EXPLORING MIDDLE SCHOOL STUDENTS' THINKING IN AN ENGINEERING PROGRAM USING AN ASYNCHRONOUS VIDEO REFLECTION TOOL

A Thesis

by

NATASHA LAGOUDAS WILKERSON

Submitted to the Graduate and Professional School of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Chair of Committee,	Joanne Olson
Committee Members,	Michael de Miranda
	Bonnie Dunbar
Head of Department,	Joanne Olson

December 2021

Major Subject: Curriculum and Instruction

ABSTRACT

Pre-college engineering education is gaining popularity, and most state science standards now include engineering in some capacity. However, others are calling for engineering as a separate discipline. The 2020 *Framework for P-12 Engineering Learning* acts as a foundational document that outlines concepts, practices, and habits of mind for promoting engineering literacy in all students. This study investigates a subset of these to determine their presence during an informal engineering program that included weekly engineering design challenges conducted through distance learning. Students worked from home to complete the engineering activities, followed by submitting a reflection video on Flipgird. The researchers employed a mixed-methods research design using a coding guide developed a priori based on engineering practices and habits of mind. Flipgrid was found to have potential as an educational tool that captures student thinking, but the students overwhelmingly focused on the final product of the engineering activity. Additionally, the elements of the engineering activity, including open-ended design constraints and the building time of a prototype, may promote different levels of engagement in the design process. The study also highlights the need for more guidance around developmentally appropriate learning outcomes for engineering literacy.

DEDICATION

I would like to dedicate this thesis to my loving and supportive husband. Thank you for being my greatest champion and partner in life. I could not have done this without you!

ACKNOWLEDGEMENTS

I would like to thank you my committee chair Dr. Joanne Olson for her guidance and insight during every stage of this thesis study. I would also like to thank my committee members, Dr. Michael de Miranda and Dr. Bonnie Dunbar for their support in this process.

I would also like to thank the other students in the department for their friendship, advice, and encouragement. I also greatly appreciated the department faculty, especially those in the science education group, whose teaching and guidance promoted my deeper understanding of science and engineering education.

CONTRIBUTORS AND FUNDING SOURCES

Contributors

This work was supervised by a thesis committee consisting of Dr. Joanne Olson and Dr. de Miranda of the Department of Teaching, Learning, and Culture, and Dr. Bonnie Dunbar of the Department of Aerospace Engineering.

The video coding presented in Chapter 4 was supported by Iliana Del La Cruz.

Funding Source

There was no outside funding for this study.

NOMENCLATURE

AEEE	Advancing Excellence in P12 Engineering Education
ASEE	American Society for Engineering Education
DM	Decision-Making
NAE	National Academy of Engineering
NGSS	Next Generation Science Standards

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Page

CHAPTER I

INTRODUCTION

The release of the Next Generation Science Standards (NGSS; NGSS Lead States, 2013) represents a shift in science education to include engineering in the K-12 classroom. The goal of the NGSS is to raise "engineering design to the same level as scientific inquiry in science classroom instruction at all levels" (NGSS Lead States, 2013, p. 1). Since the release of the NGSS, 20 states have adopted the standards, with an additional 24 states using the NGSS to inform their standards (National Science Teaching Association, 2021). The result is that most state science standards now include engineering in some capacity (Moore et al., 2015).

The integration of engineering in the science curriculum as put forward in the NGSS has been criticized. The recently released *Framework for P-12 Engineering Learning* authored by Advancing Excellence in P12 Engineering Education (AEEE) and American Society for Engineering Education (ASEE) raises concerns that teachers following the NGSS will use engineering as a vehicle for science in a way that misrepresents the engineering discipline. Instead, engineering requires an independent framework to ensure "that every child is given an opportunity to think, learn, and act like an engineer" (American Society for Engineering Education & Advancing Excellence in P12 Engineering Education, 2020, p. 4).

This research project investigated a middle school engineering program, Space Club, focused on engineering literacy. Space Club was developed by Communities In Schools of San Antonio (CIS-SA), a non-profit organization in San Antonio, Texas. The mission of CIS-SA is to “surround students with a community of support, empowering them to stay in school and achieve in life” (CIS-SA). CIS-SA Site Coordinators are placed in targeted campuses to provided tailored support for at-risk children including access to educational and community resources such as academic assistance, food packs, counseling, and enrichment to support development of academic and life skills. In 2014, CIS-SA added Space Club programming to their list of enrichment services to engage youth in a program that promotes engineering literacy alongside social and emotional learning. Space Club involves a unique partnership between a CIS-SA social service professional specializing in mental health, teachers who contribute classroom content and management, and engineering mentors who add technical depth. Activities include engineering design challenges focused on a space theme, such as launching a rocket or designing a robotic arm. The year-long program culminates with a Space Club city-wide competition where students work in teams to design a colony in space with a focus on engineering design, architecture, and mental health solutions.

In March of 2020, Space Club programming was halted due to the COVID-19 pandemic and reconfigured for the fall of 2020 in a new format compatible with distance learning. The result was *Mission to Moon*, an all-virtual 8-unit curriculum designed in partnership with Vivify STEM and supported by engineers at NASA Johnson Space Center and Southwest Research Institute. *Mission to Moon* includes a series of engineering design challenges centered around a lunar expedition. To complete each challenge, students first watch an instructional video developed by a team of engineers that includes an explanation of the engineering challenge along with career and current event highlights. Students then complete a digital engineering journal and design and build a device that meets specific criteria. The final step is to upload a video of the design to Flipgrid, a learning management system that centers around students uploading reflection videos in response to a prompt.

In October of 2020, the *Mission to Moon* curriculum and a self-paced teacher training program were made available to a national audience. CIS-SA received a grant from NASA to supply kits to participating schools, provide ongoing teacher support, manage student video submissions, and host weekly live Space Club Career Chats. From October through December 2020, 381 middle school students representing 19 schools participated in the program.

From serving students in a few schools in San Antonio to delivering content across the country, the all-virtual *Mission to Moon* curriculum allows CIS-SA to reach more students and schools than an in-person program. However, what is not known is the extent to which the goals of the engineering program are being met in the virtual format. The research reported here will address this issue by analyzing the student reflection videos submitted on Flipgrid.

The focus of this research investigated the use of Flipgrid in assessing learning outcomes of an engineering design challenge by focusing on the following:

1. To what extent do students use the entertainment features of Flipgrid?
2. How do students allocate time in the Flipgrid video?
3. What engineering process elements are present?

CHAPTER II

LITERATURE REVIEW

Increasing Popularity of K-12 Engineering

Pre-college engineering began to enter K-12 education in the late 1990s (NRC, 2009), but the movement was ignited after the 2012 NRC report and the resulting *Next Generation Science Standards* placed a heavy emphasis on the critical role of engineering in science learning (NGSS Lead States, 2013; NRC, 2012; NSTA, 2021; Moore et al., 2015). Most state science standards now include engineering in some capacity (Moore et al., 2015).

Engineering education is also gaining popularity outside of the science classroom. In 2018, 46% of all US high schools offered at least one stand-alone engineering course, a 92% increase from 2012 (Banilower et al. 2013; 2018). Curriculum companies and organizations are seeing huge demands for engineering content such as *Engineering is Elementary*, which claims to have been used by 44,000 teachers across all 50 states to reach over 18 million K-12 students (Engineering is Elementary, 2021). Another popular engineering program, *Project Lead the Way*, boasts a reach of 12,200 schools and nearly 77,500 teachers (Project Lead the Way, 2021).

Informal settings are also seeing dramatic increases. Engineering clubs at the elementary level have increased from 7% of schools offering clubs in 2012 rising to 28% in 2018. Middle schools rose from 19% in 2012 to 35% offering engineering clubs in 2018 (Banilower et al. 2013; 2018). One popular engineering club is FIRST, an international robotics competition founded in 1989 that now includes over 679,000 student participants from across the world (FIRST, 2021). Clearly, engineering is wide-reaching across the K-12 landscape.

An Argument for Engineering Literacy

The National Assessment Governing Board (NAGB) of the US Department of Education argue that "it is time for technology and engineering literacy to take its place alongside the traditional literacies in reading, mathematics, and science as a set of knowledge and skills that students are expected to develop during their years in school" (NAGB 2018, p. 2). What is behind this surge of interest in pre-engineering education? Proponents of engineering education include the following main arguments: (1) critical need for engineering professionals, (2) development of critical 21st century skills, and (3) potential to increase student achievement. The following provides additional details.

Workforce Development

In *Engineering in K-12 Education*, the National Academy of Engineering (NAE) and the NRC argued that engineering education is important to develop a workforce that is prepared to fill engineering jobs that are critical for the United States to be competitive in a global economy (NAE & NRC, 2009). The NAE also highlights current inequities in access to engineering learning, which is a detriment to cultivating a diverse engineering workforce (NAE & NRC, 2009). Furthermore, industry leaders cite a growing talent shortage, as reported by the 2017 *Workforce Development Survey* by Deloitte and SEMI, where 77% of semiconductor industry executives are experiencing a critical talent shortage with engineering professionals being the most difficult roles to fill (Richard, et al., 2018).

In response to these calls for action, researchers have studies ways to increase interest and retention of students in engineering pathways. Studies have found a increased interest in these fields after exposure to an engineering activity in the classroom (Apedoe et al., 2008) and during informal engineering programs (Cunningham, 2008; Rivoli & Ralston, 2009). Brophy et al (2008) argue that engineering activities can provide intrinsic motivation as "they engage a natural design to make something and they tap into the curiosity that comes from wanting to learn how things work" (p. 371).

Development of 21st Century Skills

While workforce development dominates the headlines, proponents of engineering literacy also cite the value of engineering education to prepare students to become global citizens of the 21st century regardless of profession. The NRC argues that "understanding science and engineering, now more than ever, is essential for every American citizen […] knowledge of science and engineering is required to engage with the major public policy issues of today as well as to make informed everyday decisions" (NRC, 2012, p. 8). According to the *Framework for P-12 Engineering Learning*, "an engineering-literate society is believed to be better positioned to assess, value, and ultimately support politician positions that aim to advance our engineering and scientific capacity" (ASEE & AEEE, 2020, p. 9). Furthermore, engineering thinking also includes the development of habits of mind such as systems thinking, creativity, optimism, collaboration, and communication (NRC, 2009) that along with the understanding of engineering design may better equip students to solve major global challenges and interdisciplinary problems (NRC, 2012).

Improved Learning Outcomes

The rise of engineering in K-12 has led to an increased interest in studying engineering activities in the science classroom (Brophy, Klein, Portsmore, & Rogers, 2008; NAE & NRC, 2009). While still a developing research area, multiple studies find the potential for engineering to impact the learning of science (Atman et al., 2007; Apedoe et al., 2009; Cunningham & Carlsen, 2014). One example is a study by Riskowski et al. (2009) which found that middle school students who engaged in an engineering design activity on water resources generally had a lower number of misconceptions compared to students who experienced a traditional lecture-style science class. However, other studies highlight the critical need for professional development and curriculum resources to promote effective engineering instruction in the science classroom (Capobianco & Rupp, 2014; Cunningham & Carlsen, 2014; Pleasants et al., 2021).

Defining Learning Goals for K-12 Engineering Education

While the integration of engineering education in K-12 has many advocates, the definition and framework of engineering for K-12 students are still under development. The NAE and NRC conducted a review of curricular materials and concluded the following:

> There is no widely accepted vision of what K–12 engineering education should include or accomplish. This lack of consensus reflects the ad hoc development of

educational materials in engineering and that no major effort has been made to define the content of K–12 engineering in a rigorous way. (2009, p. 7)

National educational standards in science (NGSS Lead States, 2013) have included engineering practices within a science context, and generally, science classrooms incorporate engineering through activities that involve design practices to build and test physical artifacts as a solution to a context-specific problem (Moore et al., 2014; Brophy et al., 2008; National Academy of Engineering, 2009). These engineering design activities have the potential to provide an authentic context to apply science concepts (Atman et al., 2007; Johri & Olds, 2011).

However, others argue for students to understand engineering as a separate discipline (Moore et al., 2014; NAE & NRC, 2009). According to the *Framework for P-12 Engineering Learning*, "engineering continues to be largely disguised as a vehicle for science education, or as career education for the few. This framework is for those of us who value engineering for the sake of engineering and the opportunities it opens for all students" (AEEE & ASEE, 2020, p. 1). The authors commend the inclusion of engineering in the NGSS, but the singular focus on engineering design practices does not capture the full scope of engineering learning (AEEE & ASEE, 2020). The AEEE/ASEE framework attempts to define a more authentic and comprehensive engineering learning experience that expands beyond the NGSS to include additional engineering practices such as materials processing and professionalism, the introduction of habits of mind, and engineering content areas such as structural analysis and computer architecture.

This AEEE/ASEE framework for engineering learning is the basis for this study. The framework outlines a three-dimensional approach where engineering learning should allow students to: "(1) orient their ways of thinking by developing Engineering Habits of Mind, (2) be able to competently enact the Engineering Practices, and (3) appreciate, acquire, and apply, when appropriate, Engineering Knowledge to confront and solve the problems that they encounter" (AEEE & ASEE, 2020, p. 39). While three dimensions are outlined, the authors describe the need to scaffold the dimensions across grade levels with an earlier focus on habits and practices before engineering knowledge. At the middle school level, which is the grade level of students in this study, the authors propose that the "focus is on building proficiency in engineering habits of mind and engineering practices and on developing engineering knowledge concepts" (AEEE & ASEE, 2020, p. 22). Therefore, this study investigates learning around engineering practices and engineering habits of mind developed during a middle school engineering program.

