simple rational and exponential functions.*

- CCSS.MATH.CONTENT.HSA.CED.A.2: Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales.
- CCSS.MATH.CONTENT.HSN.Q.A.2: Define appropriate quantities for the purpose of descriptive modeling.

The guide begins with the inquiry phase in which an educator teaches students how to modify parabolas by translating them, changing the width, and changing directions using the provided worksheet. Then the educator will present a challenge by providing students with a set of equations, which are located in Appendix A of the guide, and asking them to predict how the widths and locations of the parabolas will compare (see Figure 4). Then, students will plug in numbers in order to mark points that form the parabola with these given equations. Using pipe cleaners, students will connect the points and compare the actual parabola to the predictions they made. By comparing their pipe cleaner parabolas with their predictions, students can correct their misunderstandings and form concrete understanding of how parabolas can be manipulated. Students can also apply this to OK Go's flight, deepening the connection between concepts and real-life. How would changing the width of the parabola flown impact OK Go's flight? If OK Go wanted their time spent in microgravity to increase, how would they need to change their flight's course?

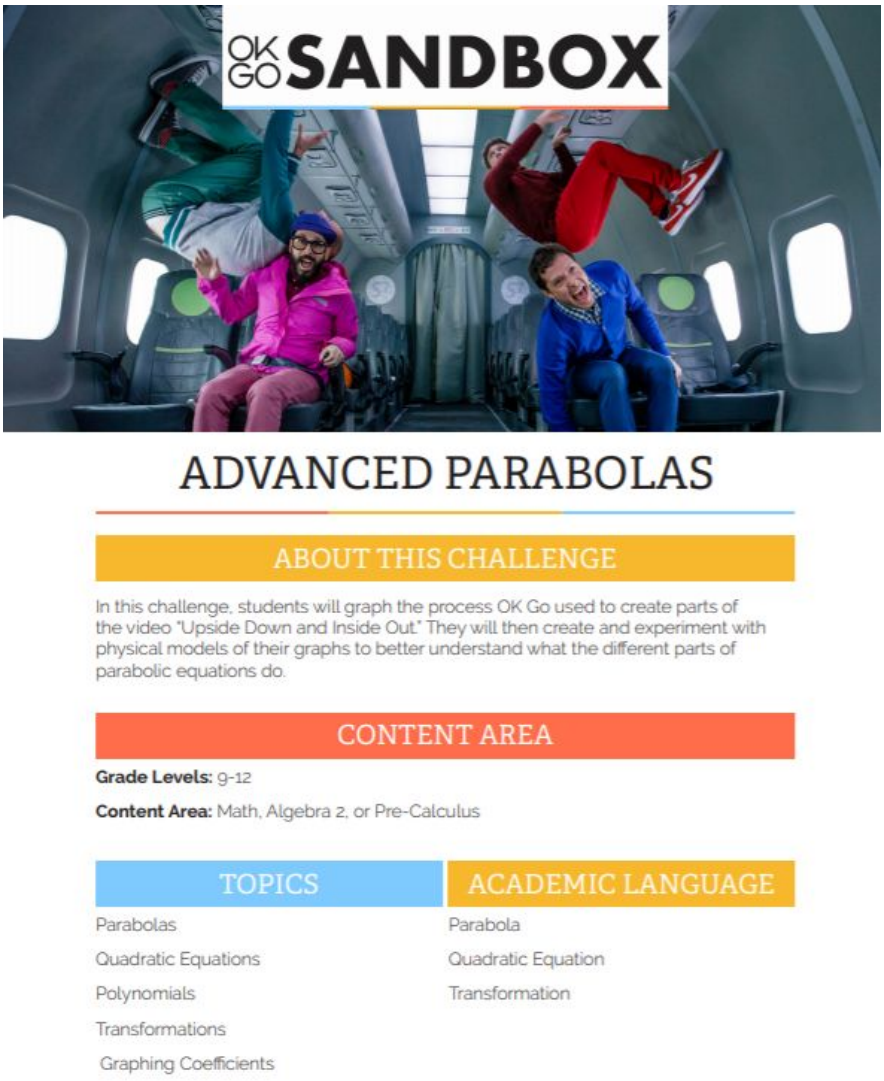

Figure 4: "Upside Down & Inside Out" is accompanied by a grades 9-12 parabola challenge.

Current Outreach and Future Work

The video content created by OK Go Sandbox is uploaded on Youtube, which helps the OK Go Sandbox team see the reach of the resources through the views and comments on the platform. Also, OK Go Sandbox uses survey feedback from educators to improve the website and content; however, the questions asked on the current surveys concern OK Go Sandbox generally and are not specific to the math content. As this project continues to progress, surveys

will be created that target math content in particular. This survey will likely include student feedback about their interest in pursuing an education and career path in STEM fields prior to and after the activity and how engaged they felt in comparison to a traditional learning environment for math. The video "How We Did It," which is paired with the "Upside Down & Inside Out" music video, has 723,00 views; and the "How Parabolas Work" has 49,000 views. "The One Moment of Math" video has been viewed 411,000 times on Youtube. While the views on videos do not show which setting they are being used and viewed in, it allows for some understanding of the reach of the content created for OK Go Sandbox. In addition to views, OK Go Sandbox has received numerous positive comments from educators on "The One Moment of Math" including the following:

- "I cannot thank you guys enough!! As an 8th grade math teacher in an inner city district, it is extremely difficult to find any math videos online that actually apply to something FUN in REAL LIFE. I was able to show this video to my students and discuss the use of mathematics that applied. THANK YOU!"
- "As a Physics teacher and artist I love this. I show your videos to my classes. The art and science is awesome. I am an advocate for STEAM."
- "Thank you so much for this! Showing this to my students!!!"

This positive feedback is valuable; however, feedback from Youtube comments do not often provide constructive criticism and are influenced by the opinions of fans of OK Go. Because of this, more thorough research on the impact and outreach of the materials will be constructed in the future.

The OK Go Sandbox team is currently looking at OK Go's back catalog of music videos and identifying future applied mathematics lessons that can be created. The feedback on the initial mathematics content has been mostly positive, and OK Go Sandbox hopes to work closely with the Mathematics and Engineering Education communities to identify topics that would be uniquely suited for use in this project.

Acknowledgements

We would like to extend our gratitude to our funders that make OK Go Sandbox possible: Cognizant, Google, and Morton Salt. We also are grateful for the educators who participated in our survey and continually offer feedback to the OK Go Sandbox team so we can strengthen and improve our resources.

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