As outlined in the AEEE/ASEE framework, engineering habits of mind include optimism, persistence, collaboration, creativity, conscientiousness, and systems thinking. Habits are to be developed gradually through engineering experiences with the goal for students to effortlessly apply them to engineering-related activities (Royal Academy of Engineering, 2017). Engineering practices, the behaviors associated with the engineering field, include engineering design, material processing, quantitative analysis, and professionalism (AEEE & ASEE, 2020). Each practice is further defined by a set of core concepts. For example, engineering design includes nine core concepts such as, problem framing, ideation, prototyping, and decision-making. This study will focus on the practice of engineering design due to the overlap with the NGSS and the identification as a common element of pre-college engineering education (Brophy et al., 2008; Cunningham & Carlsen, 2014; Katehi, Pearson, & Feder, 2009; Sidawi, 2009).

Within the engineering design practice, one concern raised by researchers is the emphasis of engineering instruction on students building a product instead of focusing on engineering practices (Pleasants & Olson, 2020). One possible explanation for a product-centric instruction is the tendency of engineering instructional materials to center around a step-by-step process (Capobianco, DeLisi, & Radloff, 2018; Hirsch, Berliner-Heyman, & Cusack, 2017). Organizing instruction around the EDP model may bring focus to an end product instead of building a meaningful understanding of engineering practices (Hynes, 2012; King & English, 2016; Pleasants & Olson, 2020).

Mission to Moon Program

This study investigates the learning outcomes of student participants in the *Mission to Moon* program run by CIS-SA. The program is run by a network of instructors who implement the engineering curriculum through an informal setting (e.g., after school or out-of-school) or elective STEM course. *Mission to Moon* is focused on engineering outcomes including the goals of increasing interest in engineering career pathways and increasing understanding of the engineering discipline. The program is also aligned with the mission of CIS-SA to support student success in school through enjoyable experiences that build self-confidence, social and emotional skills, and thinking habits that translate into increased school attendance and improved academic performance. Therefore, while the engineering goals of the *Mission to Moon* program are closely aligned to those in the *Framework for K-12 Science Education*, an important note is the informal setting and additional intended outcomes of the program.

Using Flipgrid to Capture Student Thinking

In response to the COVID-19 pandemic, the *Mission to Moon* program was forced to pivot to all-virtual instruction, including finding a new way to assess student thinking asynchronously. The program developers selected Flipgrid, a popular online video response platform that enables students to record, post, and view videos in a private page that is created by the teacher. The following provides a background and overview of Flipgrid as well as relevant literature.

Overview of Flipgrid

According to the website, Flipgrid is all about "simple, free video discussions to make learning fun, fulfilling, and empowering" (Flipgrid, 2021). Flipgrid was developed in 2014 by University of Minnesota Learning Technologies Professor Charles Miller as a tool for his students to create and share videos on various topics (Grayson, 2015). The platform was acquired by Microsoft in 2018 and made free to use. As a result, popularity increased dramatically, likely bolstered by the move to distance learning, with an estimated 100 million users across 190 countries (Green et al., 2021).

Flipgrid is a stand-alone app and website that is accessible on computers, tablets, and phones. Teachers create an assignment through a written and video prompt and send the assignment link or QR code to students. Students then respond by uploading a short video. Educators can customize the experience by setting time limits on video responses (up to five minutes), making student videos public or private, and enabling features such as stickers and filters. Educators can also moderate student videos and responses as well as assign grades via an embedded rubric tool.

Research on Flipgrid

While a popular tool, research on Flipgrid is still limited. Most articles found were descriptive, such as providing an overview of features and exploring the potential instructional uses (e.g. Agan et al., 2020; Green & Green, 2018). For example, Miller et al. (2020) proclaim that Flipgrid "has the power to change how students engage in course material" (p. 2) and outline a series of instructional strategies to use Flipgrid that may have the potential to deeper learning, critical thinking, and problem-solving skills (Miller et al., 2020, p. 2).

One study by Kiles et al. (2020) investigated the potential of Flipgrid as a self-reflection tool during a distance learning class. Researchers administered a survey to cohorts of pharmacy students to compare experiences in a class using written reflections with a class using Flipgrid videos. The pilot study found that students strongly preferred submitting reflections via Flipgrid over written submissions and noted an increase in participants' sense of connectedness with faculty after using Flipgrid. Kiles et al. proposed that Flipgrid "allows students to be more conversation about their learning experiences, which may result in greater depth of reflection" (p. 4). However, engagement was not significantly increased compared to written responses. Overall, the authors found that Flipgrid has potential as a self-reflection tool, but "may not be a 'magic-bullet' to increase student engagement" (Kiles et al., 2020, p. 1).

Green, et al. (2021) explored educators' experiences and perceptions of using Flipgrid in the classroom through a survey of 230 Flipgrid users. When asked about uses for Flipgrid in the classroom, teachers reported primarily using Flipgrid for providing opportunities for creativity (n=100) and as formative evaluation for learning (n=90). For evaluation, teachers stated that Flipgrid allowed for greater insight into student thinking. One teacher said, "[Through Flipgrid,] students have been able to demonstrate their learning better than they could ever articulate on a test such as multiple choice" (Green et al., 2020, p. 791). When asked about Flipgrid's effect on learning outcomes, teachers described increases in engagement, but a few contradictory results found that some educators perceived Flipgrid as empowering shyer students while others reported having students who would not turn on cameras during reflection videos. Overall, researchers concluded that "participants perceived Flipgrid as a valuable teacher tool in addition to a student tool" (Green et al., 2020, p. 793).

Comparison to Social Media

Many have noted that Flipgrid is attractive because it requires students to use a familiar tool to create and upload video in a way that mimics popular social media platforms such as TikTok, YouTube, and Instagram (Kiles et al., 2020; Miller et al., 2020). However, those social media outlets have the specific aim of entertainment. Using Flipgrid to assess performance in an educational setting prioritizes different goals where entertainment is typically of less value than the thoroughness and accuracy of the content. Learning theory makes clear that students use their prior knowledge and experiences as a filter for new information (e.g., Posner et al., 1982), and educators cannot assume that students using a technology that behaves in a similar way as TikTok will be interpreted by students through the lens of summative assessment rather than entertainment.

This study investigated the use of Flipgrid as an asynchronous video reflection tool that attempts to capture student thinking during a distance learning engineering program. The study focused on analyzing student reflection videos submitted after participating in an engineering activity to capture learning outcomes related to engineering habits of mind and engineering practices.

CHAPTER III

METHODS AND APPROACH

Theoretical Approach

This study is based on a constructivist paradigm. Research on human learning indicates that students construct meaning and make sense of it based on prior experiences. Students' prior knowledge is often at odds with accurate science and engineering concepts. Thus, students construct knowledge in idiosyncratic ways, often resulting in misconceptions. A crucial task for educators is to diagnose students' thinking in ways that enable misconceptions to be made apparent. In this study, Flipgrid was used to seek students' thinking to determine its effectiveness as an assessment tool and to inform teaching decisions.

Research Questions

The following research questions guided this study: 1) To what extent do students use the entertainment features of Flipgrid?; 2) How do students allocate time in the Flipgrid video related to the engineering process and end product?; and 3) What engineering process elements are present?

Research Design

The researcher employed a mixed-methods research design that examined a selected sample of Flipgrid videos submitted by students. Researchers qualitatively coded Flipgrid reflection videos using a coding guide developed a priori (described below) to align with research questions. Then, descriptive statistics were employed to analyze the codes.

Instrumentation

This study seeks to determine if Flipgrid is a viable educational tool and if student videos captured the program's intended learning outcomes. By using the performance matrix presented in the *Framework for P-12 Engineering Learning* and considering the *Mission to Moon* program goals and student handout prompts, the researcher developed a coding guide in advance. The guide reflected two engineering learning goals: 1) cultivation of engineering habits of mind; and 2) application of the engineering design process to develop a solution to solve a problem using provided design constraints. These learning goals and the viability of Flipgrid were assessed in a coding guide that included three components: 1) assessment for entertainment features; 2) timeline analysis; and 3) assessment for engineering design process elements and habits of mind.

Entertainment Features

On Flipgrid, students record a video as a response to an assignment. Students can add filters, background images, stickers, GIFs, and text to enhance the videos during the upload process. These features mimic popular tools on social media platforms like TikTok. To capture if students included these features in the *Mission to Moon* response videos, the coding guide prompted researchers to mark if "The student makes an effort to make the video entertaining such as using filters or stickers." A second question addressed whether the videos were on-topic and asked researchers to mark if "the majority of the video is not related to the engineering activity." An additional notes section provided space for further context or to note items that may warrant revising the coding guide.

Timeline Analysis

A timeline analysis was conducted to determine if student videos captured the program's intended learning outcomes. The researcher, working with a second researcher, discussed appropriate markers to include in the analysis that would signify when and how long students spent on content that aligned with program goals. In the handouts, students were prompted to describe the product "Share your design! How does it work?" and the process "What happened during building and testing?" Based on these prompts, the markers in the analysis included:

1. Process: The student reflects on the process of designing and building the prototype.
2. Product Description: The student describes the features and function of the prototype.
3. Product Showcase: The student conducts a demonstration of testing the prototype meeting design criteria.

The researchers then added the total amount spent on each element into the coding guide.

Assessment for Process Elements and Habit of Mind

While the timeline analysis would reveal whether students reflected on the engineering process, the coding guide further assessed for specific process elements present along with engineering habits of mind. After viewing the video and conducting the timeline analysis, the researcher determined if the video included any of the ten elements in the coding guide. Before the analysis, the researcher determined the coding guide elements by utilizing the performance matrix in the *Framework for P-12 Engineering Learning* and considering the *Mission to Moon* program goals and constraints.

The first learning goal, cultivating engineering habits of mind, was defined by the six habits outlined in the *Framework for P-12 Engineering Learning*: optimism, persistence, collaboration, creativity, conscientiousness, and systems thinking (ASEE & AEEE, 2020). However, due to the virtual format of *Mission to Moon,* the program was severely limited in the ability to develop all six engineering habits of mind. Students completed all activities independently at home, and teamwork was not part of the curriculum. Another challenge was the limited insight provided by a short student reflection video dictated by the *Mission to Moon* video prompts compared to an in-classroom observation over time. Because of these constraints, the coding guide only evaluates "persistence" from the six areas. The *Framework for P-12 Engineering Learning* describes persistence in the following way: "Failure is expected, even embraced, as engineering-literate individuals work to optimize the solution to a particular challenge. Engineering— particularly engineering design—is an iterative process. It is not about trial and error. It is trying and learning and trying again" (AEEE & ASEE, 2020 p. 5).

The second goal, application of the engineering design process, was also captured in the coding guide after consideration of the constraints of the *Mission to*

Moon program. For example, unlike a traditional classroom setting, students completed activities asynchronously from home without instructional support. Therefore, the students relied on the provided handouts to guide them through the engineering design process in a step-by-step format (see Appendix A). This approach runs counter to the *Framework for P-12 Engineering Learning,* which states that engineering design is a "messy, iterative, and complicated practice that follows no set procedure" (ASEE & AEEE, 2020, p. 30). Instead, the authors define the engineering design practice around a set of "core concepts," including problem framing, decision-making, ideation, project management, design methods, and prototyping (ASEE & AEEE 2020, p. 30). Considering the limitations of *Mission to Moon* and the distance learning format*,* the coding guide for this study focused on four core concept areas outlined in Table 1: problem framing, ideation, prototyping, decision-making, and engineering graphics. Using the performance matrix in *Framework for P-12 Engineering Learning* as a guide, researchers created categories based on the core concept areas and identified specific elements for analysis. Table 2 outlines the elements of the coding guide, including assessment of engineering design practice and the engineering habit of persistence.

Table 1 Engineering Design Core Concepts under Study from the *Framework for P-12 Engineering Learning*

Engineering Design Core Concepts	**Description**
Core Concept 1 **Problem Framing**	Process of "identifying the goals and essential issues related to developing a desired solution" (ASEE & AEEE, 2020, p. 65).
Core Concept 4 **Ideation**	"Process of mentally expanding the set of possible solutions to a design problem in order to generate a larger number of ideas, with the hope to finding a better and more innovative resolution" (ASEE & AEEE, 2020, p. 66).
Core Concept 5 **Prototyping**	"Process of transforming an idea into a form (physical or digital) that communicates the idea with others, with the intention to improve the idea over time through testing and the collection of feedback" (ASEE & AEEE, 2020, p. 66).
Core Concept 6 **Decision-Making**	"Process of making a logical choice from a variety of options through the gathering of information […] making evidence/data/logic-driven decisions" (ASEE & AEEE, 2020, p. 67).
Core Concept 8 **Engineering Graphics**	"Detailed and well-annotated visual illustrations the communicate the features and functions of a design or ideas" (ASEE & AEEE, 2020, p. 67).

Table 2 Engineering Elements Assessed in Coding Guide

Category	**Element**	**Description**	***Framework for P-12 Engineering Learning* Performance Matrix**
Problem Framing	Design Criteria	Student shows an understanding that the product needs to meet specific design criteria to solve a problem.	EP-ED-1 Engineering Design Problem Framing: *Identify Design Parameters*
	Context	Student describes the larger context of the problem being solved.	EP-ED-1 Engineering Design Problem Framing: *Problem Statement Development*
Ideation	Engineering Graphics	Student refers to or shows an engineering sketch of a design idea.	EP-ED-4 Engineering Design Ideation: *Conveying Ideas through Sketching*
	Multiple Solutions	Student describes brainstorming multiple ideas for solving the problem.	EP-ED-4 Engineering Design Ideation: *Brainstorming Techniques*
Prototyping	Testing	Student describes the process of testing the prototype to gather data to improve the design.	EP-ED-5 Engineering Design Prototyping: *Procedures of Testing & Modifying Physical & Digital Prototypes*
	Material Properties	Student describes selecting materials to meet design criteria. Answers the question, *why did you choose a material for the prototype?*	EP-ED-5 Engineering Design Prototyping: *Material Selection*
	Material Processing	Student describes the process of manipulating materials to meet design criteria. Answers the question, *how did you manipulate the materials to create the prototype?*	EP-ED-5 Engineering Design Prototyping: *Manufacturing Process*
Decision-Making	General	Students describes the logic behind a design decision or prototype feature.	EP-ED-6 Engineering Design Decision-Making: *Evidence / Data / Logic-Driven Decisions*
	Science	Student describes applying scientific knowledge to inform a design decision.	EP-ED-6 Engineering Design Decision-Making: *Application of STEM Principles*
Engineering Habit of Mind	Persistence	Student describes overcoming a challenge during the activity.	EM-PR Engineering Habit of Mind: *Persistence*

Once the coding guide was developed, a second researcher reviewed the guide and provided feedback on what should be coded binary (present or not present) and elements relevant to the analysis. The coding guide also contained additional notes to enable researchers to collect student exemplars, note items that may warrant a revision of the coding guide, and opportunities for additional context around the selected elements. Therefore, while this study did not use grounded theory to develop the coding guide, it was informed by the student videos and modified as needed (Corbin & Strauss, 2014).

To establish consistency in coding, a third researcher analyzed five Flipgrid videos independently using the coding guide and met with the first researcher to discuss differences and address potential definition refinements. The coding guide was revised based on the discussion. While the elements did not change, the criteria for whether an element was marked present was further refined. For example, in identifying the prototyping element of "material properties," the initial criteria asked that students compare the properties of materials in determining the best option for a design. However, researchers did not find any videos comparing material properties, but a student would often describe why the material was selected. Therefore, the criteria were broadened to include any reflection on "why did you choose this material for the prototype?" The researchers also decided that all process elements must consist of insight into student thinking. Therefore, merely providing a list of materials used in the design did not qualify as a prototyping element. For example, student 11 in the Robot Hand mission says, "the materials I used are string, construction paper, and straws"

(S11RH). In contrast, student 6 reveals the purpose behind the materials in their Roller Coaster design by stating, "there is a platform here made out of straws and a border made out of a top of a cup. I used plates to make sure it stays in place" (S6RC). After these updates to the coding guide, the researchers repeated the process of independently analyzing an additional five videos, meeting to discuss, and updating the coding guide.

After finalizing the coding guide, the two researchers independently coded ten videos. From the two sets of scores, Cohen's Kappa was used to calculate an inter-rater reliability of K=0.92 (Cohen, 1960). The researchers then split the remaining videos with the lead researcher coding 65 videos and the third researcher coding 15 videos.

Selection Criteria

Engineering Activities

The curriculum, *Mission to the Moon,* is divided into eight weekly engineering design activities that connect to an overall space exploration theme. Table 3 outlines the sequence of engineering activities that follow a storyline about a team of astronauts on various missions on the Moon. Activities build up to the capstone project of researching and designing a colony on the Moon that addresses engineering and mental health solutions to keep a team of humans alive and happy.

To complete the program, *Space Club* students, a majority working from home, are provided with kits of materials, printed handouts, and links to Flipgrid topics. Since learning is asynchronous, students rely on the instructional videos and provided handouts to complete the activity independently. Each week, students watch a pre-recorded instructional video assigned by the teachers on Flipgrid. The approximately 12-

minute video includes an engineer host providing context to the engineering activity through connections to current events (e.g. NASA's Artemis mission), science topics (e.g. open and closed circuits), and interviews with STEM professionals (e.g. an aerospace engineer at NASA). The video then provides an overview of the design activity including framing of the problem, design constraints, available materials and how to use them, and other instructions needed to complete the activity.

After the video, students follow instructions on the printed handout to plan, build, and test a device that solves the problem and meets design criteria. The final step listed on the handout is to upload a reflection video, no longer than three minutes, on a classroom Flipgrid board. During the *Mission to Moon* program, students submitted eight reflection videos on Flipgrid. The video content was in response to a prompt on the student handout. Prompts varied across the weekly activities, and to eliminate any concerns for differences based on the prompts, the researchers focused on three lessons with identical prompts (see Appendix A). The selected lessons included a prompt with two parts. The first question asked about the end-product: "Share your design! How does it work?" The second part asked about the engineering process: "What happened during building and testing?" The activities selected for the study are identified with an asterisk in Table 3 and include: Roller Coaster, Robot Hand, and Rover. Note that the student handouts refer to the weekly activity as a "mission."

Table 3 *Mission to Moon* Activities

Week	Mission	Description of Engineering Activity
1	Roller Coaster*	Design a safe and fun Roller Coaster to mimic the effects of the "vomit comet" used in astronaut training.
2	Space Suit Design	Design an astronaut helmet with your mission patch.
3	Plants in Space	Design a device to support your plant as it grows.
4	Welcome Tower	Design a welcome tower powered by the sun.
5	Robot Hand*	Design a robotic arm to pick up a rock sample.
6	Rover*	Design a Rover to transport rock samples.
7	Design Lunar Base	Research and design a colony on the Moon to keep humans alive and happy.
8	Build a Lunar Base	Build a selection of your lunar base powered by a solar panel.

School Selection

During the fall of 2020, 52 schools across the United States implemented *Mission to Moon* curriculum through asynchronous distance learning. Schools varied in the curriculum implementation, instructor background, student demographics, access to materials, and other factors. As a result, the researcher used homogenous purposive sampling and focused on a single school site to minimize potentially confounding variables across schools.

The selected site was a public, urban, Title I school in New York City. With 132 7th grade participants, this school offered the largest group of students at a single site. *Mission to Moon* curriculum was implemented through an elective STEM course led by a technology teacher with ten years of experience. In September, Communities In Schools of San Antonio provided the instructor with a *Mission to Moon* teacher guide, student handouts, instructional videos, and a 3-hour self-paced virtual training program. The instructor then led students through the eight weeks of Space Club engineering activities from October through December 2020.

Due to the COVID-19 pandemic, all students were learning remotely and completed school coursework at home. The instructor sent home individual supplies with printed handouts for each activity for *Mission to Moon*. Students watched the pre-recorded instructional videos, completed the engineering design challenges, and uploaded a reflection video to the assigned Flipgrid topic board. The instructor was then able to view the videos and provide feedback.

Student Selection

The selected school provided access to the videos of 132 students, but not all students completed every mission. Therefore, the researcher narrowed the population to the 118 students who submitted a Flipgrid video for all eight missions. From this group, 15 male and 15 female students were selected at random to analyze changes across time. This study is focused on reviewing the 90 Flipgrid videos for 30 students across the three missions. Each video was assigned an identifier that included a randomly assigned number (1 through 30) to each student along with a reference to the mission: RC represented the Roller Coaster activity, Hand represented Robot Hand, and Rover represented the Rover mission. For example, the Roller Coaster video for student 5 would be assigned "S5RC".

Limitations

As discussed, the *Mission to Moon* curriculum was designed to support learning from home during the COVID-19 pandemic and does not reflect the typical learning environment in an in-person classroom setting. Students at home do not receive the same instructional support, and they may face other challenges like limited materials or distractions. Therefore, the data set may not translate to the use of Flipgrid during in-person learning.

A second limitation of this study is the focus on a single site. The student demographics, school location (urban rather than suburban or rural), the experience of the instructor, and other factors may limit how representative this data set is of the general student population.

A third limitation of this study is the elective nature of this engineering program. Because students participated in the program by choice, the student population studied may not be representative of students as a whole.

Finally, the study is limited to the context of engineering design challenges. The results of this data set may not translate to the use of Flipgrid in other subject areas, or for the assessment of content knowledge.

CHAPTER IV

RESULTS

Introduction

This study analyzed videos uploaded on Flipgrid during *Space Club*, a distance learning engineering program for middle school students. Working from home over eight weeks, students asynchronously completed a weekly engineering design challenge and uploaded a reflection video on the activity to Flipgrid. The following results are of 30 students, half male and half female, and their reflection videos from three out of the eight activities: Roller Coaster, Robot Hand, and Rover.

Research Question One

To what extent do students use the entertainment features of Flipgrid?

Finding #1:

Students did not utilize the entertainment features of Flipgrid.

Across the 90 Flipgrid videos, all videos stayed on topic and included content related to the engineering activity. Additionally, while Flipgrid provides many video features such as backgrounds, stickers, GIFS, frames, and filters that can be added to a student's video, none of the videos used any available features to enhance the videos. However, two videos, both for the Robot Hand activity, did have some entertainment elements. The first video coded for entertainment included the student saying, "Please like and subscribe to this channel!" The video ended with the Robot Hand doing a peace sign and the student saying, "Well, I think all I can say to you guys is peace-out!" The second video coded for entertainment included the TikTok logo with the student's handle displayed throughout the video as a watermark indicating the video was uploaded to TikTok before posting to Flipgrid. While these entertainment features were present in two videos, both videos still focused on the engineering activity and reflection.

Research Question Two

How do students allocate time in the Flipgrid video?

Finding #1:

Flipgrid videos were significantly shorter than the provided time limit.

The 90 videos were limited to a maximum of three minutes, but the average Flipgrid video was 52 seconds in duration. As shown in Figure 1, the Roller Coaster videos were, on average, the shortest at 27 seconds in length, followed by the Robot Hand (51 seconds) and the Rover (79 seconds). Across the missions, the shortest Flipgrid video was 7 seconds and the longest was 158 seconds. When categorized by gender, female videos averaged 55 seconds compared to male videos averaging slightly shorter at 50 seconds.

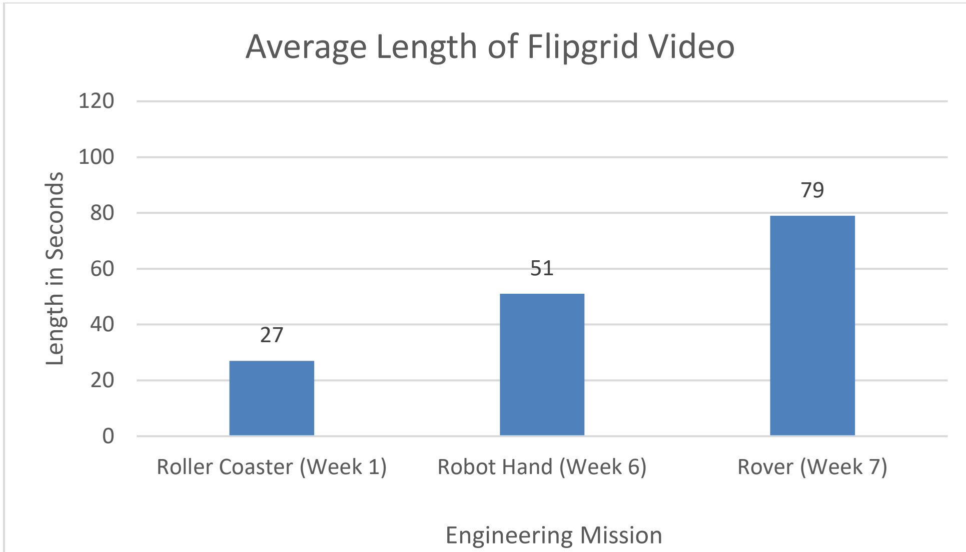

Figure 1 Average length of videos by engineering mission.

Finding #2:

All student videos featured a product demonstration, and about half included a reflection on the process.

Researchers coded three categories in the timeline analysis: process, product description, and product showcase. Table 4 describes each category and provides student exemplars from the videos. Figure 2 depicts how many videos included each category. The selection of the two product categories (description and showcase) reflected the handout prompt "Share your design. How does it work?" All Flipgrid videos answered this prompt by demonstrating that the product met the specified design criteria (product showcase). For example, during the Roller Coaster videos, students showed a ball traveling down the track and landing in the cup. However, only 64% verbally described the features and functions of the prototype (product description). Finally, only a little over half, 52%, of the videos included reflection on the process of designing and building the prototype in response to the prompt "What happened during building and testing?" Exemplars of each category are presented in Table 4.

Table 4 Flipgrid Timeline Elements

Video Element	**Exemplar**
Process The student reflects on the process of designing and building the prototype.	*After a couple of tries, I made something else. I used this, and I basically took the ping pong ball and did it like this, and then it would hold it up. But then it was too heavy.* (S13Rover) *I cut the colored papers into strips. Then I folded the paper into fourths, and then I left the sides of the paper up to create a wall that keeps the ball from falling off the Roller Coaster.* (S7RC) *The Roller Coaster requires a turn, which is why I used the plate for this. The ramp helps the ball gain energy also known as potential energy.* (S4RC) *I used construction paper for my arm and wrapped around my wrist area so it would stay put. I also put a few extra straws on the inside and outside over here for extra support so my hand wouldn't drop down. So those were a few revisions I had to make.* (S11Hand)
Product: Description The student describes the features and function of the prototype	*This is what it looks like. I made it using a cup, a motor, and a coin cell battery.* (S5Rover) *This is my robotic arm. My arm is made out of cardboard, floss, embroidery string, and tape. The robotic arm is separated into two parts. The hand and the arm.* (S10RH) *Here is my Roller Coaster that has 1 turn and can successfully land a ball in a cup.* (S29RC)
Product: Showcase The student conducts a test of the prototype to show that it can meet design criteria.	*Now I am going to show you a video of the Roller Coaster.* The student drops the ping pong ball at the top of the Roller Coaster product and films as it falls down the track. (S10RC) *Here is a video of my robotic arm working.* Student demonstrates the robotic arm picking up a ping pong ball. (S6RH) *Next I will be showing you my Rover moving 1 foot while carrying the rock sample, in this case the ping pong ball.* The student connects the motor to the battery on the Rover and shows the Rover moving 1 foot across the table between two rulers. (S9Rover)

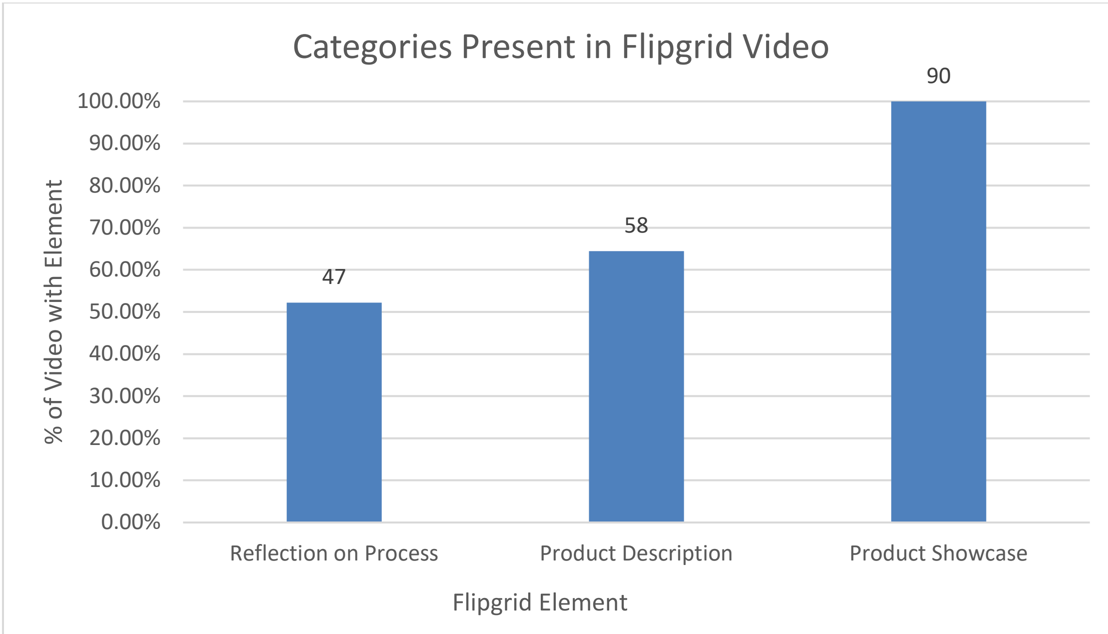

Figure 2 Number videos that included each category.

Finding #3:

Students were more likely to reflect on the process during the Rover activity than the Roller Coaster or Robot Hand activities

Sorting the videos by engineering activity, shown in Figure 3, reveals how the type of activity and/or the timing of the activity impacted the product and process elements included in the Flipgrid video. For example, a larger number of Robot Hand videos had a description of the product (N=22) than the Roller Coaster and Rover videos (N=18). Additionally, the Rover videos, completed during week 6, were more likely to include a reflection on the process (N=14 compared to N=11 for Roller Coaster and Robot Hand).

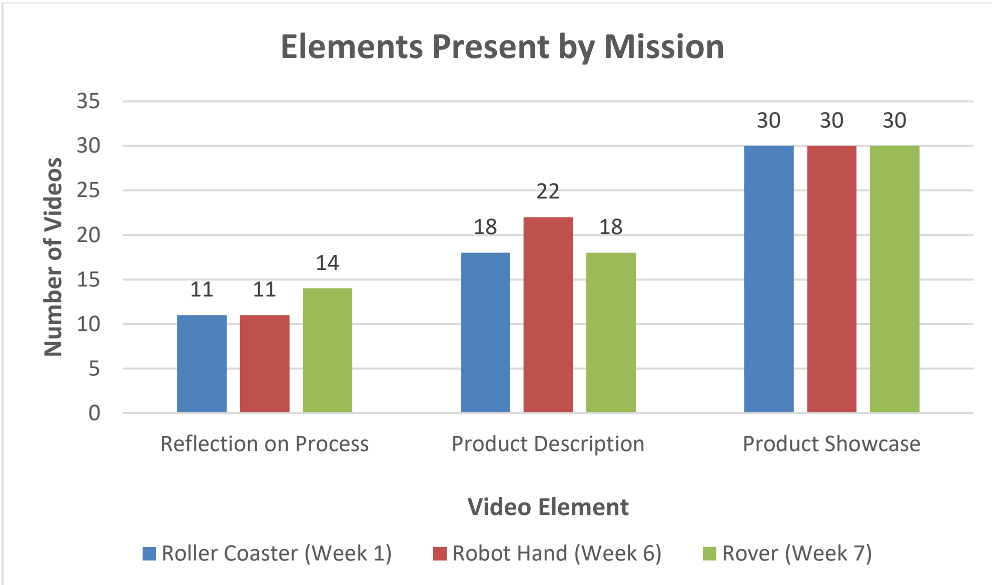

Figure 3 Number of videos by mission that include each element.

Finding #4:

Videos were most likely to start with a reflection on the process and showcase of the product and end with testing of the prototype.

The timeline analysis determined when and for how long students focused on the product and process elements. Table 5 shows the five timeline patterns observed across the student videos signifying how students decided to present the information. The two most common patterns, 1 and 2, made up 59% (N=53) of the videos. Both patterns started with student discourse and ended with a demonstration of the product features. Thirty-one of videos (34%) included both process and product elements (pattern 1), while 22 (24%) only included product elements without reflecting on the process (pattern 2). Figure 4 displays how the timeline patterns varied by mission. The last in the eight-week series, the Rover activity was most likely to have a pattern 1 timeline with all three elements present. The Robot Hand activity, completed the week before the Rover, was more likely to have a pattern 2 timeline (no process elements).

Table 5 Order of Elements in Flipgrid Videos

Pattern	Order of Elements	Description	No. of Videos
1	1. Process & Description 2. Showcase	Students describe the product features and reflect on the process. The video ends with a demonstration that the product meets design criteria.	31
2	1. Description 2. Showcase	Students describe the product features followed by a demonstration that the product meets design criteria. No reflection on the design process or insight into student thinking is present.	22
3	Showcase	Students demonstrate that the product meets design criteria. Any verbal communication relates to the testing of the product.	21
4	1. Description 2. Showcase 3. Process	Students first describe the product features, demonstrate the product meeting design criteria, and conclude with a reflection on the design process.	12
5	1. Showcase 2. Process & Description	Students start with a demonstration of how the product works. This is followed by a discussion on the product features and a reflection on the design process.	4

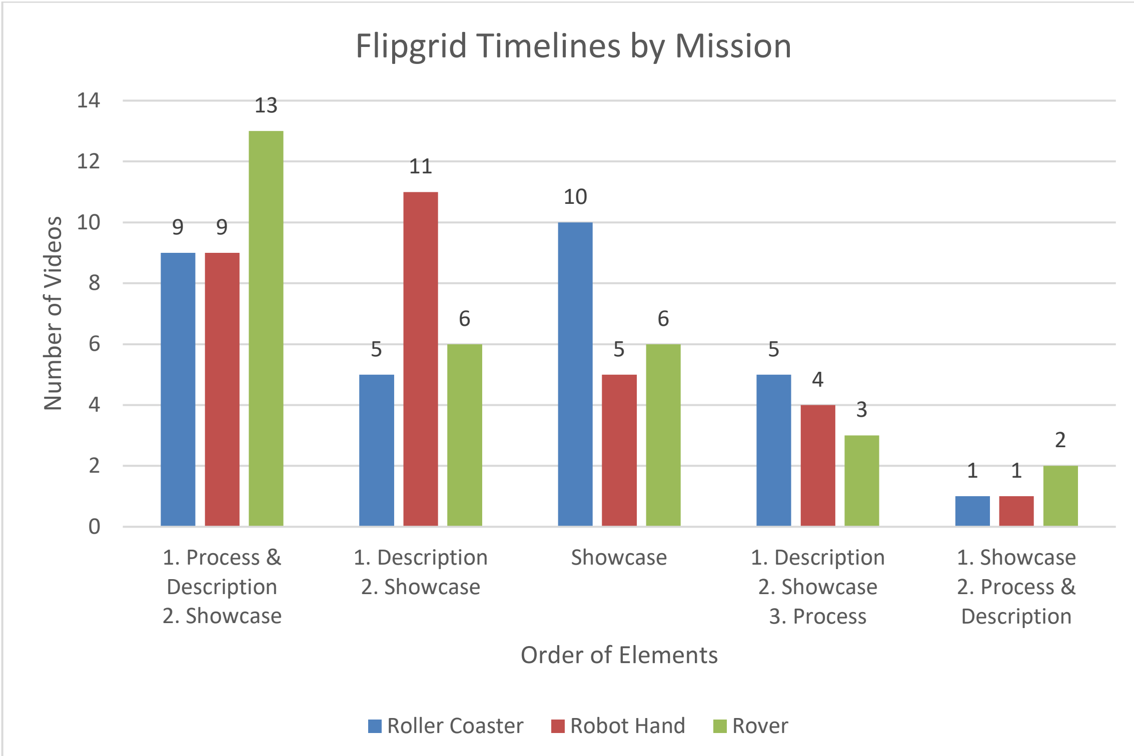

Figure 4 Flipgrid timeline patterns by mission.

The timelines for each pattern were examined in more detail to determine how and when time was spent for each element. For each timeline pattern, a dominant style emerged across the videos except for pattern 1 where two dominant styles emerged. These six video timelines are shown in Figure 5 to provide a more detailed depiction of how time was spent on each element.

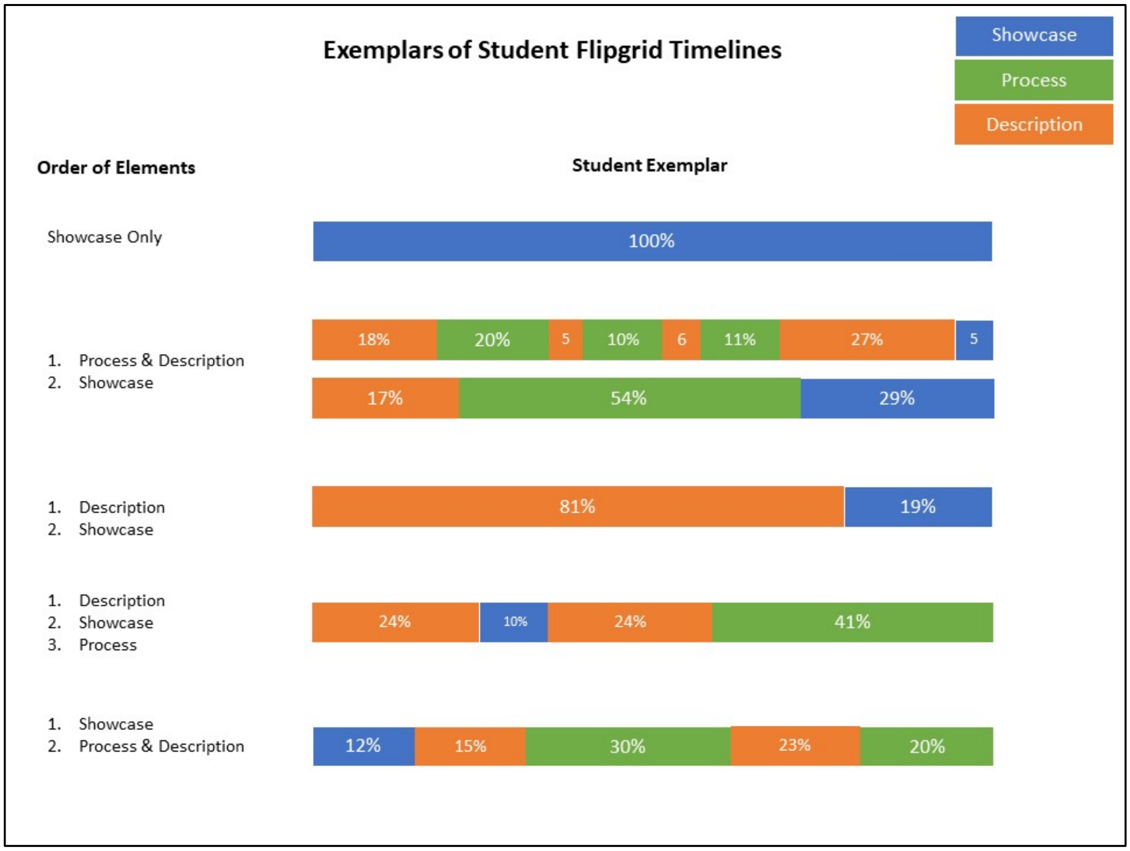

Figure 5 Exemplars of Flipgrid timeliness

Note that in Figure 5, all timelines are shown as percentages of the total time of the video to enable visual comparisons. Not all videos were the same length and varied from 7 to 158 seconds.

Finding #5:

Almost a quarter of videos only included a product showcase.

Of the 90 student videos, 23% (N=21) only featured a product showcase (Table 5). These videos had minimal student dialogue, and the researchers did not find any elements of reflection on the process or description of the product. For example, a Roller Coaster video in this category would simply show the student rolling a ball down the roller coaster and landing in the cup. This timeline pattern was much more likely for the Roller Coaster mission, as shown in Figure 4.

Research Question Three

What engineering process elements are present?

After completing a timeline analysis, researchers used a coding guide to conduct an in-depth analysis on pre-selected process elements and one engineering habit of mind (see Chapter 3). Out of the 90 videos analyzed, a little over half, N=47, included a process element defined in Table 6. Before the video analysis, the researchers determined the categories of process elements to be investigated (see Table 2 in Chapter 3). However, for a more precise presentation of results, the researchers merged “prototyping” and “decision-making into the more general construct of “decision-making” that captured all the elements in both categories. The ASEE/AEEE framework defines “decision-making” as the practice of “making evidence/data/logic-driven decisions” (AEEE & ASEE, 2020, p. 67). Prototyping is defined as a separate learning outcome, but every statement coded for prototyping was determined to fit within the definition of decision-making. For example, S30RC described decisions made during testing, “The ball kept flying off. I used paper so it could be taller, and the ball would instead go into the cup.” This statement was coded under both prototyping and decision-making categories. All other categories did not overlap between process elements; therefore, the researchers determined that merging “prototyping” and “decision-making” provided the most percise results.

Additionally, researchers removed the element of "general decision-making." Every use of this marker overlapped was also coded as another process element. For example, a student describing the decision to use cardboard as a support due to it being stiffer than paper would be categorized as both general decision-making and material property. Therefore the "general decision-making" element was removed as other identifiers more precisely captured it.

Table 6 Description of Reflection Elements in Coding Guide

Category	**Reflection Element**	**Exemplar**
Problem Framing	Design Criteria	*Here is my Roller Coaster that has 1 turn and can successfully land a ball in a cup.* (S29RC) *The Robot Hand needs to pick up the ball to be successful.* (S29Hand)
	Context	*The Rover is supposed to transfer rock samples.* (S18Rover) *And here [the Robot Hand] will pick up the rock sample, which is the ping pong ball.* (S10RH)
Ideation	Engineering Graphics	N/A: No videos included this element.
	Multiple Solutions	*Let me show you my other prototypes.* (S13Rover)
Decision-Making	Testing	*The ball kept flying off. I used paper so it could be taller, and the ball would instead go into the cup.* (S30RC) *After a couple of tries I made something else. I used this, and I basically took the ping pong ball and did it like this and then it would hold it up. But then it was too heavy.* Student shows straws holding the ball. *So then I went with this, and I attached something to it. But then again it was too heavy. So then I just used something like this and put it here. And now it goes. This one I made was very light weight so it moved quicker.* (S13Rover) *This part kept wanting to bend so I decided to put a roll of tape to make a hard surface. This allowed it to stop bending and allowed me to pick up the ball.* (S30Hand)
	Material Properties	*I put a AAA battery because it is lighter than the other battery.* (S27Rover) *I placed a straw in here to cause less friction.* (S22Rover) *In the back, I had to add to add extra cardboard and tape so it can be more durable.* (S10Hand)

Table 7 Description of Reflection Elements in Coding Guide

Category	**Reflection Element**	**Exemplar**
Decision-Making	Material Processing	*I cut the colored papers into strips. Then I folded the paper into fourths, and then I left the sides of the paper up to create a wall that keeps the ball from falling off the Roller Coaster.* (S7RC) *I made a hole in here so it won't go out because the hole is smaller than the ping pong ball.* (S27Rover) *I used construction paper for my arm and wrapped it around my wrist area so it would stay put. I also put a few extra straws over here for extra support so my hand wouldn't drop down.* (S11Hand) *I poked holes so it can move faster.* (S29Rover) *On the hand, I had to bend each finger, glue on some straws, and thread the string through. Each string I had to make a loop so I can fit my fingers through. As a result, the fingers can bend and move.* (S10Hand)
	Science	*In the process of making this, the ball actually didn't gain enough kinetic energy to go over that hill so then I actually made the slope a little bit longer.* *There is a straw at the back to keep it balanced and another straw for less friction.* (S24Rover)
Engineering Habit of Mind	Persistence	*There were a lot of difficulties, but it works now!* (S13Hand)

Finding #1

Decision-making and problem framing dominated the categories present across videos.

From the subset of videos that featured a process element, Figure 6 shows the number of videos that incorporated each process and habit of mind category. Figure 7 provides a more detailed breakdown of each element. The most common process category present across the videos was decision-making (DM). 73% (N=33) of the videos featured the student providing insight into making a logic or data-driven decision. Within this category, the most popular elements were material processing (N=21) and material properties (N=19). A much smaller group of videos included a science-informed decision (N=6) and a testing-informed decision (N=6).

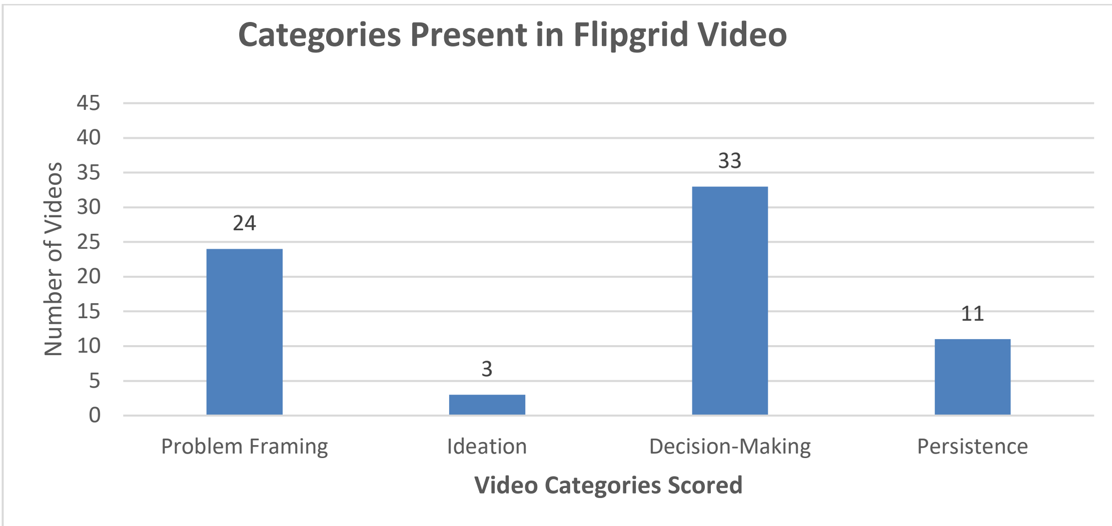

Figure 6 Categories present across Flipgrid videos.

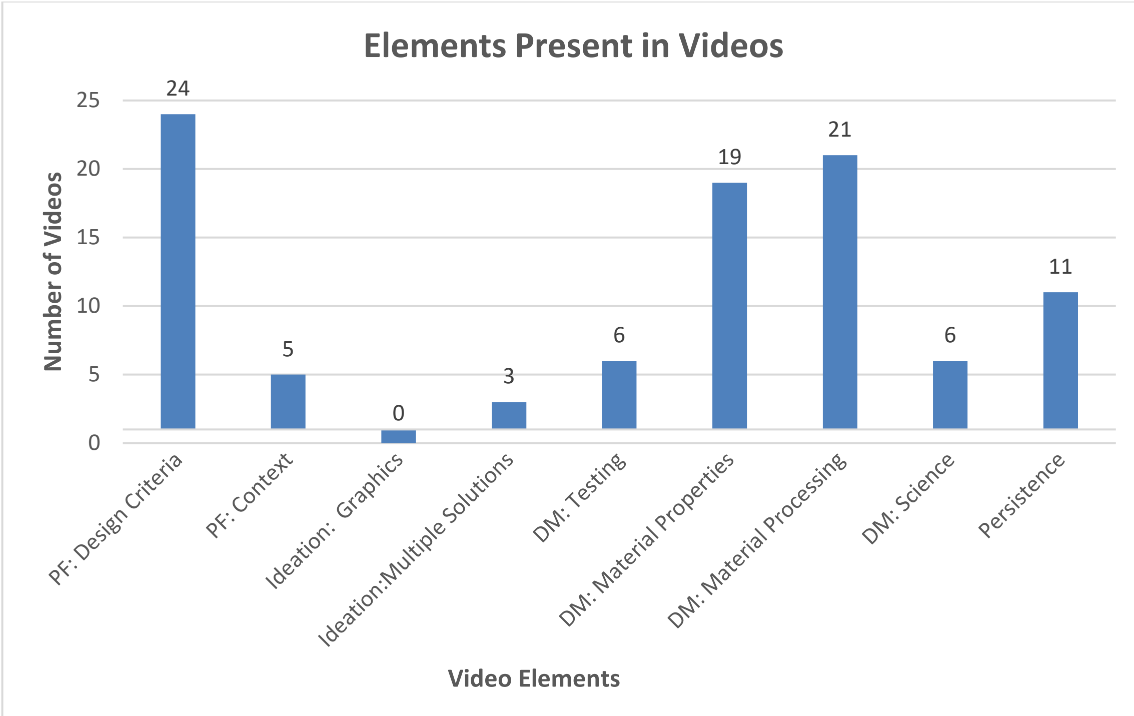

Figure 7 Process and habit of mind elements present in Flipgrid videos.

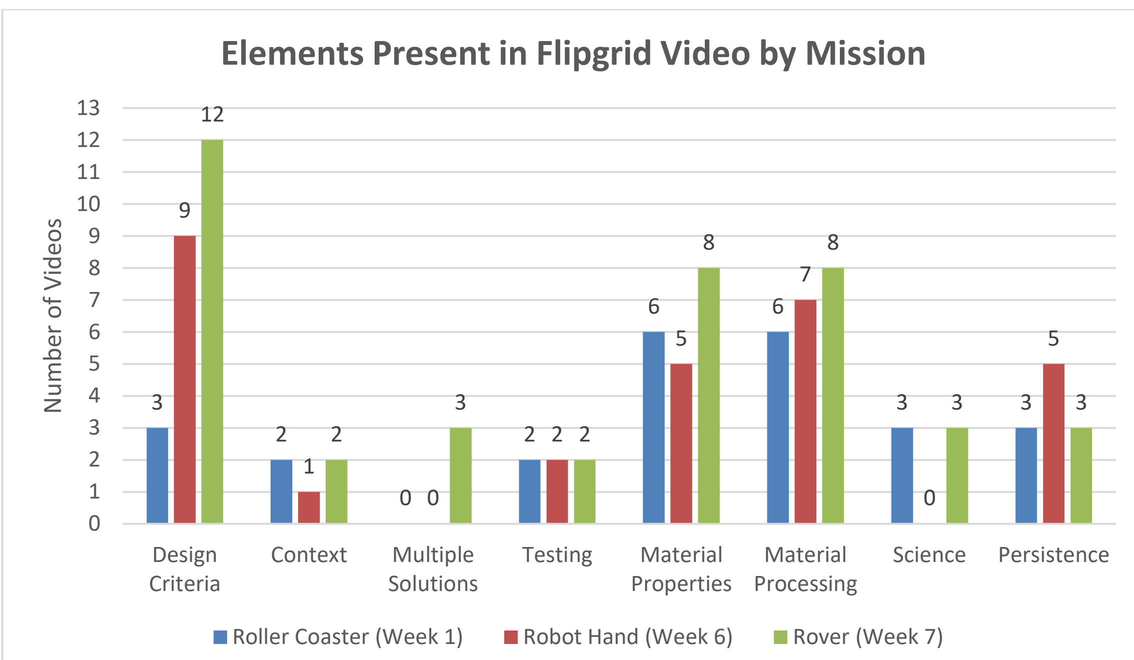

Figure 8 Reflection elements present by engineering activity.

Finding #2

Problem-framing was common across videos, but students rarely connected the product to the larger context.

The second most popular category across Flipgrid videos 53% (N=24) was problem-framing, as shown in Figure 7. All videos coded for problem framing included a description of the design criteria that defined the problem with only a few (N=5) adding additional context. The discussion of design criteria often appeared before testing the product. Students would first explain the necessary design (e.g., "My rover is able to travel the required 1-foot distance," S9Rover) before demonstrating the product (e.g., showing the rover traveling the 1-foot distance). Additionally, Figure 8 shows how this element became significantly more common over time as only a small number of students mentioned design criteria during the Roller Coaster videos (N=3) compared to the Robot Hand (N=9) and the Rover (N=12) activities.

While the connection to design criteria increased across the weeks of the program, students rarely connected the product to the larger context in any of the Fliprid reflection videos. Only five videos, spread across the three activities, referred to the purpose of the prototype. For example, one student stated, "The Rover is supposed to transfer rock samples on the Moon" (S18Rover). While the *Mission to Moon* handouts provided a problem statement at the top of the handout and the instructional videos emphasized the larger context of the design challenge, students rarely referred to these in the videos.

Finding #3

Videos rarely included reflection on the ideation process and none of the videos featured engineering graphics.

The ideation category, including engineering graphics and multiple solutions, was rarely seen in the Flipgrid videos. Only three of the student Flipgrid videos (see Figure 7) referred to developing multiple solutions, and none of the videos described the use of engineering graphics.

The three videos with ideation elements referred to having multiple solutions. All three videos referenced building and testing at least two prototypes to solve the problem, and one of the students demonstrated two prototypes during the Flipgrid video (A13Rover). Interestingly, all three of these videos were during the Rover mission, the last week in the series.

Finding #4

Reflections on the Rover activity resulted in the most process elements across all categories.

Table 8 highlights how the number of reflection elements increased across the three missions. While a slight increase occurred from Roller Coaster to Robot Hand, a significantly higher number of Rover videos had coded reflection elements.

Table 8 Number of Videos with Reflection Elements

	Roller Coaster Week 1	**Robot Hand** Week 6	**Rover** Week 7
Number of videos with 1 or more reflection elements	12	14	21

Figure 9 plots the number of process elements for each student across the three missions using the Roller Coaster (week 1) as a baseline to explore possible improvement over time. Table 9 numerically presents the same data and includes a change in the number of elements from Robot Hand to Rover missions. Interestingly, 57% of the students showed no change from week 1 (Roller Coaster) to week 6 (Robot Hand) in the number of process elements present. Furthermore, only 20% of the students improved with more elements present from week 1 to 6. In comparison, only 30% showed no change from week 1 to week 7, and 50% improved from week 6 to 7, illustrating that many students actually decreased in performance from Roller Coaster to Robot Hand and then improved during the final week to Rover.

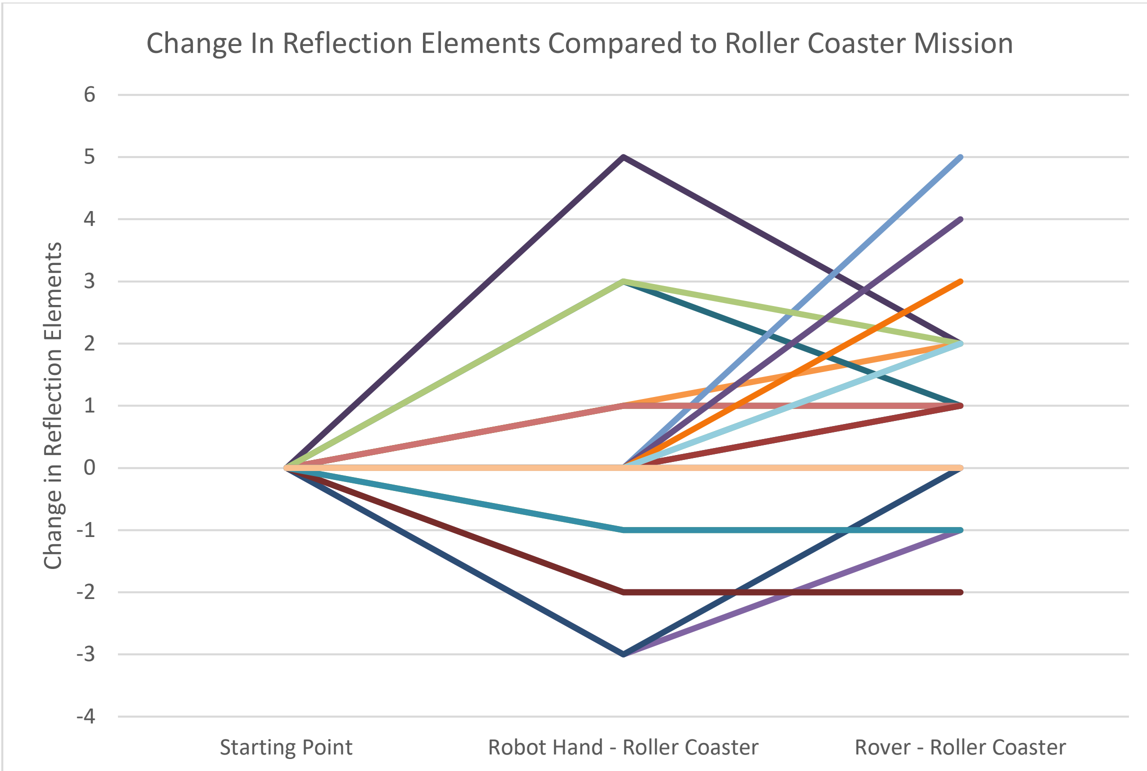

Figure 9 Change in reflection elements by individual student. Each line represents a single Space Club student.

Table 9 Change in Reflection Elements for Individual Students Across Missions

Change in Reflection Elements for Individual Student Videos	**Robot Hand Videos**	**Rover Videos**
No change compared to Roller Coaster	57% (N=17)	30% (N=9)
Increased # of elements from Roller Coaster	20% (N=6)	50% (N=15)
Decreased # of elements from Roller Coaster	23% (N=7)	20% (N=6)
No change compared to Robot Hand		50% (N=15)
Increased # of elements from Robot Hand		40% (N=12)
Decreased # of elements from Robot Hand		10% (N=3)

Finding #5

Rover projects had the most variety in designs.

Figures 9 – 11 show examples of final projects featured in the Flipgrid videos to highlight the differences across student projects. The students were working from home, so they were unlikely to see other students' projects during the building. Thus, any similarities are likely to be a result of the project instructions and design constraints. In comparing the projects, the Roller Coaster and Robot Hand projects appear to look similar across student videos. Despite using the least amount of materials, the Rover mission seemed to have the most variety in designs. Additionally, the students often personified the rover in the videos. For example, one student encouraged their rover during the testing saying, "You can do it! Oh no. Alright, there it is moving again. Yay, you did it!"

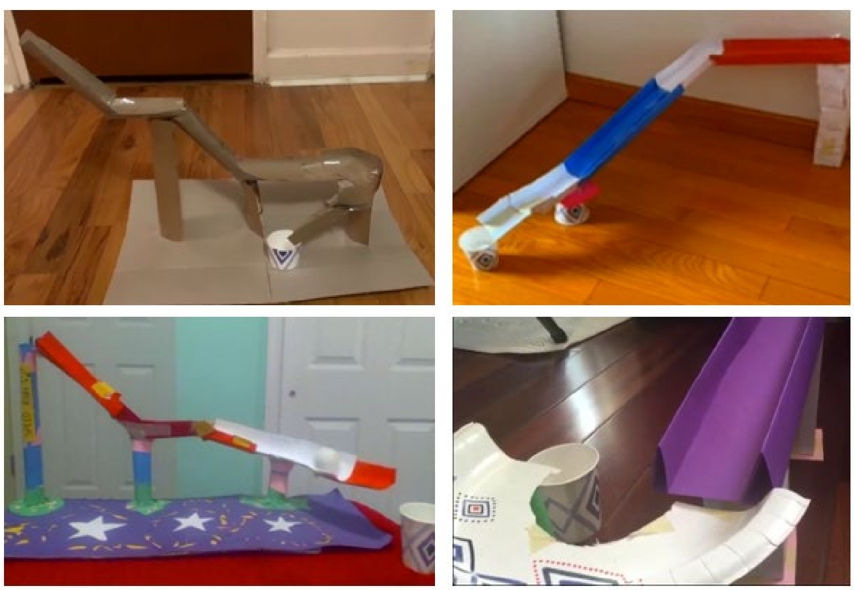

Figure 10 Roller Coaster Design Examples

Figure 11 Robot Hand Design Examples

Figure 12 Rover Design examples

Finding #5

The testing process element rarely appeared in videos and focused on trial-and-error.

The handout prompt, "What happened during building and testing?" explicitly addressed testing. However, as shown in Figure 7, only six videos (13%) mentioned the process of testing and improving the prototype. All six videos that included this element focused on a trial-and-error approach, and none of the videos described collecting data for a systematic approach to optimizing the design. For example, one student explained how "the ball kept flying off. I used paper so it could be taller, and the ball would instead go into the cup" (S30Rover). Another student explained, "After a couple of tries, I made something else. I used this, and I basically took the ping pong ball and did it like this, and then it would hold it up. But then it was too heavy. So then I went with this, and I attached something to it. And now it goes" (S13Rover).

The tinkering approach was also evident in the material process elements. As shown in Figure 7, 19 of the videos (45%) featured a material properties element, and 21 videos (40%) included material processing elements. For example, a student may explain the thinking behind choosing a material by stating, "This part kept wanting to bend, so I decided to put a roll of tape to make it a hard surface. This allowed it to stop bending and to pick up the ball" (S30Hand). The tinkering approach was also evident in material processing. One student explained, "I decided to improve my Roller Coaster by making the base thicker with cardboard as it kept collapsing" (S5RC) Another student described the Robot Hand testing and stated, "I used construction paper for my arm and wrapped it around my wrist area because it kept falling. I also put a few extra straws on the inside and outside over here for extra support so my hand wouldn't dropdown. So those were a few revisions I had to make" (S21Hand).

Finding #6

Except for testing and multiple solutions, female students were more to include process elements across all categories. Male students were more likely to describe challenges.

The videos were sorted by gender to determine any trends in the use of reflection elements by gender. Since the analysis included a small sample size of only 15 students for each gender, a statistical analysis cannot be performed, but a few potential trends were observed. First, the same number of male and female students (N=12) submitted at least one video that included a coded reflection element. However, across the 47 videos with at least one process element, 25 came from female students compared to 22 from male students.

From this subset of videos, Figure 13 presents a percentage of each element by gender. The most significant discrepancy was in testing, where 23% of males described testing-informed decisions compared to only 4% of females. Additional differences were in material properties and materials processing, where female students were more likely to incorporate these elements in the videos. Finally, for the engineering habit of mind, male students were more likely to describe overcoming challenges (N=7, 32%) than female students (N=4, 16%).

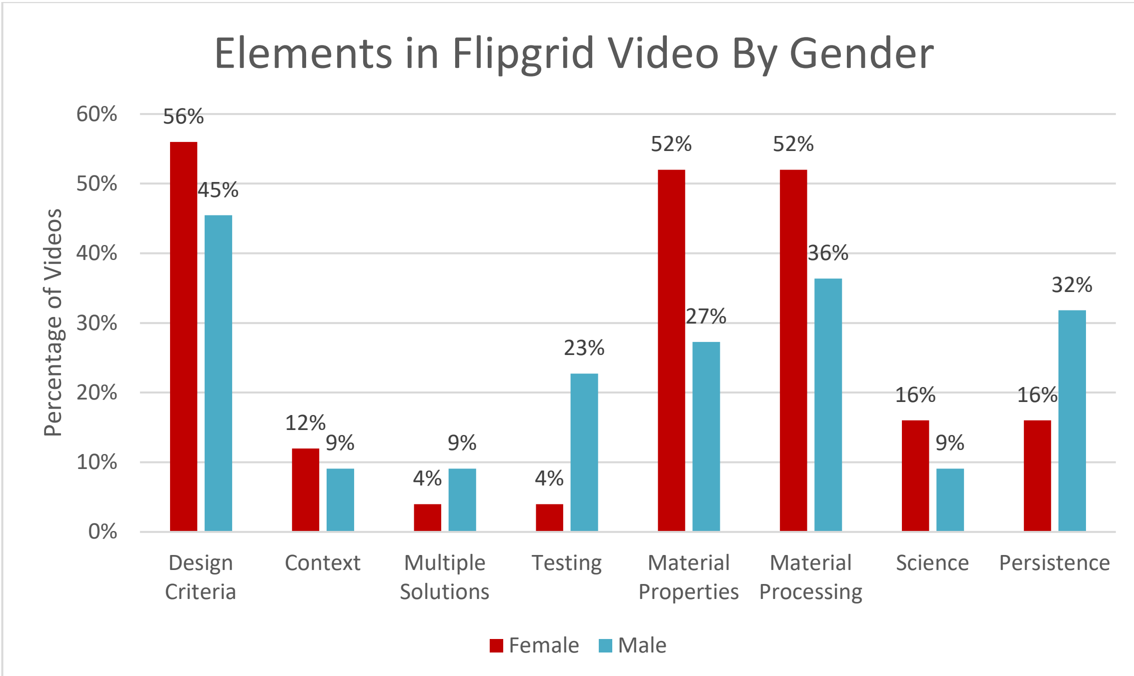

Figure 13 Percentage of male and female student videos that incorporated reflection elements.

CHAPTER V

DISCUSSION

Pre-college engineering education is gaining popularity and reaching a growing number of students, but an area of concern is the unclear learning goals for students. The NGSS integrates engineering practices as a vehicle for enhancing science education (NGSS Lead States, 2013), but others argue for engineering as a separate discipline (Moore et al., 2014). The 2020 *Framework for P-12 Engineering Learning* acts as a foundational document for promoting engineering literacy for all students by outlining a set of concepts, practices, and habits of mind. This study investigates a subset of these to determine their presence during an informal, distance learning engineering program. Researchers analyzed student reflection videos collected on Flipgrid to determine how students allocated time and whether desired engineering learning outcomes were present. The study also investigated the viability of Flipgrid as a learning tool during distance learning.

Assessment of Flipgrid

Fliprid is a popular tool to capture student thinking, especially during distance learning. Researchers hypothesized that since Flipgrid mimics popular social media platforms, which have different goals than education, students may be influenced by their prior experiences with these entertainment platforms. However, students in this study remained on-task across all the self-reflection videos and did not use the available entertainment features popular with other platforms like TikTok. Moreover, the videos in the study were rich in content with all including a showcase of the engineering prototype, 64% describing the features and functions of product, and 52% providing insight into student thinking around the engineering process. Despite the average video length of 52 seconds, the videos allowed for a fruitful analysis of the learning outcomes and student thinking.

Students' appropriate use of Flipgrid may reflect extensive experience using multiple digital platforms across a variety of settings and ability to distinguish between educational and entertainment tools (e.g. YouTube, TikTok, Instagram, Snapchat, Schoology, Google). Additionally, the students in the study may have prior experience using Flipgrid in the classroom and understand the expectations and intended purpose of the tool. The instructor may have also modeled and provided feedback on prior assignments. Despite concerns on the quality of reflection videos, students utilized Flipgrid in an appropriate manner, and the reflection videos provided insightful content to further assess for learning outcomes.

Assessment of Progress Towards Engineering Learning Goals

Through a timeline analysis and coding guide, researchers investigated the presence of select engineering elements outlined in the ASEE/AEEE framework. The researchers found that all 90 videos included showcase of the product, 64% described the product features or function, but only 52% reflected on the process. The following is a discussion on these results and how the included reflection elements compared to desired engineering learning outcomes.

Product Versus Process

Many have raised the concern that engineering instruction is focused on building a product instead of on engineering practices (Pleasants & Olson, 2020). While the program handouts asked students to both share the product and reflect on the process, the emphasis on the product was evident in this study. All the reviewed Flipgrid videos included a product demonstration, but only 52% featured students reflecting on the process. However, students did improve in reflection elements over time in the program. The videos submitted during week 1 were the most likely to showcase the product without any reflection on the process. By week 6, videos included the greatest number of reflection elements. One explanation is that students had not yet developed an understanding of the process during the first activity and focused on the object. Another possibility is the novelty effect with the self-reflection videos. Perhaps after seeing the other student submissions that included reflection elements, students used them as a model for incorporating them in future videos. Instructors may have also provided feedback to encourage reflection on the process.

In reviewing the video timelines, researchers noted that when Flipgrid videos started with the product showcase, they rarely resulted in any reflection elements. However, videos that began with the product description often resulted in the student providing some insight into their experience with the engineering process as they explained the different product features. The showcase of the product meeting design constraints would then occur at the end of the video. Perhaps encouraging students first to explain their product before demonstration will promote more reflection elements and greater insight into student thinking and experience.

Despite some improvement in reflection elements, almost a quarter (23%) of the videos only demonstrated the product meeting design constraint with little to no verbal discussion. Even in the week six activity, 20% of the videos still only demonstrated the product (e.g. the rover traveling 1-foot). This emphasis may reflect that students perhaps equate the design constraints with a grading rubric and believe the end product defines success. In many of the reflection videos, students assured the teacher that the product met the specified design constraints, such as student S29RC who states, "Here is my Roller Coaster that has 1 turn and can successfully land a ball in a cup." However, the ASEE/AEEE framework promotes engineering design as a systematic process used to develop solutions to problems. The desired result of engineering literacy programs is not the ability to use paper and tape to build a track; instead, educators aim for students to develop habits of mind and practices that reflect those of engineers. Educators should strive to make these learning goals explicit in grading rubrics and during instruction.

Furthermore, the program under study presented the engineering activity instructions through a step-by-step EDP model, which may have influenced the students' focus on the product. Other researchers have noted that the use of an EDP model may place emphasis on the end product instead of building a meaningful understanding of engineering practices (Hynes, 2012; King & English, 2016; Pleasants & Olson, 2020). Even in the reflection elements present, the most popular reflection element was around the design constraints, which are directly tied to the end-product. Students may not recognize the value of other components of the design process. For example, only five of the 90 videos connected the activity to a larger context (i.e. problem framing), and only three videos described the ideation process. The timing of the video submission likely influences the exclusion of these elements. Students have just built a product that meets design criteria, and they are excited to share the result. Educators may consider assigning reflection videos at various stages of the activity, such as immediately after initial brainstorming to emphasize the value of the elements and gain greater insight into student thinking during various stages of the engineering activity.

Tinkering versus Systematic Testing

The ASEE/AEEE framework (2020) defines engineering design as a "systematic" process (p. 73), and the expectations are for students to be able to establish "appropriate testing/data collection procedures to improve their design" (p. 66). Instead, all Flipgrid videos that described the testing process used a tinkering or trial-and-error approach. For example, S13Rover describes the process of creating the rover, "After a couple of tries I made something else. I used this, and I basically took the ping pong ball and did it like this and then it would hold it up. But then it was too heavy. So then I went with this." Another example is through the elements coded for material properties. The ASEE/AEEE framework promotes the selection of materials based on prior analysis and comparison of characteristics before building a prototype (ASEE & AEEE, 2020). Instead, students in the study determined viability by trying out various materials and modifying as they went. Student S5RC states, "I decided to improve [the roller coaster] by making the base thicker with cardboard to prevent it from collapsing."

While a systematic approach in testing and material selection was not evident, an important note is that the outlined performance matrix intends to capture learning outcomes for students at the end of secondary school. The participants in the study are middle school students, and the ASEE/AEEE framework proposes scaffolding towards engineering learning outcomes. For example, should middle school students learn to collect testing data to inform improvement more systematically? Should middle school students compare and contrast material properties to inform design decisions? Educators may not have clarity on the expectations for different levels of students. A more grade-specific outline of engineering learning outcomes is needed to capture developmentally appropriate concepts and outline how to scaffold learning across grade levels.

Impact of Design Activity on Reflection Elements

Finally, the specific design challenge and constraints may influence progress towards desired learning outcomes. As noted, reflection elements increased over time from the Roller Coaster (week 1) to the Rover activity (week 6). However, researchers found an interesting pattern when investigating the change in reflection elements by student. A significant number of students declined in performance from Roller Coaster (week 1) to Robot Hand (week 6) and then improved during the next week's Rover activity. Perhaps the type of activity led to more reflection on the engineering design process. When observing the final products in the videos, the Rover prototypes resulted in the most variety of designs compared to the Roller Coaster and Robot Hand. In reviewing the design constraints and instruction, the Roller Coaster had the most precise constraints ("create a track with one turn") that likely limited the potential variety in students' designs. The Robot Hand's design constraints were more open-ended (e.g. "attaches to arm," "movable"). However, the instructional video demonstrated how to build the hand with step-by-step instructions, and all the students' projects mimic the video's example.

While the instructions and constraints likely resulted in the differences in reflection on the design process, each activity has different goals. The first activity, Roller Coaster, is intended to engage students, introduce the *Mission to Moon* program, and set a foundation for using the design process. The Robot Hand activity is a more complex project that introduces students to bioengineering, exoskeletons, and robotics. The program designers did not want students to struggle through the intricate building of the hand, but the engineering goal was to design ways to attach the hand as an extension of their arm. Finally, the Rover activity was intentionally placed as the final design challenge before the capstone project. Program developers knew from prior experience that this activity required the most iterations, and the instructional video provided little guidance in design or building the prototype.

Additionally, the Rover activity used the least amount of materials, and each prototype involved the shortest build time. In comparison, the Roller Coaster was the largest product and consumed the most materials. Because of the time and material constraints, students were perhaps unlikely to make multiple prototypes or significant changes after testing. The Robot Hand was the most time-consuming project as students needed to spend considerable time threading each of the strings inside the straws to make the hand. The Rover challenge used only a small amount of materials and took less time to build a single prototype. However, as program developers expected, the students had trouble in optimizing the placement of the battery and motor to achieve forward motion. One student stated, “the Rover took me quite a few amount of tries!” (S13Rover). Perhaps the combination of short build time and open-ended constraints that were challenging and promoted innovative solutions resulted in the most opportunities for decision-making, prototypying, and other aspects of the design process. Additional study is needed to determine how different engineering activities and design constraints promote engagement in the design process and desired learning outcomes.

This study provides insight into how the current state of engineering education promotes desired learning outcomes around engineering literacy. Flipgrid appears to have potential as an educational tool that captures student thinking in an engineering program, but the students overwhelmingly focused on the final product. Educators may consider assigning reflection videos in different stages of the design process and explicitly emphasizing the intended learning outcomes. The study also suggests that the design constraints and building time of the engineering activity may promote different levels of engagement in the design process. Curriculum designers and educators should consider these elements, but more guidance around developmentally appropriate learning outcomes is critical for our students to reach desired engineering literacy levels.

REFERENCES

Advancing Excellence in P12 Engineering Education & American Society for Engineering Education. (2020). *Framework for P-12 Engineering Learning*. https://www.p12engineering.org/framework

Agan, T., Anderson, D., Atwood, A., Casarez, L., Heron, A., & Self, R. (2020). FlipGrid to enhance communication in distance education. Delta Kappa Gamma Bulletin, 85(4), 35–37.

Apedoe, X., Reynolds, B., Ellefson, M., & Schunn, C. (2008). Bringing engineering design into high school science classrooms: The heating/cooling unit. *Journal of Science Education and Technology*, 17(5), 454–465.

Atman, C. J., Adams, R. S., Cardella, M. E., Turns, J., Mosborg, S., & Saleem, J. (2007). Engineering design processes: A comparison of students and expert practitioners. Journal of Engineering Education, 96(4), 359–379. https://doi.org/ 10.1002/j.2168-9830.2007.tb00945.x.

Banilower ER, Smith PS, Weiss IR, Malzahn KA, Campbell KM, Weis AM. (2013). *Report of the 2012 National Survey of Science and Mathematics Education.* Horizon Research, Inc. http://horizon-research.com/NSSME/2012-nssme.

Banilower ER, Smith PS, Malzahn KA, Plumley CL, Gordon EM, Hayes ML. (2018). Report of the 2018 NSSME+. Chapel Hill: Horizon Research, Inc. http://horizon-research.com/NSSME/2012-nssme.

Brophy, S., Klein, S., Portsmore, M., & Rogers, C. (2008). *Advancing engineering education in P-12 classrooms* (97 (3), 369-387 ed.). Journal of Engineering Education.

Bybee, R. W. (2011). Scientific and engineering practices in K-12 classrooms: Understanding a framework for K-12 science education. *Science and Children*, 49(4), 10.

Capobianco, B. M., DeLisi, J., & Radloff, J. (2018). Characterizing elementary teachers' enactment of high-leverage practices through engineering design-based science instruction. Science Education, 102(2), 342-376.

Capobianco, B. M., & Rupp, M. (2014). STEM teachers' planned and enacted attempts at implementing engineering design-based instruction. School Science and Mathematics, 114(6), 258-270.

Change the Equation. (2016). Left to chance: U.S. middle schoolers lack in-depth experience with technology and engineering. Vital Signs. https:// www.ecs.org/wp-content/uploads/TEL-Report_0. pdf

Cohen, J. (1960). A Coefficient of Agreement for Nominal Scales. Educational and Psychological Measurement, 20(1), 37–46. https://doi.org/10.1177/001316446002000104

Communities In Schools of San Antonio. (2019). *Home Page*. Retrieved July 1, 2021, from https://www.cissa.org/

Corbin, J. & Strauss, A. (2014). Basics of qualitative research: Techniques and procedures for developing grounded theory. 3rd Edition. Los Angeles: Sage.

Cunningham, C. (2008). Elementary teacher professional development in engineering: Lessons learned from Engineering is Elementary. Paper presented at the American Society for Engineering Education National Conference, Pittsburgh, PA.

Cunningham, C. M. (2009). Engineering is elementary. The Bridge, 30(3), 11–17

Cunningham, C. M., & Carlsen, W. S. (2014). Teaching engineering practices. *Journal of Science Teacher Education*, *25*(2), 197-210.

Custer, R. L., Daugherty, J. L., & Meyer, J. P. (2010). Formulating a concept base for secondary level engineering: A review and synthesis. Journal of Technology Education,22(1), 4-21.

Engineering is Elementary. (2021). EiE Programs by the Numbers. Retrieved September 13, 2021 from https://info.eie.org/integrated-stem

Flipgrid. (2021). Learn Together. Retrieved September 14, 2021 from https://info.flipgrid.com/

For Inspiration and Recognition of Science and Technology (FIRST). (2021). FIRST At A Glance. Retrieved September 13, 2021 from https://www.firstinspires.org/about/at-a-glance.

Grayson, K. (2018, June 18). Microsoft snaps up Minneapolis tech startup Flipgrid. Minneapolis / St. Paul Business Journal. https://www.bizjournals.com/twincities/news/2018/06/18/microsoft-snaps-up-minneapolis-tech-startup.html

Green, T. D., Besser, E. D., & Donovan, L. C. (2021). More than Amplifying Voice and Provide Choice: Educator Perceptions of Flipgrid Use in the Classroom. TechTrends, 785–795. https://doi.org/10.1007/s11528-021-00635-3

Green, T., & Green, J. (2018). Flipgrid: Adding Voice and Video to Online Discussions. TechTrends, 62(1), 128–130. https://doi.org/10.1007/s11528-017-0241-x

Hirsch, L. S., Berliner-Heyman, S., & Cusack, J. L. (2017). Introducing middle school students to engineering principles and the engineering design process through an academic summer program. *International Journal of Engineering Education*, 33(1), 398-407

Hirsch, L. S., Carpinelli, J. D., Kimmel, H., Rockland, R.,&Bloom, J. (2007). The differential effects of pre-engineering curricula on middle school students' attitudes to and knowledge of engineering careers. Frontiers in Education Conference, Milwaukee, WI.DOI: 10.1109/FIE.2007.4417918

Holub, J., & Kruse, J. (2020). Inquiry and Design: Using Science and Engineering to Understand Particle Motion and Thermal Energy. *Science Scope, 043*(06).

Johri, A., & Olds, B. M. (2011). Situated engineering learning: bridging engineering education research and the learning sciences. Journal of Engineering Education, 100(1), 151–185. https://doi.org/10.1002/j.2168- 9830.2011.tb00007.x.

Katehi, L., Pearson, G., & Feder, M. (2009). *Engineering in K-12 education: understanding the status and improving the prospects.* National Academies Press, Washington.

Kiles, T. M., Vishenchuk, J., & Hohmeier, K. (2020). Implementation of Flipgrid as a Self-Reflection Tool for Student Engagement– A Pilot Study. INNOVATIONS in Pharmacy, 11(4), 15. https://doi.org/10.24926/iip.v11i4.3340

Lantz, H. B. (2009). Science, technology, engineering, and mathematics (STEM) education: What form? What function? CurrTech Integrations. Retrieved from, http://www.currtechintegrations.com/pdf/ STEMEducationArticle.pdf.

Miller, S. C., McIntyre, C. J., & Lindt, S. F. (2020). Engaging Technology in Elementary School: Flipgrid's Potential. Childhood Education, 96(3), 62-69.

Moore, T. J., Glancy, A. W., Tank, K. M., Kersten, J. A., Smith, K. A., & Stohlmann, M. S. (2014). A framework for quality K-12 engineering education: Research and development. Journal of Precollege Engineering Education Research, 4(1), 1–13.

Moore, T. J., Tank, K. M., Glancy, A. W., & Kersten, J. A. (2015). *NGSS and the landscape of engineering in K-12 state science standards* (296-318 ed., Vol. 52 (3)). Journal of Research in Science Teaching. 10.1002/tea.21199

National Academy of Engineering and National Research Council. (2009). *Engineering in K-12 Education: Understanding the Status and Improving the Prospects.* Washington, DC: The National Academies Press. https://doi.org/10.17226/12635

National Academy of Engineering. (2010). Standards for K-12 Engineering Education? Washington, DC: National Academies Press.

National Assessment Governing Board. (2018). *Technology and Engineering Literacy Framework for the 2018 National Assessment of Educational Progress.* United States Department of Education. https://www.nagb.gov/content/nagb/assets/documents/publications/frameworks/technology/2018-technology-framework.pdf

National Research Council. (2008). *Changing the conversation: Messages for improving public understanding of engineering.* Washington,DC: National Academies Press.

National Research Council. (2012). *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas.* Washington, DC: The National Academies Press. https://doi.org/10.17226/13165

National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts,and core ideas.* Washington, DC: The National Academies Press.

National Science Teaching Association. (2021). *NGSS Hub*. NGSS @ NSTA. Retrieved March 21, 2021, from https://ngss.nsta.org/about.aspx

NGSS Lead States. (2013). *Next Generation Science Standards: For states, by states.* The National Academies Press.

Miller, S. C., McIntyre, C. J., & Lindt, S. F. (2020). Engaging Technology in Elementary School: Flipgrid's Potential. *Childhood Education*, 96(3), 62-69.

Pleasants, J., Tank, K. M., & Olson, J. K. (2021). Conceptual connections between science and engineering in elementary teachers' unit plans. *International Journal of STEM Education*, 8(1).

Pleasants, J., Tank, K. M., & Olson, J. K. (2021). Conceptual connections between science and engineering in elementary teachers' unit plans. *International Journal of STEM Education*, 8(1). https://doi.org/10.1186/s40594-021-00274-3

Posner, G. J., Strike, K. A., Hewson, P. W., & Gertzog, W. A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science education*, 66(2), 211-227.

President's Council of Advisors on Science and Technology. (2010). *Prepare and inspire: K-12 education in Science, Technology, Engineering, and Math (STEM) education for America's future*. Executive Office of the President. https://nsf.gov/attachments/117803/public/2a--Prepare_and_Inspire--PCAST.pdf

Project Lead the Way. (2021). The Power of PLTW. Retreived September 13, 2021 from https://www.pltw.org/about-us/our-impact.

Richard, C., Ramachandran, K., and Pandoy, I. (2018). Looming Talent Gap Challenges Semiconductor Industry. SEMI. https://www.semi.org/en/node/581.

Rivoli, G., & Ralston, P. (2009). Elementary and middle school engineering outreach: Building a STEM pipeline. Paper presented at the American Society for Engineering Education Southeast Section Conference, Marietta, GA.

Roehrig, G. H., Moore, T. J., Wang, H.-H., & Park, M. S. (2012). Is adding the E enough? Investigating the impact of K-12 engineering standards on the implementation of STEM integration. School Science and Mathematics, 112(1), 31–44.

Royal Academy of Engineering. (2017). *Learning to be an engineer: Implications for schools.* London, UK.

Utley, J., Ivey, T., Weaver, J., & Self, M. J. (2019). Effect of Project Lead the Way Participation on Retention in Engineering Degree Programs. *Journal of Pre-College Engineering Education Research*, 9(2), 40–50.

Wendell, K. B., Swenson, J. E., & Dalvi, T. S. (2019). Epistemological framing and novice elementary teachers' approaches to learning and teaching engineering design. Journal of Research in Science Teaching, 56(7), 956-982.

APPENDIX A

MISSION TO MOON STUDENT HANDOUTS

Roller Coaster Challenge 1

Name:______________________________

1

Your Mission: Design a safe and fun roller coaster to mimic the effects of the "vomit comet" used in astronaut training.

Go to Flipgrid for mission instructions. Code:__________

2

Engineering Design Rules

- ❑ Ball must stay in motion at all times
- ❑ Must include 1 turn
- ❑ Ball must land in the cup at the end of the ride
- ❑ No materials added to the inside or bottom of cup

Gather Materials Needed

- ❑ Scissors
- ❑ Tape
- ❑ 8 Pieces of construction paper
- ❑ 4 Paper Plates
- ❑ 1 Paper cup
- ❑ 1 Ping Pong Ball

Substitute materials if needed.

3

Brainstorm ideas for your design. Draw at least one idea below.

How will you keep the ball moving throughout the roller coaster? How will you keep the ball from flying off the roller coaster?

As you build, make sure your device meets the engineering design rules above!

4 Build

Roller Coaster Challenge 1

5

Test → Evaluate → Improve

Test your roller coaster! Complete the table below to record results. Keep making changes and re-testing to improve your design. Can you make the ball reach the bottom faster? Can you increase the height of the roller coaster? Can you add more turns?

Trial	Height of roller coaster	Number of turns	Time to bottom	Design Notes
1				
2				
3				
4				

6

Share your solution on Flipgrid!

Write out a script below answering each prompt. Go to Flipgrid using the same code, and record a response to share your design.

1: Share your design! How does it work?	2: What happened during building & testing?

Robot Arm Challenge 5

Name:____________________________________

1

Your Mission: Design a robotic arm to pick up a rock sample.

Go to Flipgrid for mission instructions. Code:___________

2

Engineering Design Rules

Follow the instructions in the video to build the robotic hand. Then turn it into an exoskeleton that attaches to your arm to pick up a rock sample (ping pong ball).

- ❑ Attaches to arm
- ❑ Movable
- ❑ Aesthetically pleasing (looks good!)
- ❑ Picks up a ping pong ball

Gather Materials Needed

- ❑ Scissors
- ❑ Tape
- ❑ Marker
- ❑ 3 Straws
- ❑ 5, 12 inch pieces of string
- ❑ Paper
- ❑ Ping pong ball or similar object
- ❑ Recycled materials

3

Brainstorm ideas for your design. Draw at least one idea below.

As you build, make sure your device meets the engineering design rules above!

4 Build

Robot Arm Challenge 5

5

Test → Evaluate → Improve

Test your robot arm! Complete the table below to record results. Keep making changes and re-testing to improve your design.

Trial	Test Results	Ideas for Improvement
1		
2		
3		

6

Share your solution on Flipgrid!

Write out a script below answering each prompt. Go to Flipgrid using the same code, and record a response to share your design.

1: Share your design! How does it work?	2: What happened during building & testing?

Rover Exploration Challenge 6

Name:____________________________________

1

Your Mission: Design and build a rover to transport rock samples.

Go to Flipgrid for mission instructions. Code:___________

2

Engineering Design Rules

- ❑ Only use provided materials
- ❑ Carry at least 1 ping pong ball a distance of 1 foot or 30 cm
- ❑ Use the vibrating motor to propel the rover forward

Gather Materials Needed

- ❑ Scissors & Tape
- ❑ 1 Coin cell battery
- ❑ 1 Vibrating motor
- ❑ 2 Bendy straws
- ❑ 1 Ping Pong Ball
- ❑ 1 Paper cup
- ❑ 3 pieces of construction paper

3

Brainstorm ideas for your design. Draw at least one idea below.

How will you use provided materials to design a rover to move a ping pong ball? Brainstorm ideas for different designs.

As you build, make sure your device meets the engineering design rules above!

4 Build

Rover Exploration Challenge 6

5

Test → Evaluate → Improve

Test your rover! Complete the table below to record results. Keep making changes and re-testing to improve your design.

Trial	Does your rover move forward?	Can your rover carry a ping pong ball?	How far can your rover travel?	Design Notes
1	Yes / No	Yes / No		
2	Yes / No	Yes / No		
3	Yes / No	Yes / No		

How could you improve your rover to move the ping pong ball?

6

Share your solution on Flipgrid!

Write out a script below answering each prompt. Go to Flipgrid using the same code, and record a response to share your design.

1: Share your design! How does it work?	2: What happened during building & testing?

APPENDIX B

CODING GUIDE

I. Background Information

A. Video Identifier Number:

B. Student Gender: M / F

II. Timeline Analysis

Place a marker for each element: process, product showcase, and product testing.

A. Total video length (seconds):

B. Total time on process (seconds):

C. Total time on product showcase (seconds):

D. Total time on product testing (seconds):

III. General Observations

Mark if the following are present:

☐ Demonstration of meeting design criteria

☐ Video in student's home

☐ Involvement of family members

☐ Entertainment: The student makes an effort to make the video entertaining, such as using filters or stickers.

☐ Off-Topic: The majority of the video is not related to the engineering activity.

Notes:

IV. Analysis of Discussion of Engineering Design Process

Mark if the following are present:

A. Problem-Framing

- ☐ Design Criteria: Student shows an understanding that the product needs to meet specific design criteria to solve a problem.
- ☐ Context: Student describes the larger context of the problem being solved.

B. Ideation

- ☐ Engineering Graphics: Student refers to or shows an engineering sketch of a design idea.
- ☐ Multiple Solutions: Student describes brainstorming multiple ideas for solving the problem.

C. Decision-Making

- ☐ General: Students describes the logic behind a design decision or prototype feature. Includes all types of decision-making in other categories.
- ☐ Science-Informed: Student describes applying scientific knowledge to inform a design decision.
- ☐ Testing-Informed: Student describes the process of testing the prototype to gather data to improve the design.
- ☐ Material Properties: Student describes selecting materials to meet design criteria. Answers the question, why did you choose a material for the prototype?
- ☐ Material Processing: Student describes the process of manipulating materials to meet design criteria. Answers the question, how did you manipulate the materials to create the prototype?

D. Habit of Mind

- ☐ Persistence: Student describes overcoming a challenge during the process.

Notes: