DEVELOPMENT, IMPLEMENTATION, AND A STUDY OF AN INTRODUCTION TO ROCKETRY COURSE ON STUDENT EFFICACY AND CAREER INTEREST FOR EXPANDING THE PIPELINE AND ENHANCING EDUCATION OF STUDENTS PURSUING IN SPACE

BY

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THESIS

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ABSTRACT

Under the Department of Defense National Department of Education Program (DOD NDEP) funded grant, “Expanding the Pipeline and Enhancing Education of Students Pursuing Careers in Space”, a project was initiated to develop an introduction course on rocketry, utilizing model rockets as a means to inspire students to consider a career in space engineering. The objective was to expose students to a foundational space education course at an early stage in their academic career.

The development of a MOOC (Massively Open Online Course) began with the goal of making the course available to a diverse group of K-12 and undergraduate students. This online course was meticulously crafted, beginning with the establishment of a well-defined curriculum, aligned with educational standards, and encompassing clearly defined learning objectives. Subsequently, online videos were produced, involving the creation of scripts, studio filming, and professional video editing. These videos were complemented by a hands-on activity that involved the construction and launch of model rockets. The primary focus of this activity was to investigate the influence of mass (payload) on a rocket’s ability to reach a specific altitude. Following the acquisition of knowledge throughout online lectures, participants were tasked with predicting the target apogee of a rocket flight, given a randomly assigned payload mass.

To validate the effectiveness of this course, multiple pilot studies were conducted both on- and off- campus, involving college and high school students. Valuable insights obtained from these pilot courses were utilized to enhance and refine the course content, taking into account the specific needs and characteristics of the target student and instructor audience. The key lesson learned was the importance of providing scaffolded content at varying difficulty levels to better cater to the diverse range of participants and optimize the course duration, all the while considering the accessibility of the course. Consequently, multiple iterations of the course were developed, addressing these identified concerns.

Building upon the foundation of this introductory course, an educational study was carried out among a group of early college engineering students to explore the impact of a blended MOOC with hands-on kits, on student efficacy and career interest. In accordance with the Social Cognitive Career Theory (SCCT), the study examined participants' self-efficacy levels prior to and after accessing the online content, as well as before and after engaging in the hands-on activity, in order to assess any significant changes in their levels of interest. The collected data was analyzed, considering variables such as gender, college year, learning styles, and prior experience in rocketry and online courses. This paper provides a comprehensive account of the study, concluding that participants experienced an increase in self-efficacy levels related to rocketry tasks, and in accordance with SCCT, an associated increase in their levels of interest.

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CHAPTER 1: INTRODUCTION

1.1 PROJECT OVERVIEW

Space is increasingly becoming globally competitive, and both U.S. civilian and government agencies continue to increase and grow their activities in space. To maintain U.S. leadership in space, the Department of Defense (DoD) is growing and enhancing space research and cultivating a strong community of space scientists. However, the problem is that there is a dearth in the workforce. With the strong rise in the space industry, there is a gap between the demand in space experts and the number of professionals available. Observing further down, the U.S. overall saw a five-year decline in the number of students in engineering [1]. To address this issue, the government issued federal grant under the DoD STEM group, through the National Department of Education Program. We, the SpaceLab Illinois (SLI) team, joined forces and current work in the national grant, with a title of “Expanding the Pipeline and Enhancing Education of Students Pursuing Careers in Space”.

SLI’s goal is to increase the number of students and enhance the education of students pursuing careers in space. The objective is to create an integrated set of educational resources and implement them strategically in high school and undergraduate classrooms, outreach events, and workshops. By creating an accessible and interesting coursework, students can learn about the opportunities and benefits that exist in space-related careers. Literature suggests that engaging students in design-based science learning activities can help them develop problem-solving and science inquiry skills [2]. Therefore, we created an engaging and affordable course that many students can easily access, to reach more students throughout the country to be more exposed to space engineering.

Recently, online learning platforms have been gaining in popularity due to their accessibility to broader audiences in which the pandemic has further boosted. Additionally, previous studies have shown that incorporating hands-on activities with online classes have enhanced student foundational knowledge, hands-on capabilities, and overall engineering design aptitude. With these goals in mind, we gathered to develop a Massive Open Online Course (MOOC) with a hands-on kit in the context of an introduction to rocketry with model rockets. This blended MOOC is composed of online videos and hands-on activity with a project of predicting and gathering experimental data for the apogee of a model rocket's flight.

With this developed blended MOOC, the course was implemented at several high schools and colleges, and teacher professional development events to better receive user feedback. The lessons learned from these events served as motivation to continue enhancing the quality of the course. Once the course development and adjustments were finished, the complete rocketry blended MOOC was utilized in a controlled educational study to a group of undergraduate engineering students to study the effect of the course in student knowledge and career interest. The quantified results were analyzed using various statistical measures, and with combining the Social Cognitive Career Theory, student knowledge and career interest were determined accordingly.

This thesis focuses on the qualitative experience and lessons learned from the development and implementation process of the rocketry blended MOOC, followed by a quantitative analysis of an educational study that we conducted, observing the effect of the blended MOOC on student knowledge and career interest.

1.2 BACKGROUND

1.2.1 MASSIVE OPEN ONLINE COURSE WITH PROJECT BASED LEARNING (MOOC)

Massive Open Online Courses (MOOCs) have emerged as large-scale online courses accessible to a global audience, delivered digitally, and designed with predetermined learning outcomes [3]. However, the MOOC environment presents notable challenges, as evidenced by a survey indicating that a majority of MOOCs lack a problem-centered approach and fail to effectively demonstrate and apply new skills [4]. Project-based learning (PBL) has gained popularity due to its positive impact on students, including increased student attendance, self-reliance, and improved attitude towards learning [5]. Additionally, incorporating PBL into MOOCs have shown a clear positive effect on academic achievement compared to traditional instruction modes [6]. By integrating hands-on projects into blended MOOCs, the educational process can be optimized by leveraging the strengths of synchronous and asynchronous learning [7]. Research indicated that blended learning offers flexibility and personalized learning experiences, enabling students to progress at their own pace and cater to their individual learning styles [8].

While many courses predominantly rely on lecture videos, a limited number of courses provide hands-on experiences [9]. The inclusion of hands-on projects in MOOCs allow learners to actively engage with the problem domain through active experimentation and connect complex concepts to their own concrete experiences [10]. Learner's value and benefit from hands-on activities, as they provide a better understanding of concepts and facilitate the connection between engineering principles and theoretical concepts [11,12].

1.2.2 HANDS-ON ACTIVITY AND BLENDED MOOC

The integration of hands-on activities within blended Massive Open Online Courses (MOOCs) has emerged as a promising approach to enhance student performance and enrich the learning experience. Hands-on activities foster student learning through peer interaction via cooperate learning, object-mediated learning, and embodied experiences [13]. These factors, namely cooperative learning, object manipulation, and embodiment, all contribute to the effectiveness of hands-on activities in STEM education [13]. In STEM, the inclusion of hands-on activities in blended MOOCs has demonstrated significant benefits. A recent study found that a focus on online instruction, combined with face-to-face, hands-on activities resulted in statistically significant improvement in learners' technical understanding of the course material [14]. The active engagement and manipulation of physical materials during the hands-on activities allow students to deepen their understanding of scientific concepts and apply theoretical knowledge in practical settings [14]. Moreover, the integration of hands-on kits in blended MOOCs has been shown to positively impact student efficacy. Another study was performed comparing students with hands-on kits to a control group and found that the not only achieved significant higher exam scores, but also exhibited higher levels of self-efficacy in the topic area [15]. By actively participating in practical tasks and witnessing tangible results, students developed a sense of mastery and confidence in their abilities. The hands-on blended MOOC overall offers a promising approach to enhance student performance and positively influence learning experience.

1.2.3 SOCIAL COGNITIVE CAREER THEORY

The Social Cognitive Career Theory (SCCT) framework and various self-efficacy measures enables a comprehensive examination of the impact of a MOOC combined with hands-on kits on students' self-efficacy, interest in space engineering, and overall career aspirations. Previous studies have indicated that the most effective approach to assessing career interest among engineering students is by utilizing SCCT. This theory proposes that by examining variables such as student interest, choice, performance, and satisfaction, it is possible to establish a connection with career interest. SCCT encompasses interest, choice, performance and persistence, and satisfaction models, and provides a framework to understand the educational and occupational behavior of individuals. SCCT emphasizes three social cognitive mechanisms: self-efficacy beliefs, outcome expectations, and goal representations that all play significant roles in career development. The focus is on self-efficacy, which refers to an individual's belief in their ability to perform a specific behavior and is closely linked to their confidence level [16]. Higher self-efficacy levels have been found to positively impact academic achievement, persistence, and task value among undergraduate engineering students [17]. Moreover, self-efficacy is believed to influence outcome expectations, particularly in situations where performance quality is closely tied to the outcome [16]. SCCT suggests that individuals are more likely to develop interests and pursue and perform better in activities where they possess strong self-efficacy beliefs [16].

1.2.4 SELF-EFFICACY

Various approaches have been employed in measurements of self-efficacy in science, technology, and engineering (STEM). Previous studies have utilized three primary classes of self-efficacy measures: general academic self-efficacy measures, domain-general self-efficacy measures tailored to reflect the engineering domain, and self-efficacy measures specific to engineering tasks or skills [19]. General academic self-efficacy measures assess engineering students' confidence in their academic capabilities across different domains [20,21]. Domain-general self-efficacy measures gauge students' general confidence to succeed in the field of engineering without referencing specific tasks or problems [19]. Task and skill-specific self-efficacy measures evaluate students' efficacy in performing specific engineering tasks or demonstrating specific skills [19]. These measures not only provide insights into students' interests but also correlate with their overall performance in engineering programs as well as specific engineering courses and tasks [22]. Researchers can assess the relationship between self-efficacy and students' interest and success in engineering by considering these different levels of self-efficacy measurement.

CHAPTER 2: DEVELOPMENT OF A ROCKETRY MOOC

From the many observations made from several literature reviews and studies of other MOOCs, the development process for the online rocketry course included many similar aspects. The important factors MOOC developers must keep in mind is accessibility, engagement, and deliverance. MOOCs allow an easily accessible online classroom platform where many students can have access to. The development of a MOOC course platform must meet this accessibility needs and must not be made too complex for the user, not only the student but also the teacher, to work around the class platform. Engagement is another important factor to consider. A downside of the online videos is that engagement is hard to keep, and to track of. The online classroom consists of online educational videos, and by previous studies state, the videos should include lots of images, condensed bullet points, and should not be lengthy.

Through extensive literature reviews and studies on other MOOCs, it has become evident that the development process for the online rocketry course needs to incorporate several similar aspects. When designing MOOCs, developers must prioritize accessibility, engagement, and effective content delivery. MOOCs serve as easily accessible online platforms, ensuring widespread availability to students. Therefore, it is crucial for the development of a MOOC course to address accessibility requirements while maintaining user-friendly interface for both students and instructors.

Furthermore, maintaining high levels of student engagement is a critical factor to consider. One challenge associated with online videos is the difficulty of sustaining student engagement and effectively tracking it. As highlighted in previous studies, online educational videos should employ various strategies to enhance engagement. A few of these strategies include incorporating visual imagery, presenting condensed bullet points, and avoiding excessive length, as excessive video duration can hamper student attention and focus. In addition to online videos, the hands-on component of the course plays a crucial role in capturing student engagement. This interactive element provides students with tangible experiences and practical applications, fostering a deeper level of involvement and understanding. By combining both online content and hands-on activities, the course can optimize student engagement and facilitate a more comprehensive learning experience.

2.1 COURSE CONTENT

2.1.1 COURSE STRUCTURE

The MOOC with the addition of hands-on activities follows a structured framework, as depicted in Figure 1. The initial component comprises online content, consisting of videos dedicated to various aspects of rocketry. To assess students' comprehension and grasp of material and concepts, pre-and post-unit quizzes are included here. The video content encompasses fundamental topics such as rocket hardware and design, as well as practical demonstrations illustrating rocket trajectory modeling, build techniques, launch preparation, and analysis of the results.

The online content incorporates a web-based applet, which allows students to simulate and predict rocket trajectories. This interactive tool enhances the learning experience by providing students with an approach to explore and experiment with the principles discussed in the course. Through the applet, students can gain practical insights into the behavior and characteristics of rockets, thereby reinforcing their understanding of the subject matter.

The second part of the course encompasses the hands-on component, where students actively engage in build and launch of a model rocket, applying the knowledge acquired from the online content. This exercise serves as a direct application of the concepts and principles learned throughout the MOOC. By utilizing the data collected during the model rocket launch, students can analyze the flight trajectory and compare it to their initial predictions previously made in the online content with the web applet, and thereby assessing the accuracy of their estimations.

It is important to note that the course is designed to offer flexibility in its implementation. The three distinct parts including the online content, hands-on component, and data analysis, can be taught as cohesive unit, or individually based on the preferences and the needs of both students and instructors. This structure allows for customization, ensuring that the course can be effectively tailored to optimize learning outcomes in various educational contexts.

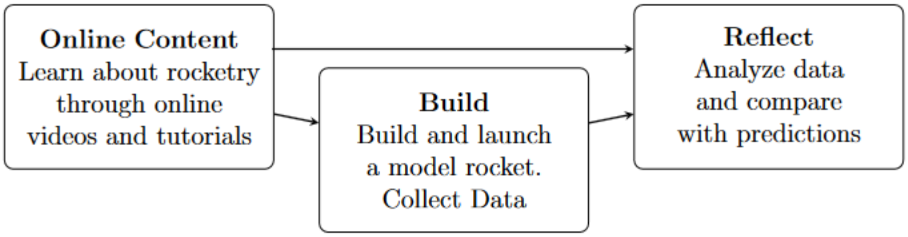
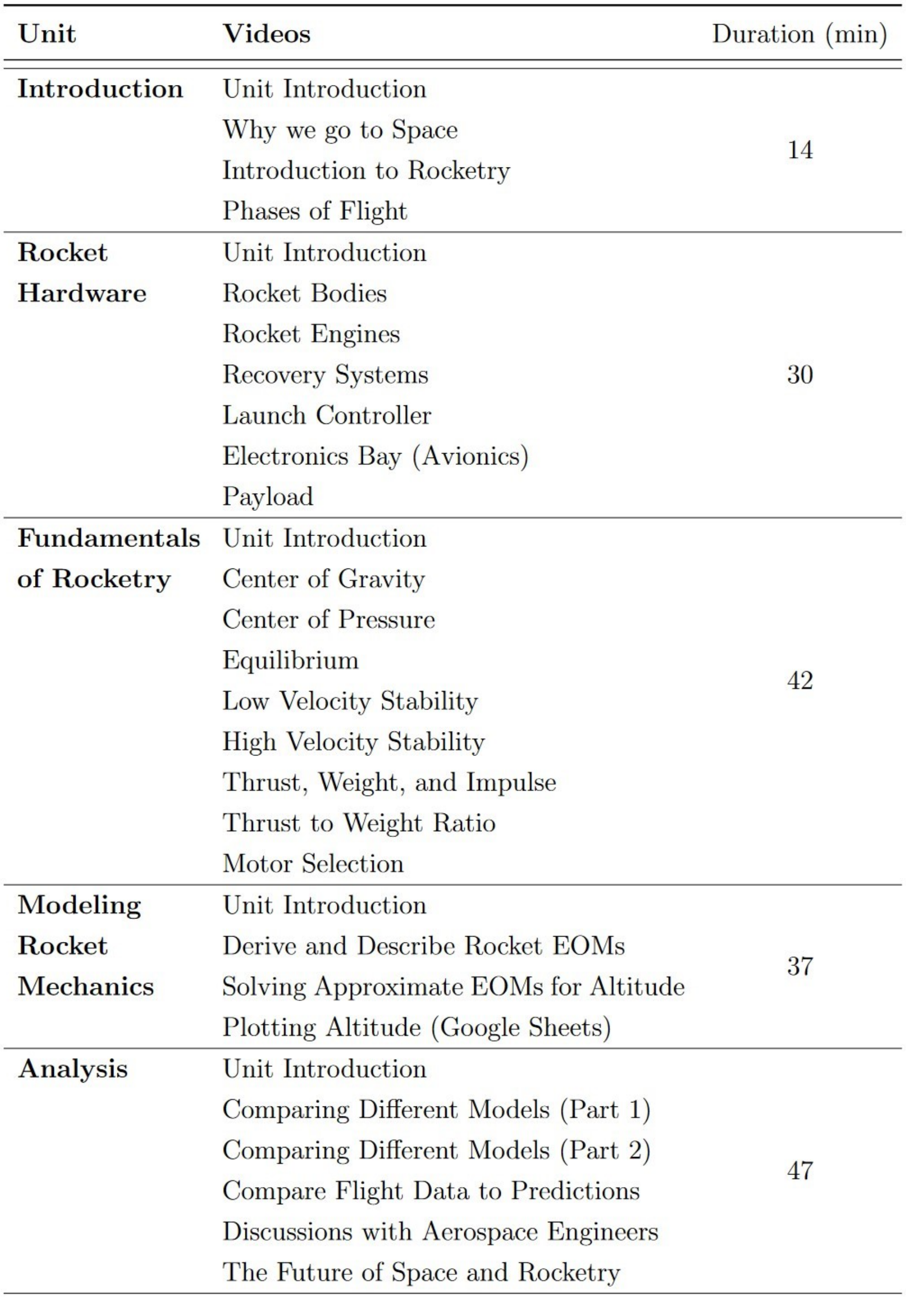


Figure 1: Course Structure

2.1.2 ONLINE CONTENT

The online content is broken up into five units, as displayed in Table 1. These units cover essential topics in model rocketry, while also establishing connections to full-scale commercial rockets. By addressing key concepts and principles, these units provide a cohesive learning experience that spans from introductory model rocketry to broader applications in commercial space engineering field. This approach ensures that students gain an understanding of rocketry fundamentals while acquiring the context and implications of the course content.

Table 1: Video Lectures by Unit with Duration in Minutes



Unit	Videos	Duration (min)
Introduction	Unit Introduction	14
	Why we go to Space	
	Introduction to Rocketry	
	Phases of Flight	
Rocket Hardware	Unit Introduction	30
	Rocket Bodies	
	Rocket Engines	
	Recovery Systems	
	Launch Controller	
	Electronics Bay (Avionics)	
	Payload	
Fundamentals of Rocketry	Unit Introduction	42
	Center of Gravity	
	Center of Pressure	
	Equilibrium	
	Low Velocity Stability	
	High Velocity Stability	
	Thrust, Weight, and Impulse	
	Thrust to Weight Ratio	
	Motor Selection	
Modeling Rocket Mechanics	Unit Introduction	37
	Derive and Describe Rocket EOMs	
	Solving Approximate EOMs for Altitude	
	Plotting Altitude (Google Sheets)	
Analysis	Unit Introduction	47
	Comparing Different Models (Part 1)	
	Comparing Different Models (Part 2)	
	Compare Flight Data to Predictions	
	Discussions with Aerospace Engineers	
	The Future of Space and Rocketry	

The first unit, the introductory section, serves as a foundation for the course by exploring the reasons behind the use of rockets and introduces the increasing demand for space travel. It also provides technical information about the different stages of a rocket's flight, establishing the necessary context and introducing relevant terminology that will be used throughout the following sections.

The second unit, the rocket hardware section, focuses on imparting fundamental knowledge about the critical components of a rocket. Each part of a model rocket is presented, along with an explanation of its purpose, followed by a comparison to full-scale rockets. This unit lays the groundwork by familiarizing students with the essential hardware elements of rockets and establishing connections between model rockets and real rockets.

In the third unit, the fundamentals of rocketry section, students dive deeper into the intricacies of rocket design and understand how various components influence the rocket's flight. The emphasis is placed on the importance of stability, relating to the center of gravity and center of pressure. This unit concludes with an introduction to key rocket performance parameters, providing students with an understanding of the factors that measure a rocket's performance.

The fourth unit, rocket mechanics section, forms the core of the course as it guides students in formulating a predictive model for a rocket's flight. This module introduces equations of motion and analyzes the forces acting on the rocket, enabling students to calculate and simulate the trajectory of the rocket. By applying these principles, students gain the ability to make accurate predictions on the rocket's flight.

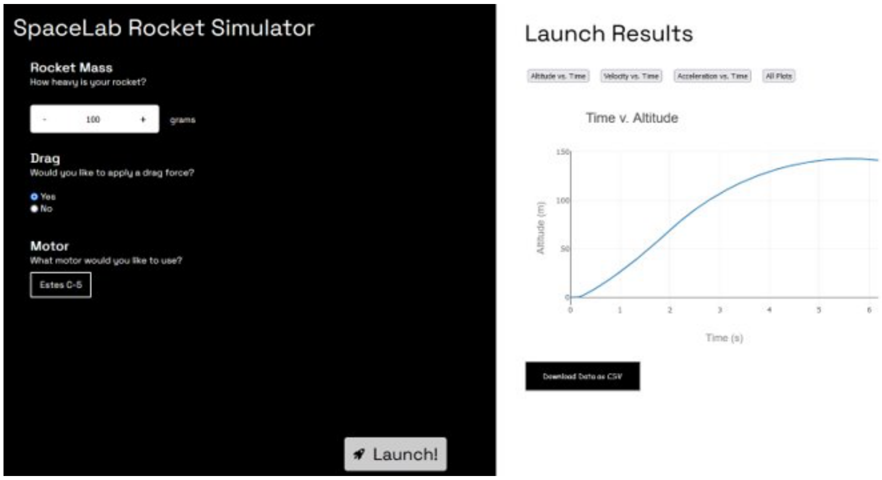
The online content concludes with the analysis section, which compares the predictive models to experimental data obtained from the model rocket flight. This section allows students to develop data literacy skills by evaluating the strengths and limitations of their predictions with the observed flight data. This final section promotes critical thinking and allows students to refine their understanding of rocketry through analysis and interpretation of results.

2.1.3 APOGEE ACTIVITY

In the apogee activity, students are assigned a target apogee and are tasked with adjusting the payload using trajectory models to achieve the desired outcome. By utilizing Newton's Second Law of Motion and other fundamental math and physics equations, students calculate the theoretical apogee of their rockets and subsequently compare this data to the actual flight data collected later during the launch.

To enhance the learning experience, an online applet has been developed and made accessible to students. This applet is shown in Figure 2 and allows students to manipulate variables such as mass of rocket and the selection of motors, which enables them to observe the differences between the simplified model and complex models that incorporate factors like drag or variable motor-thrust. The data can be downloaded in a comma-separated values file format, which can be directly loaded on to external software like Google Sheets, to make plots and compare predictions to actual flight data. This interactive tool provides students with an opportunity to explore modeling approaches.

The level of difficulty in the course can be adjusted based on the utilization of the apogee activity. We provide Google Sheets instructions for calculating and plotting the target apogee and recommend this option for high schools. Alternatively, for those seeking a more challenging option, for example for college courses, a Python walkthrough is also available to offer a more challenging method to make predictions.



SpaceLab Rocket Simulator

Rocket Mass

How heavy is your rocket?

100 grams

Drag

Would you like to apply a drag force?

● Yes

○ No

Motor

What motor would you like to use?

Estes C-5

Launch Results

Figure 2. Online Apogee Calculator

2.1.4 HANDS-ON CONTENT

Upon completion of the video lectures and the apogee activity, the hands-on kit is introduced. The build video lessons serve not only as step-by-step instructions for constructing the model rocket but also establish connections with earlier foundational and theoretical units. These videos explain the purpose and significance of each component used in the rocket, providing students with a deeper understanding of the underlying principles. The videos presented in this section are detailed in Table 2.

After building their rocket, students use the developed model previously in the apogee activity that utilizes rocket mass and average motor thrust to estimate and predict the apogee of the rocket's flight. This model serves as a tool for students to determine the payload mass required in the nose cone to achieve a desired apogee, thereby bridging the gap between the theoretical concepts and practical implementation.

The launch unit offers comprehensive information and guidance on how to conduct a proper rocket launch, emphasizing the importance of safety and addressing the logistical considerations involved. Detailed launch procedures are provided to ensure the successful and secure execution of the launch.

Following the rocket launch, students engage in the analysis of their predictions and observations. They compare their calculated apogee with the recorded flight data, enabling them to identify any disparities and examine the factors contributing to these differences. Through reflection on the data, students gain insights into the accuracy of predictions and contemplate potential improvements for future launches. This process allows students to apply their knowledge and experiences to enhance their understanding through refining their approaches.

Table 2: Hands-on Video List with Duration in Minutes

Unit	**Videos**	
Build	Build Introduction	46
	Motor Assembly	
	Fins and Launch Lug	
	Nose Cone Cut	
	Recovery System	
Launch	Launch Introduction	24
	Launch Environment	
	Launch Site Selection	
	Prepare Recovery System and Motor	
	Prepare Payload and Avionics	
	Launch Pad Set-up	
	Launch Procedure	

2.1.5 MODEL ROCKET AND AVIONICS

The development of the model rocket kit underwent several iterations to decide on a rocket that would be accessible and engaging for students and teachers while still maintain a level of complexity and challenge. The primary objective was to strike a balance between simplicity and accessibility, ensuring that the kit was user-friendly and cost-effective, yet capable of meeting the project’s goals, particularly in terms of varying payload in the rocket. The reliability of the model rocket kit was most important to provide students and instructors with a quality experience. Multiple testing sessions were conducted to ensure a safe build and launch to ensure its dependability. As a result, the current rocket and configuration have gone through evaluation and validation, making it the most reliable rocket for the use of this course

The size of the rocket was a significant consideration since larger rockets requires larger motors, and consequently, a larger launch radius. To adhere to safety guidelines and practical limitations, it was determined that C-class motors or smaller would be suitable, considering the launch diameter typically provided by a high school baseball field, of approximately 400 feet. Additionally, the rocket needed to accommodate storage space for the payload and avionics. The Aerotech Quest Courier (Figure 3) rocket was ultimately selected as the model rocket, as it fulfilled the requirements needed for the course activity.

Figure 3: Quest Courier Model Rocket

For students to record the flight data during rocket launches, an avionics system is necessary. There are numerous options available on the market, each capable of collecting various types of data. Cost-effective options typically focus on capturing the rocket's apogee, which is sufficient for comparing against the calculated apogee values for this project. These simpler avionic systems are highly recommended for participants, due to their ability to display data immediately after the flight. The AltimeterOne from JollyLogic (Figure 4) is the chosen altimeter for the course, known for its reliability and accuracy.

Figure 4: JollyLogic PerfectFlite Altimeter

The Quest Courier rocket included a storage area in the nose cone for varying the payload mass. This meant that as more payload is loaded on to the nosecone, the rocket is going to be more top-heavy and requires more thrust in the ascent stage of the launch to ensure a stable launch. To provide a high thrust in the beginning, the Estes C-5 “Super C” (Figure 5) was chosen as the optimal motor. Figure 6 shows the thrust curve of this motor, displaying the thrust power in the y-axis and time in the x-axis. As seen here, high amount of thrust is produced in the early stages of motor performance. This allows the rocket to achieve a saucerful launch off the launch rail and allow the rocket to safely ascend up into the sky.

Figure 5: Estes C-5 “Super-C” Motor

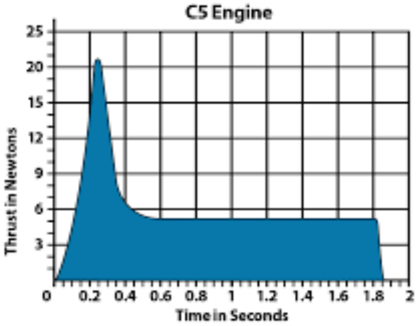


Figure 6: Thrust Curve of Estes C-5 Motor

2.2 DEVELOPMENT OF COURSE CONTENT

The development process for the course content was initiated with considerations regarding the rocketry topics to be covered. As graduate students in aerospace engineering, a colleague and I collaborated with professional educators on the team to determine the content that would be included in the rocketry course. Our objective was to select a comprehensive range of topics for the online videos, providing students with sufficient knowledge to understand and successfully participate in the hands-on model rocket launch component of the course.

The initial phase of the development process centered around defining the anchoring phenomenon of the course. We aimed to design a course where students could not only learn technical and theoretical concepts of rocketry but also apply their knowledge to the build and launch of model rockets. The hands-on model rocket activity was specifically designed to allow students to apply their acquired knowledge and avoid the passive approach of “learning by doing”. In this activity, students were given the opportunity to choose different payload masses to achieve a specific apogee. This anchoring phenomenon of the course dove into the question of what it takes to deliver payload to the International Space Station (ISS). By studying rocketry and engaging in an activity where students could manipulate payload masses to achieve an apogee under 500 ft., students were prompted to contemplate the broader connected phenomenon of the common use of rockets in space missions and the requirements for launching payloads into the outer atmosphere.

The answer to this question unfolded in three distinct phases within the course. First, students acquired knowledge about basic rocket hardware and then proceeded to construct their own model rockets, while gaining an understanding of the fundamental principles underlying rocket flight. This phase established a connection to the anchoring phenomenon by imparting essential knowledge about rocket hardware and the forces that enable rockets to achieve stable flight, thereby delivering payloads to the ISS.

Then, the design and mechanics phase allowed students to dive deeper into the concept of payloads. During this phase, students explored the influence of payload mass on the rocket's maximum height and manipulated the variable of mass to achieve a desired apogee. Mathematical models, including Newton's second law of motion, were introduced to aid students in making informed decisions regarding the desired payload mass and its corresponding contents. Utilizing these models, students developed their optimal rocket payload designs for the upcoming launch day, where they would test their designs in practice.

Following the launch, students engage in data analysis by examining the data collected through onboard electronics on the rockets. This analysis phase enabled students to assess the success of their design approaches. By comparing the performance of different rocket designs and contrasting computational data with experimental data, students gained insights into the disparities between the two and furthered their understanding of the principles of rocketry.

With this course content, students would not only acquire a comprehensive understanding of rocketry fundamentals encompassing hardware, design, build, and launch, but also developed skills in data analysis, basic electronics, evaluation of performance through model-data comparison, and the application of critical thinking and problem-solving strategies to achieve desired apogees. The selection of these course content was also made to align with sections of the Next Generation Science Standards (NGSS), which are commonly adopted in K-12 schools, facilitating easier implementation in high school settings.

2.3 PRODUCTION OF ONLINE VIDEOS

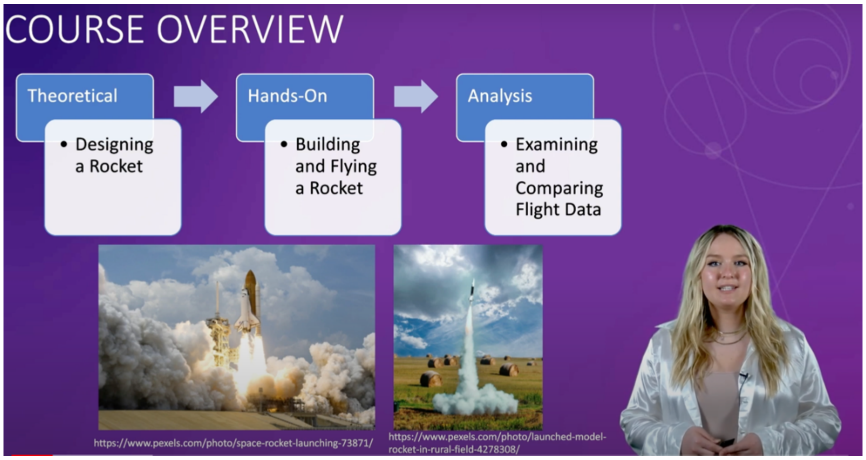
The development of the online content involved the creation of informative and concise videos. The production process was completed with the help of UIUC Center for Innovative Technology (CITL) team, where they provided great insights and direct assistance with video production and editing. Drawing from previous studies, it was essential to present the content effectively within a short timeframe. Thus, the goal was to incorporate visually appealing images and bullet points that highlight the key information in each video.

To accomplish this, a team of undergraduate students from various engineering departments at UIUC was hired as online video producers. The pre-developed course content was divided among the students, who took charge of creating the technical videos. Close supervision and management were maintained throughout the process to ensure accuracy and prevent deviations from the intended content. The video production process, as depicted in Figure 7, involved several iterations, including outlining, scripting, filming, and editing. Multiple reviews were conducted to assess the technical accuracy and ensure that the videos remained concise and focused. During the review process, particular attention was given to the visual aspects, making sure that bullet points and images were clear and easily readable in the presentations.

Outline	**Review**	**Script & Presentation**	**Review**	**Filming**	**Editing**	**Final Review**

Figure 7: Video Production Process

After an extensive review of the content and the presentation, the filming process was completed at CITL's studios to ensure good video and audio quality. Students stood in front of a green screen, delivering their presentations with a clear and audible voice while referring to their scripts. Once the filming was completed, the videos were edited using Adobe Premiere Pro, with guidance from CITL. The finalized videos were then uploaded to the SpaceLab's YouTube website. Figure 8 showcases an example image from one of the videos featured in the course, highlighting the clear and visually engaging content aimed at facilitating student engagement and understanding.



COURSE OVERVIEW

Theoretical
- Designing a Rocket

Hands-On
- Building and Flying a Rocket

Analysis
- Examining and Comparing Flight Data

https://www.pexels.com/photo/space-rocket-launching-73871/

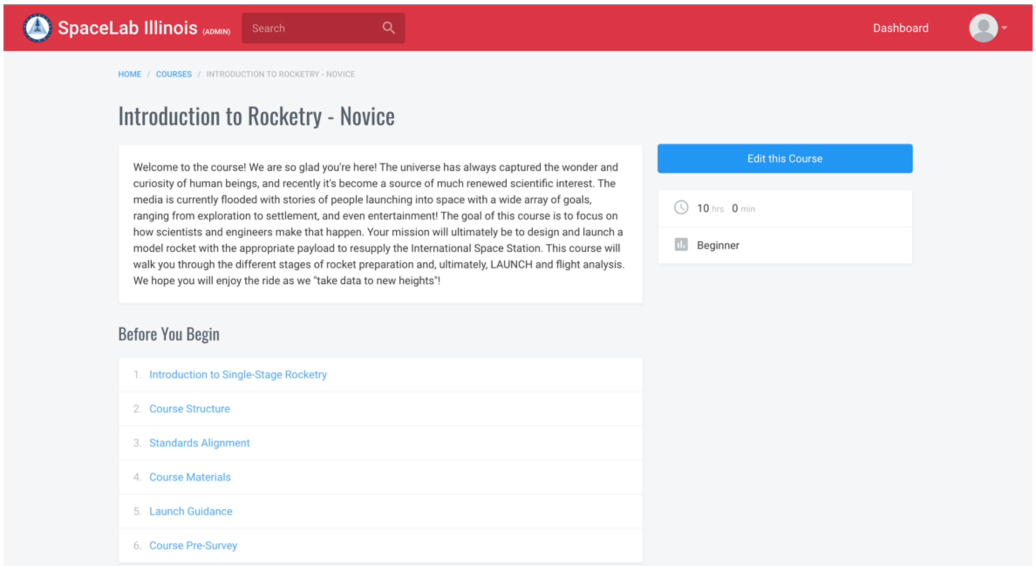
https://www.pexels.com/photo/launched-model-rocket-in-rural-field-4278308/

Figure 8: Example Video

2.3.1 ONLINE COURSE PLATFORM

In tandem with the production of the online videos, the online classroom platform was developed. The overarching objective of the project was to create a freely accessible online course that could be readily accessed by both students and instructors without any limitations. To fulfill this goal, a decision was made to establish a public web platform for the course, integrating it into the existing SpaceLab website.

To execute this task, another undergraduate student with expertise in web design and development was hired, and regular meeting were conducted to oversee the construction of the online classroom platform. Both backend and frontend coding were implemented to create a user-friendly web platform. By registering a free account, users gain access to the online course, including a comprehensive list of videos. Figure 9 shows a captured image of the online classroom and it can be accessed freely at https://learnrockets.spacelab.web.illinois.edu/.



Introduction to Rocketry - Novice

Welcome to the course! We are so glad you're here! The universe has always captured the wonder and curiosity of human beings, and recently it's become a source of much renewed scientific interest. The media is currently flooded with stories of people launching into space with a wide array of goals, ranging from exploration to settlement, and even entertainment! The goal of this course is to focus on how scientists and engineers make that happen. Your mission will ultimately be to design and launch a model rocket with the appropriate payload to resupply the International Space Station. This course will walk you through the different stages of rocket preparation and, ultimately, LAUNCH and flight analysis. We hope you will enjoy the ride as we "take data to new heights"!

Before You Begin

1. Introduction to Single-Stage Rocketry
2. Course Structure
3. Standards Alignment
4. Course Materials
5. Launch Guidance
6. Course Pre-Survey

Figure 9: Online Course Platform

CHAPTER 3: IMPLEMENTATION AND LESSONS LEARNED

To ensure the completeness and the effectiveness of the course, gathering feedback from users was an essential step. Multiple variations of the course were implemented at various locations, targeting specific audiences, to verify and validate the course content and usability. The details of these implementations and their corresponding target audiences can be found in Table 3 below. This section presents the qualitative results derived from these implementations, outlining the lessons learned and adjustments made to the course based on the feedback received. The insights gained from these experiences served as the foundation for continuous improvement, ensuring the course's alignment with the needs of its users and optimizing the educational impact.

Table 3: Implementation Information

Type	Audience		Location
Teacher PD Workshops	Middle school and high school STEM teachers	>60	Midwest region and New Mexico
Pilot Courses	Undergraduate students (most in STEM)	90	UIUC & SIUE
High School Implementation	High school students (Freshmen – Senior)	~350	Bloomington High School

3.1 TEACHER PROFESSIONAL DEVELOPMENT EVENT

The initial version of the introduction to rocketry course was presented at teacher professional development events across the Midwest and New Mexico. The course featured a different hands-on kit, which involved a more complex avionics system and a larger rocket. The

Super Big Bertha (Figure 10) rocket was used, measuring approximately 3 feet in length and designed to reach heights of around 1500 feet, requiring a motor size of E or F motors. The avionics system utilized the Raspberry Pi4 and Navio2 sensor system (Figure 11) along with its avionics bay, making the rocket heavier and requiring a high thrust motor for a successful flight. The Aerotehc F67 motor (Figure 12) was selected for its adequate thrust to launch the heavy rocket, enabling the fully loaded rocket to reach heights of approximately 300-500 feet.

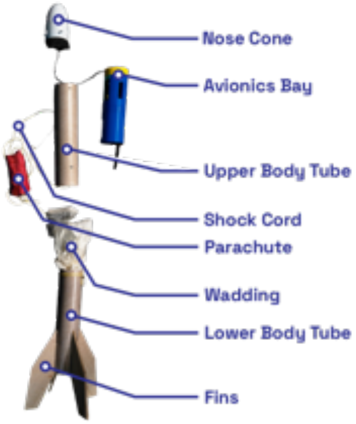


Figure 10: Components of the Super Big Bertha

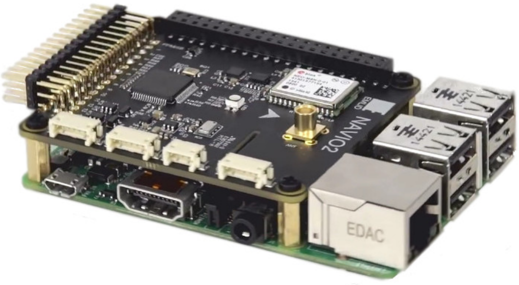


Figure 11: Raspberri Pi4 with Navio2

Figure 12: AeroTech F67 Motor

The complexity of the hands-on kit translated into a more intricate course content as well. Additional instructional videos were created to explain the usage of specific computer software connecting to the avionics system and the utilization of power tools for rocket constructions.

During the presentation of the course in New Mexico, it was conducted over a one-week duration, with a significant emphasis on the hands-on kit. Teachers invested considerable time in constructing the rocket and familiarizing themselves with the avionics system. At the end of each day and at the conclusion of the event, feedback was obtained from the teachers regarding their experiences with the course content and its potential implementation in their classrooms. The qualitative feedback received from this event is organized in Table 4.

Table 4: Feedback from Professional Development Events

Feedback Received		
Online Content	**Hands-on Project**	**Implementation**
Too many videos	Safety issues	NGSS
Length of course	Difficult to use software	Technology Limitations
Lack of connection to hands-on kit	Trouble locating a launch site	Cost

The initial version of the course received constructive feedback, primarily centered around the complexity and accessibility of the hands-on kit. Teachers expressed concerns about the complexity and the safety of the rocket and avionics system, considering them unsuitable for middle school and high school classrooms. One teacher remarked, “I feel unsafe myself when assembling this rocket, and I could not trust my students with it.” Teachers also encountered challenges in working with the avionics system, struggling to establish connections and operate the complex setup. Additionally, technology limitations emerged as a significant issue, as most students in school are only provided with Google Chromebooks that imposed restrictions on external software usage, rendering the required software unusable in classrooms.

The hands-on kit introduced various issues related to the online content and the implementation proves as well. The total cost of the rocket and avionics kit amount to approximately $400 per kit, posing a significant barrier to classroom implementation. Moreover, the hands-on kit extended the course duration considerably, making it challenging for teachers to allocate sufficient time for learning power usage, downloading problematic software, and incorporating these activities into ongoing classes.

The teachers enjoyed the apogee activity that was involved in this course. Despite facing challenges with avionics and flight data acquisition, teachers appreciated the usage of Newton’s second law of motion to make rocket flight predictions. They emphasized the value of connecting theoretical concepts with the application of mathematical equations. This positive feedback inspired the development of additional options for the apogee activity, offering varying difficulty levels. This included the creation of the online apogee calculator, a tutorial on Google Sheets, and a Python tutorial as described previously.

Based on the lessons learned from the New Mexico PD event, it was evident that a change in the hands-on kit was imperative. Issues such as accessibility, cost, safety, and course length necessitated an alternative approach. As a solution, the Quest Courier rocket and the AltimeterOne were chosen as the final hands-on kit for the course to mitigate the technical challenges, safety concerns, and cost issues faced by instructors.

3.2 COLLEGE IMPLEMENTATION

Based on the feedback received from instructors at the professional development events, the hands-on kit was revised, and corresponding adjustments were made to the online course content. By simplifying the complexity of the kit, the focus of the online content shifted towards the theoretical aspects, reducing the burden of cumbersome build instructions. The revised version of the course, featuring the new hands-on kit, was piloted at the University of Illinois at Urbana-Champaign. As the instructor for this course, a colleague and I gathered a group of approximately 40 students through department-wide mass emails.

Feedback from the college students who participated in the pilot course is summarized in Table 5. During the build and launch sessions, numerous students expressed their enjoyment of the hands-on activities. However, they found the online videos to be lengthy and faced many challenges in maintain engagement. Additionally, they perceived the assessment questions to be difficult, and the hands-on project required substantial instructor assistance, particularly during the launch phase.

Table 5: Feedback from College Students

Feedback Received	
Online Content	**Hands-on Project**
Difficult assessment	Engaging
Lengthy videos	Required too much instructor assistance

In response to the feedback from college students, the assessment questions were modified to consist entirely of multiple-choice format. We ensured that the questions only tested knowledge within the scope of the course, eliminating the need for external knowledge. For implementation in local schools, based on this experience, we decided to provide our own assessments as guides rather than making them mandatory for all students. We discovered that the difficulty of the course was strongly influenced by the assessment questions, making it challenging to create a standardized exam suitable for students at different academic levels.

3.3 HIGH SCHOOL IMPLEMENTATION

The final iteration of the course, incorporating the content described in Chapter 2, was implemented at a local high school with the participation of multiple physics teachers across various grade levels, totaling approximately 350 students. To support the teachers in implementing the course, they were provided with course information in advance, along with teacher guides to assist with the implementation process.

Table 6 displays the feedback received from the high school teachers regarding the course implementation. Once again, the teachers expressed concerns about the length of the videos and requested for an easier version of the course. Students had difficulty staying engaged with the videos, and the course content proved challenging for freshmen-level students. As for the hands-on kits, the teacher allocated several class sessions to complete the rocket launches for all students. They aimed to launch 20 rockets within a 50-minute timeframe in multiple class periods, which required smooth execution of the launch procedures. However, they encountered launch failures due to the poor storage of rocket motors. The launches took place in cold weather, and the motors had been stored outside over a week, which likely resulted in cracks in the propellants and subsequent misfires during the launch. In terms of implementation, the high school teachers expressed a need for more comprehensive teacher training. They felt the need for additional instruction to properly guide the students and requested more training specifically focused on the course.

Table 6: Feedback from High School Instructors

Feedback		
Online Content	**Hands-on Project**	**Implementation**
Video Duration	Bad motors causing launch failure	Need for teacher training day
Need for an easier version of the course	Challenges with launch logistics	

3.4 QUALITATIVE RESULTS AND LESSONS LEARNED

Throughout the development and implementation processes, the course has undergone numerous iterations and continuous updates to optimize the benefits of blended MOOCs. Time and accessibility have emerged as major concerns during course implementation. Due to various constraints faced by teachers, not all of them were able to fully integrate the course into their classrooms. This necessitated the provision of scaffolded content, allowing teachers to implement selected components of the course based on their available time. While the complete course yields the best outcomes, offering flexible options enables broader adoption.

Accessibility is another significant factor to consider when implementing the course in schools. Limited access to personal computers and school firewalls can hinder students' ability to participate fully. By hosting the course on a public web domain, we have enhanced accessibility, enabling easy access for those interested in taking the course. Moreover, the accessibility of hands-on kits is crucial. As instructors play a supervisory role, the kits must be user-friendly, safe to build, and cost-effective. The cost of materials must be kept at a reasonable level to facilitate broader adoption in educational settings.

Instructors highly valued the application and analysis components of the course. The apogee activity, in particular, received positive feedback from teachers. This activity involved making height predictions, launching the rocket to collect experimental data, and subsequently analyzing and comparing the results. Not only does this align with NGSS standards, but it also provides a meaningful experience for students to apply their learned concepts in a real-world context. The apogee activity serves as a vital bridge between the online theoretical concepts and hands-on experimentation, engaging students and reinforcing the content covered in the course.

CHAPTER 4: STUDY OF A BLENDED MOOC WITH HANDS-ON KITS

4.1 INTRODUCTION

A controlled educational study was conducted to examine the impact of a blended Massive Open Online Course (MOOC) with a hands-on kit on student efficacy and career interest in rocketry and space engineering. The study aimed to understand the influence of the course on student efficacy, career interest, and the potential effects of student demographics, previous experience, and learning styles.

The study involved a group of undergraduate college students, mostly in STEM background, at the University of Illinois at Urbana-Champaign. Questionnaires were administered at strategic timing to measure the change in student self-efficacy, and interest. The study sought to provide quantitative answers to the following questions:

1. How does the MOOC with hands-on kit impact student efficacy?

   The study aimed to assess the effectiveness of the course in improving student efficacy by comparing assessment scores before and after the exposure to online content and the hands-on kit.

2. How does the MOOC with a hands-on kit influence career interest?

   The study sought to determine whether participation in this course had an impact on students' interest in pursuing a career in rocketry and space engineering. This was evaluated through self-reported questionnaire administered at strategic timing.

3. How do personal background and learning style affect efficacy and interest?

   The study aimed to explore the potential influence of student demographics, previous experience, and learning styles on the learning experience outcomes. This involved analyzing the data collected from the questionnaires to identify any patterns or correlations

By addressing these questions through a systematic educational study, the research aimed to provide valuable insights into the effect of the blended MOOC with a hands-on kit, its impact on student efficacy and interest, and the role of personal background and learning styles in the learning experience.

4.2 METHODOLOGY

We conducted a comprehensive assessment of the introduction to rocketry course by measuring changes in self-efficacy among a group of undergraduate college students. The assessment approach involved collecting data from participants at three different time points, as illustrated in Figure 13.

Assessment 1 took place at the beginning of the course, prior to any instruction. Assessment 2 occurred after the participants completed all online course content, including the video lessons and quizzes. Assessment 3 was conducted after participants completed the hands-on activity, which marked the end of the course.

To evaluate the impact of the online content, we compared the results of Assessment 1 and 2. This comparison allowed us to study the effect of the online course materials on participants' self-efficacy. Similarly, by comparing the results of Assessment 2 and 3, we examined the impact of the hands-on component of the course on self-efficacy. Finally, we compared the results of Assessment 1 and 3, to examine the overall impact of the course on participants' self-efficacy.

Additionally, Assessment 1 included a personal background survey that collected participant information such as demographics, year in college, gender, previous experience with rocketry and MOOCs, and learning styles. This data allowed us to analyze the potential influence of these factors on self-efficacy and course outcomes.

Figure 13: Overall course structure including assessment

The study was conducted within an 8-week, spring 2023, introduction to rocketry course called AE298: Introduction to Rocketry taught by the Aerospace Engineering Department at the University of Illinois Urbana-Champaign (UIUC). Students were recruited through advertising and promotion across multiple channels within the University, including distribution of mass emails via engineering departments, placement of course flyers in strategic locations across campus, and targeted distributions to undergraduate engineering student organizations. Recruitment efforts targeted freshman and sophomore non-aerospace engineering STEM students at UIUC. Students enrolled and who participated in AE298 (i.e., completed the quizzes and surveys) received course credit (all students in this study participated and received course credit). This level of credit (2 hours) is not sufficient to satisfy a technical elective in any engineering curriculum (3+ hours). Over the 8 weeks, students progressed through the course content as illustrated in Figure 13. Additional details on the course content are provided in the following sections.

4.2.1 SELF-EFFICACY ASSESSMENT

We applied components of SCCT and developed a self-efficacy assessment to test for the interest, choice, performance, and satisfaction of students. The self-efficacy assessment consists of three sections, each comprising questions derived from questionnaires validated by experts. These sections correspond to the three primary classes of self-efficacy measures identified in previous studies: general academic, domain-general, and task and skill efficacy [16]. The general academic section of the self-efficacy assessment includes five questions from the Patterns of Adaptive Learning Scales (PALS). These questions assess a student's perception of their competence to do their general class work [23]. Additionally, the ten-item Generalized Self-Efficacy Scale was employed to measure a participant's belief in their ability to respond to novel or difficult situations and overcome obstacles or setbacks [24]. The domain-general section of the assessment incorporates questions adapted from the Motivated Strategies for Learning Questionnaire (MSLQ) and the Longitudinal Assessment of Engineering Self-Efficacy (LAESE) [25]. The self-efficacy for learning and performance section of the MSLQ was modified to reflect engineering classes specifically [26]. The questions in this section aim to assess a participant's self-efficacy in the broader context of engineering. Finally, the task and skill section of the assessment comprises seven questions tailored to the specific topics of this study, i.e., rocketry and online study. Four questions are used to inquire about a participant's confidence in working with model rockets and engaging in rocketry activities. An additional three questions focus on a participant's confidence in navigating through a MOOC and participating in the specific AE 298 online classroom format.

We use a 7-point Likert scale for our self-efficacy survey. Compared to the traditional 5-point Likert scale, the 7-point scale offers a greater number of response options, enabling students to express their level of confidence in a more nuanced manner and facilitating analysis of data. Prior research has indicated that the utilization of a 7-point Likert scale enhances the variability of responses, thereby increasing the likelihood of capturing a more objective representation of individuals' perceptions [27]. Our self-efficacy survey questions are given in Appendix Y.

4.2.2 LEARNING STYLES

We employed the Felder-Silverman's Index of Learning Styles (ILS) to determine participant learning styles [28]. This survey enables assessment of a learner's preference for perceiving and processing information and engaging in learning activities. Results enable learners to be categorized based on their preferences in various dimensions of learning styles, including active vs. reflective, sensing vs. intuitive, visual vs. verbal, and sequential vs. global. Many or most engineering students are active, sensing, visual, and global [28]. The survey consists of a comprehensive set of 44 questions, each offering two options for participants to choose from. These questions primarily revolve around determining an individual's learning preferences, prompting them to select one option over the other. Upon completing the questionnaire, the assessment generates results for all four learning styles, assigning scores ranging from 1 to 11. Scores falling within the range of 1-3 indicate a balanced learning style between the two corresponding categories, while scores between 5-7 suggest a moderate preference. The strongest preference is indicated by scores falling within the range of 9-11. All students in this study completed this survey as part of assessment 1.

4.2.3 DATA ANALYSIS

We use changes in technical knowledge quiz and survey scores to determine the effect of the online content, hands-on kit, and overall blended MOOC on student knowledge, self-efficacy, and interest. These data are gathered at assessment 1, 2, and 3 as shown in Figure 13. To assess the significance of a change in scores, the paired t-test was employed. The paired t-test is appropriate when analyzing score differences within a single group across two distinct time points.

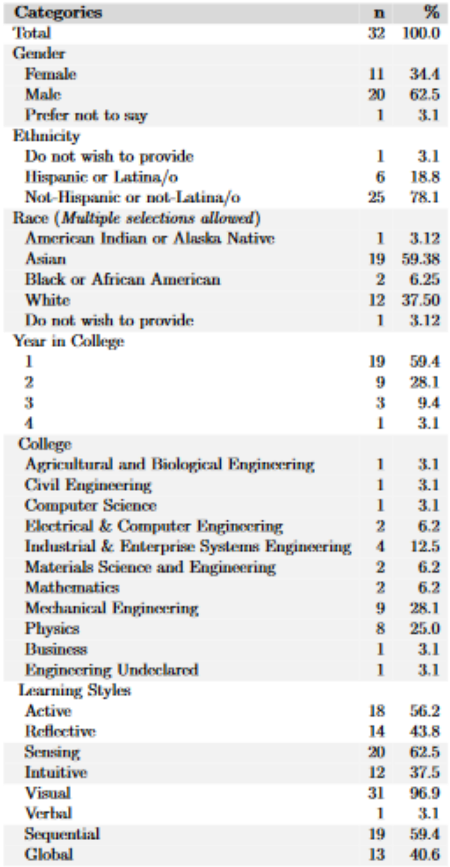
By calculating the p-value based on the true mean difference and the standard deviation of the dataset, it is possible to either accept or reject the null hypothesis. In this study, the null hypothesis posits that the mean of the paired difference is equal to zero, while the alternative hypothesis is that the mean of the paired difference is not equal to zero. The upper-tailed alternative hypothesis was utilized, with a significance level of $\alpha = 0.05$, indicating an assumption that the true mean difference would be greater than zero. If the calculated p-value falls below the predetermined significance level of 0.05, the null hypothesis is rejected and the alternative hypothesis, that the change in the scores is significant, is accepted.

CHAPTER 5: QUANTITATIVE RESULTS ON STUDENT EFFICACY

5.1 PARTICIPANT INFORMATION

The details and demographics of the student group used in the study are given in Table 7 were undergraduate students at UIUC. About 63% were male and 34% female. The majority were either Asian (59%) or white (38%) and first-year students (59%) studying mechanical engineering (28%) or physics (25%) (physics is part of engineering at UIUC). Three students were from outside of engineering, two from mathematics and one from business. The participants in early stages of college were favored in selection, resulting in mostly freshmen and sophomore students (87.5%), with a few juniors and seniors (12.5%). In terms of learning styles, students exhibited active (56.2%) learning styles more than reflective (43.8%), more sensing (62.5%) than intuitive (37.5%), all visual (96.9%) but one student of verbal (3.1%), and more sequential (59.4%) than global (40.6%).

Table 7: Details and demographics of the student group used in the study



Categories	n	%
Total	32	100.0
Gender		
Female	11	34.4
Male	20	62.5
Prefer not to say	1	3.1
Ethnicity		
Do not wish to provide	1	3.1
Hispanic or Latina/o	6	18.8
Not-Hispanic or not-Latina/o	25	78.1
Race (*Multiple selections allowed*)		
American Indian or Alaska Native	1	3.12
Asian	19	59.38
Black or African American	2	6.25
White	12	37.50
Do not wish to provide	1	3.12
Year in College		
1	19	59.4
2	9	28.1
3	3	9.4
4	1	3.1
College		
Agricultural and Biological Engineering	1	3.1
Civil Engineering	1	3.1
Computer Science	1	3.1
Electrical & Computer Engineering	2	6.2
Industrial & Enterprise Systems Engineering	4	12.5
Materials Science and Engineering	2	6.2
Mathematics	2	6.2
Mechanical Engineering	9	28.1
Physics	8	25.0
Business	1	3.1
Engineering Undeclared	1	3.1
Learning Styles		
Active	18	56.2
Reflective	14	43.8
Sensing	20	62.5
Intuitive	12	37.5
Visual	31	96.9
Verbal	1	3.1
Sequential	19	59.4
Global	13	40.6

5.2 SELF-EFFICACY RESULTS

This results section showcases figures depicting the average values for all students in each efficacy exam section. The scores of all students were averaged for each respective section, and the resulting mean scores are visually represented. Figure 15 illustrates the overall efficacy scores across different sections. The graph reveals a notable trend, where the initial efficacy scores for general academic, domain general, and task & skill online questions were already quite high, approaching a value of nearly 6 out of 7 on the scale. As the course progresses, these scores further increase, indicating a positive upward trajectory both before and after the online course and the hands-on activity. The efficacy levels of participants show improvement across all components of the blended MOOC, highlighting that both the online course and the hands-on kit contribute to enhancing students' confidence not only in rocketry-related questions, but also in academics, engineering-domain, and online course-related aspects.

The most significant improvement is observed in the task and skill rocketry questions. Although students were self-registered in the course and displayed initial interest, many did not possess high self-confidence in rocketry. However, with the aid of online videos, the efficacy scores experienced a noticeable surge, which further intensified after the hands-on activity involving the model rocket. In comparison to other sections, the task and skill rocketry section exhibited a remarkable increase in scores, thereby substantiating the positive impact of both the online component and the hands-on component on bolstering confidence in rocketry skills.

Figure 14: Graph Legend

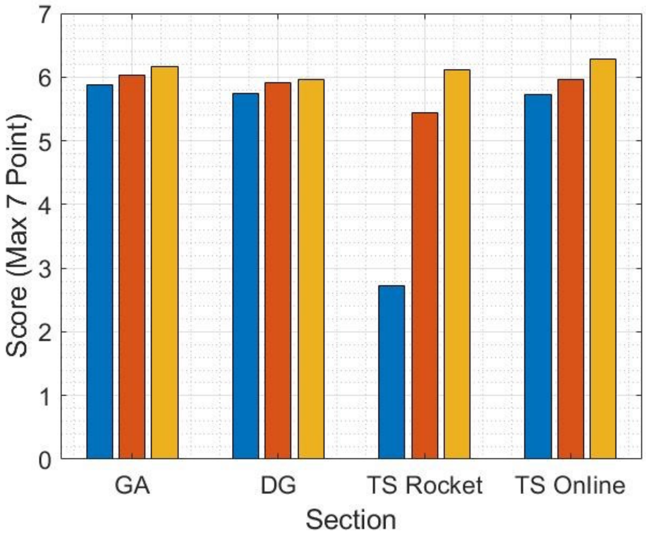


Figure 15: Overall Efficacy Scores by Section

In light of the pattern observed in the rocketry task and skill section, an investigation into personal backgrounds was conducted to ascertain potential influencing factors. One of the inquiries posed in the initial survey pertained to prior experience in rocketry. Figure 16 depicts those individuals with previous experience in rocketry achieved higher scores compared to those without experience. Moreover, as the course progressed, both groups exhibited significant gains subsequent to engaging with online videos. The most noteworthy observation emerged towards the conclusion of the study, wherein participants lacking previous experience ended with a similar efficacy score. This data underscores the notion that irrespective of prior experience, the participants, upon completion of this blended MOOC and the active involvement in online videos and hands-on activities, displayed a substantial increase in the level of efficacy, thereby exhibiting similar scores between the two groups.

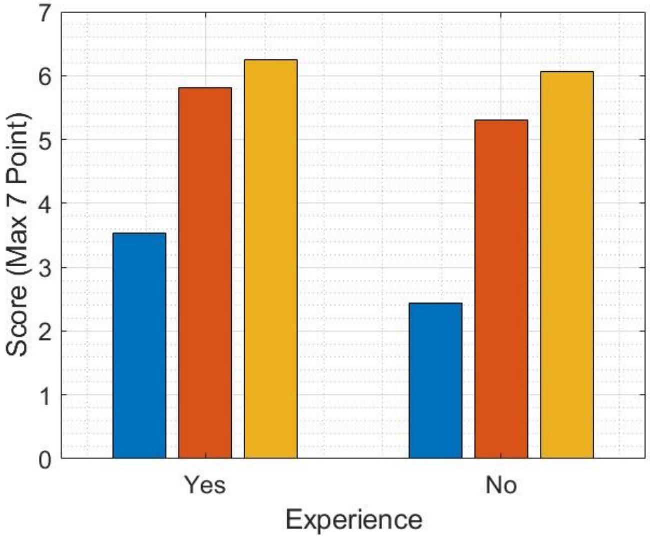


Figure 16: Task and Skill Scores by Experience

In the analysis of the data presented in Figure 17, it is observed that the male students had higher initial confidence levels compared to the female students. However, as the course progressed, the female students showed a significant improvement in their scores, particularly in the domain-general section. It is noteworthy that despite starting with a lower efficacy level, the female students experienced substantial gains in their scores throughout the course to match the final exam scores of male students. These findings indicate that gender can influence students' perceptions on how they will perform and progress in the course. The data suggests that female students have more potential to excel and improve their confidence scores as they complete course activities.

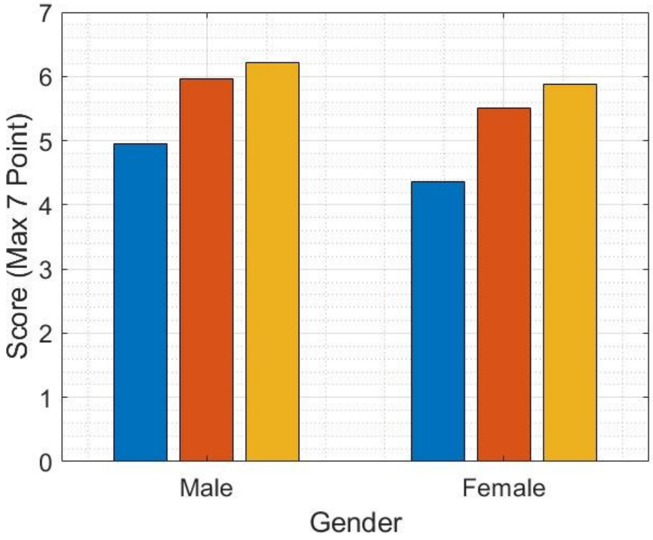


Figure 17: Overall Efficacy Scores by Gender

Additionally, the examination of the data based on the year in college showed that students from all four years demonstrated significant improvements in their scores as the course progressed. This suggests that regardless of their academic level, students across different years showed progress and growth throughout the course.

As seen in Figure 18, the participants of this study predominantly exhibited active, sensing, visual, and sequential learning styles, which is closely aligned with findings with previous research stating that the majority of engineering students tend to possess these similar learning styles. The average scores obtained by the participants ranged from 4 to 7, indicating a moderate preference for each learning style. These results suggest that most participants demonstrated a balanced inclination towards these learning styles, neither strongly favoring nor strongly disfavoring any particular style. Notably, only one student reported as ‘verbal’ with a score of 1, showing that most learners in this study were visual learners.

The result showed an analysis completed between each learning styles for each section of the efficacy exam. The task and skill rocketry section shows that students with learning styles of active, sensing, visual, and global showed the most improvement in the scores overall. This aligns with most engineering students having the same learning styles as presented in previous studies. This trend is present in the other efficacy sections as well. For general academic, domain-general, and task and skill online sections, the participants with the above-mentioned learning styles reported to have higher scores after the completion of all MOOC activities.

According to previous studies, most engineering students predominantly exhibited active, sensing, visual, and global leaning styles. The efficacy exam analysis for each section based on learning styles showed that students with these specific learning styles showed higher scores overall. As seen in the figures below, groups with these learning styles showed the most improvement and a higher score for the task and skill sections. This trend is further exemplified in other efficacy sections as well, showing that participants with these learning styles tended to show a higher end score.

These findings indicate that the learners with most common engineering learning styles were more effectively impacted in terms of performance and improvement across different sections of the efficacy exam. These results align with previous studies conducted on engineering students, highlighting the importance of considering individual learning styles specific to this group when developing educational materials and activities. Thus, it can be inferred that the course was well-suited for learners who possess engineering learning styles.

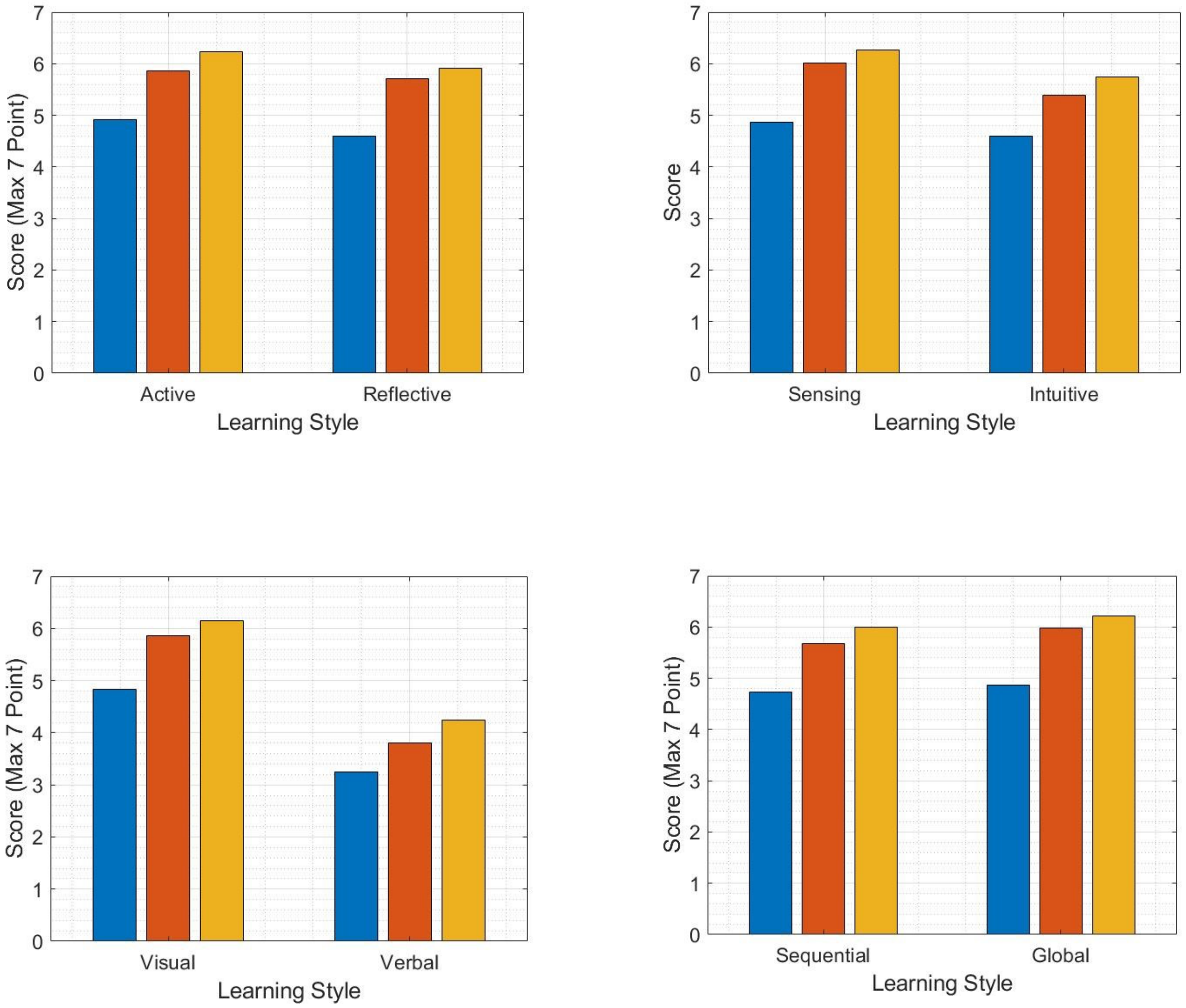


Figure 18: Overall Average Scores by Learning Styles

CHAPTER 6: CONCLUSION

6.1 DISCUSSION

Taking components from the Social Cognitive Career Theory, the integration of the results obtained from the efficacy questions will establish a link to students' subsequent interest in the topic. SCCT posits that individuals are more likely to develop interests, pursue, and perform better in activities in which they possess strong self-efficacy beliefs (Lent, 2013; Bandura, 1997). Therefore, by combining observing changes in self-efficacy, we can gain insights into the relationship overall interest in the topic of study. This comprehensive approach allows for a more holistic understanding of the factors influencing students' career-related interests and motivations.

How does a MOOC with a hands-on kit effect student efficacy?

The results of the self-efficacy assessments demonstrated that the blended MOOC with hands-on kits had a positive impact on participants' efficacy levels in relation to rocketry tasks. It is important to note that the participants in this study were students who voluntarily registered for the course, indicating their pre-existing interest in rocketry. Consequently, their initial efficacy scores were already relatively high. However, despite their already high efficacy levels, both the online content and the hands-on kit contributed to significant increases in efficacy by the end of the course. This indicates that both components of the course had a positive effect on participants' confidence and belief in their ability to successfully engage in rocketry-related activities.

How do personal background and learning style affect efficacy and interest?

The MOOC with hands-on kit had a positive impact on participants' career interest, as indicated by the increase in efficacy scores. According to the Social Cognitive Career Theory (SCCT), increased self-efficacy is associated with a greater likelihood of pursuing courses and careers related to the subject matter. This boost in confidence in their ability to successfully complete rocketry tasks is likely to stimulate participants' interest in pursuing further education and careers in related fields.

How does personal background and learning style effect career interest and achievement?

The analysis of personal background and learning style in this study revealed some interesting findings. Students with prior experience in rocketry demonstrated higher initial efficacy scores, indicating a greater confidence in their abilities. However, non-experienced students showed significant improvement in efficacy levels throughout the course, suggesting that they became equally confident in performing rocketry-related tasks as their experienced counterparts.

Examining the impact of genders, it was observed that female students initially scored lower than male students. However, they showed substantial improvement over the course, reaching similar scores to male students by the end. Additionally, students of all academic standing showed improvement throughout the course.

Regarding learning styles, students with active, sensing, intuitive, and global learning styles exhibited higher scores in the efficacy exam. This suggests that the blended MOOC with a hands-on kit learning platform was particularly effective in capturing the interest of undergraduate engineering students and improving their knowledge in rocketry. Based on these finding, it is recommended that the blended MOOC with a hands-on kit approach be considered for undergraduate engineering students or high school students interested in pursuing a college major in engineering.

6.2 CONCLUSION

In conclusion, this study found that the blended MOOC approach had a positive impact on student efficacy in the context of rocketry. The online videos significantly enhanced knowledge acquisition, while both the online lectures and hands-on activities contributed to increased efficacy and interest scores. Students without prior experience and female students showed significant improvements in efficacy levels, highlighting the importance of providing educational opportunities that build confidence and comfort. Students with active, sensing, visual, and global learning styles excelled in acquiring confidence in rocketry topics. Overall, the blended MOOC approach proved effective in enhancing student efficacy and generating interest in pursuing related courses and career-related topics in the future.

6.3 FUTURE STUDIES

6.3.1 INCREASING ENGAGEMENT

The results from this study showed that level of engagement is very hard to retain as the course progresses. For individual MOOC videos, there is a definite need that the videos absolutely do not go over 10 minutes. Shorter videos with good visuals to show any images, graphs, and facts seem to be the best at keeping students engaged throughout watching of the videos. To maximize the benefits and maintain the engagement of MOOCs, the instructor should well manage the student progress. For example, sending out multiple reminders and grading assignments by accuracy may further motivate students to stay focused in watching videos and thus accurately learning the course material.

6.3.2 SUGGESTED STUDIES

This study lacked in providing the extensive details regarding the sole impact of the hands-on kit itself. This study’s design involved students being exposed to the online videos first, then completing the hands-on activity afterwards, resulting in an already notable increase in scores. Consequently, the hands-on activity’s contribution to the scores was difficult to ascertain accurately. To conduct a more thorough investigation into the effect of the hands-on activity, a new study should incorporate varied groups. One group would solely engage with the online videos, another group would exclusively participate in the hands-on activity, and potentially a third controlled group would receive both components. This way, it would enable data analysis and comparison among two or three distinct groups, facilitating a more comprehensive assessment of the online course's effectiveness in comparison to the hands-on activity.

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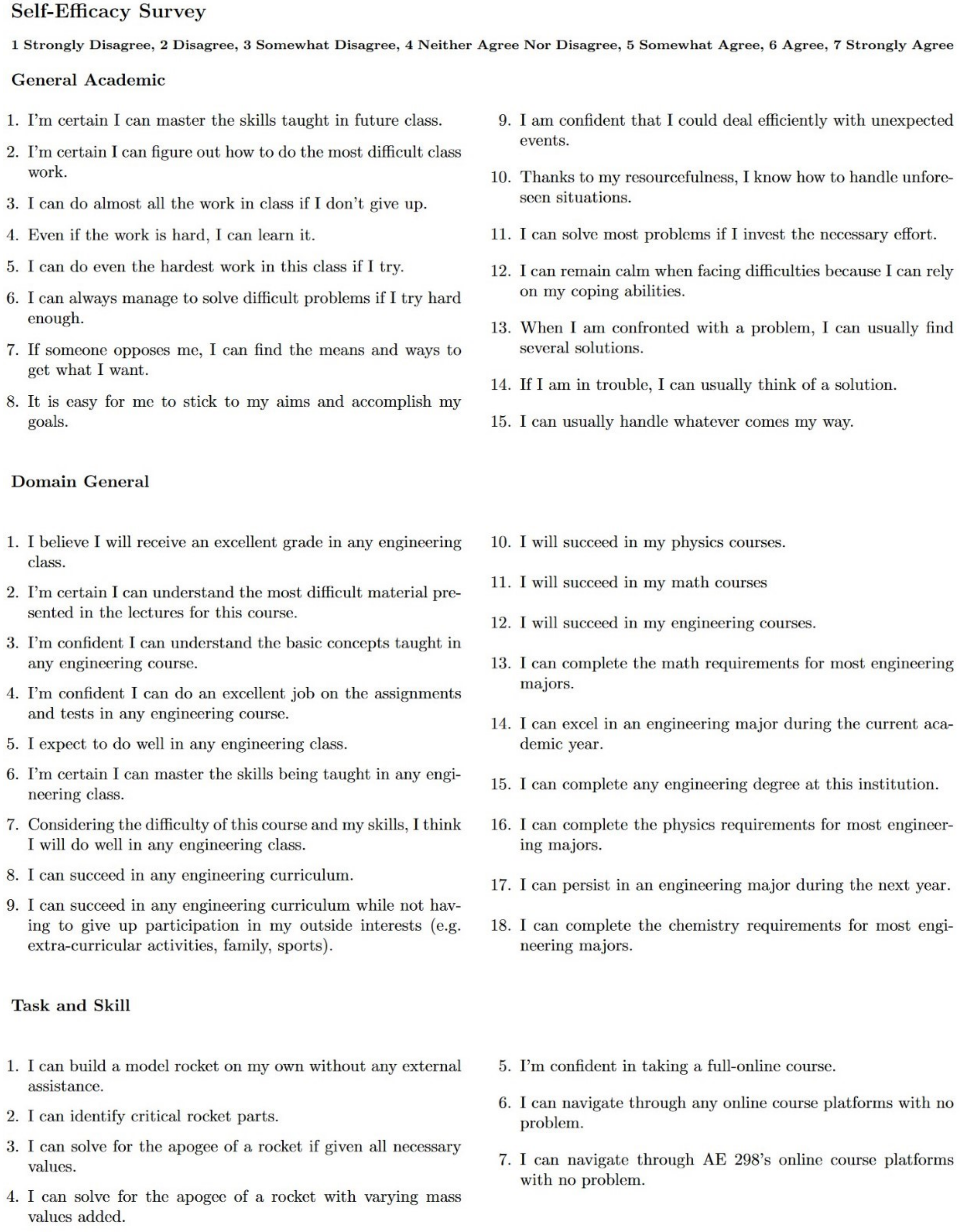
APPENDIX A: SELF EFFICACY ASSESSMENT



Self-Efficacy Survey

1 Strongly Disagree, 2 Disagree, 3 Somewhat Disagree, 4 Neither Agree Nor Disagree, 5 Somewhat Agree, 6 Agree, 7 Strongly Agree

General Academic

1. I'm certain I can master the skills taught in future class.
2. I'm certain I can figure out how to do the most difficult class work.
3. I can do almost all the work in class if I don't give up.
4. Even if the work is hard, I can learn it.
5. I can do even the hardest work in this class if I try.
6. I can always manage to solve difficult problems if I try hard enough.
7. If someone opposes me, I can find the means and ways to get what I want.
8. It is easy for me to stick to my aims and accomplish my goals.
9. I am confident that I could deal efficiently with unexpected events.
10. Thanks to my resourcefulness, I know how to handle unforeseen situations.
11. I can solve most problems if I invest the necessary effort.
12. I can remain calm when facing difficulties because I can rely on my coping abilities.
13. When I am confronted with a problem, I can usually find several solutions.
14. If I am in trouble, I can usually think of a solution.
15. I can usually handle whatever comes my way.

Domain General

1. I believe I will receive an excellent grade in any engineering class.
2. I'm certain I can understand the most difficult material presented in the lectures for this course.
3. I'm confident I can understand the basic concepts taught in any engineering course.
4. I'm confident I can do an excellent job on the assignments and tests in any engineering course.
5. I expect to do well in any engineering class.
6. I'm certain I can master the skills being taught in any engineering class.
7. Considering the difficulty of this course and my skills, I think I will do well in any engineering class.
8. I can succeed in any engineering curriculum.
9. I can succeed in any engineering curriculum while not having to give up participation in my outside interests (e.g. extra-curricular activities, family, sports).
10. I will succeed in my physics courses.
11. I will succeed in my math courses
12. I will succeed in my engineering courses.
13. I can complete the math requirements for most engineering majors.
14. I can excel in an engineering major during the current academic year.
15. I can complete any engineering degree at this institution.
16. I can complete the physics requirements for most engineering majors.
17. I can persist in an engineering major during the next year.
18. I can complete the chemistry requirements for most engineering majors.

Task and Skill

1. I can build a model rocket on my own without any external assistance.
2. I can identify critical rocket parts.
3. I can solve for the apogee of a rocket if given all necessary values.
4. I can solve for the apogee of a rocket with varying mass values added.
5. I'm confident in taking a full-online course.
6. I can navigate through any online course platforms with no problem.
7. I can navigate through AE 298's online course platforms with no problem.

APPENDIX B: SELF-EFFICACY RESULTS

Assessment		**1**		**2**		**3**		**1 → 2**		**2 → 3**		**1 → 3**	
	n	μ_1	σ_1	μ_2	σ_2	μ_3	σ_3	$\mu_2 - \mu_1$	σ_{2-1}	$\mu_3 - \mu_2$	σ_{3-2}	$\mu_3 - \mu_1$	σ_{3-1}
General Academic													
	32	5.85	0.68	6.03	0.63	6.16	0.61	0.21	0.65	0.12	0.68	0.31***	0.52
Questions													
1	32	6.19	0.82	6.32	0.79	6.41	0.61	0.13	0.99	0.10	0.79	0.22*	0.71
2	32	5.84	1.05	6.03	1.08	6.28	0.96	0.23	1.09	0.26	0.93	0.44*	1.11
3	32	6.38	0.94	6.42	0.67	6.47	0.62	0.06	0.93	0.06	0.57	0.09	0.82
4	32	6.31	0.74	6.35	0.66	6.44	0.67	0.06	0.77	0.06	0.68	0.12	0.79
5	32	6.28	0.85	6.39	0.76	6.59	0.61	0.13	0.99	0.19	0.79	0.31**	0.64
6	32	5.97	0.93	6.32	0.91	6.22	0.79	0.39	1.09	-0.10	1.11	0.25	0.95
7	32	5.22	1.50	5.39	1.20	5.62	1.24	0.23	1.52	0.23	1.31	0.41*	1.34
8	32	5.34	1.33	5.61	1.02	5.84	1.08	0.26	1.44	0.26	1.32	0.50**	1.11
9	32	5.41	0.98	5.90	0.79	6.06	0.84	0.52	1.18	0.16	0.97	0.66***	0.97
10	32	5.66	0.97	6.03	0.80	6.06	0.84	0.42	0.99	0.03	1.02	0.41*	1.01
11	32	6.12	0.71	6.23	0.72	6.28	0.73	0.13	0.81	0.06	0.81	0.16	0.68
12	32	5.91	1.00	5.90	1.01	5.97	0.93	0.03	1.17	0.06	1.41	0.06	1.08
13	32	5.25	1.41	5.71	0.90	5.81	1.00	0.48	1.48	0.06	1.18	0.56**	1.08
14	32	5.88	0.83	5.87	0.81	6.16	0.68	0.00	1.10	0.29	0.86	0.28*	0.73
15	32	5.94	0.95	6.03	0.87	6.12	1.07	0.13	1.02	0.10	1.16	0.19	0.78
Learning Styles													
Active	18	6.01	0.77	6.00	0.71	6.20	0.63	0.02	0.71	0.21	0.72	0.19	0.55
Reflective	14	5.63	0.50	6.08	0.55	6.10	0.59	0.45**	0.50	0.01	0.63	0.47**	0.45
Sensing	20	5.87	0.74	6.09	0.62	6.27	0.60	0.21	0.60	0.18	0.65	0.40**	0.54
Intuitive	12	5.80	0.61	5.94	0.68	5.97	0.59	0.21	0.77	0.01	0.74	0.17	0.47
Visual	31	5.86	0.69	6.02	0.64	6.19	0.59	0.18	0.64	0.18	0.62	0.33***	0.52
Verbal	1												
Sequential	19	5.90	0.68	6.05	0.68	6.13	0.64	0.19	0.76	0.08	0.66	0.23*	0.43
Global	13	5.77	0.70	6.01	0.59	6.19	0.57	0.24	0.50	0.18	0.73	0.43*	0.63
Year in College													
1	19	5.91	0.74	6.13	0.63	6.12	0.69	0.21	0.74	-0.01	0.66	0.21*	0.45
2	9	5.73	0.59	5.93	0.76	6.27	0.49	0.32	0.49	0.36	0.83	0.55*	0.67
3	3	5.73	0.87	5.80	0.37	6.11	0.62	0.07	0.67	0.31	0.32	0.38	0.38
4	1												
Rocketry Experience													
Yes	8	5.71	0.38	5.82	0.71	6.24	0.40	0.11	0.54	0.42	0.84	0.53*	0.60
No	24	5.89	0.76	6.11	0.60	6.13	0.67	0.25	0.70	0.02	0.60	0.24*	0.48
MOOC Experience													
Yes	21	6.05	0.59	6.15	0.59	6.34	0.48	0.10	0.54	0.20	0.63	0.30*	0.55
No	11	5.46	0.70	5.80	0.70	5.80	0.68	0.45	0.83	-0.03	0.78	0.34*	0.49
Gender													
Female	11	5.58	0.87	5.84	0.59	6.02	0.75	0.27	0.78	0.18	1.01	0.44*	0.71
Male	20	5.99	0.54	6.20	0.61	6.24	0.53	0.24	0.55	0.05	0.39	0.25**	0.40
Other	1												

$^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

Assessment		1		2		3		1 → 2		2 → 3		1 → 3	
	n	μ_1	σ_1	μ_2	σ_2	μ_3	σ_3	$\mu_2 - \mu_1$	σ_{2-1}	$\mu_3 - \mu_2$	σ_{3-2}	$\mu_3 - \mu_1$	σ_{3-1}
Domain General													
	32	5.70	0.95	5.91	1.07	5.97	0.92	0.23	0.97	0.10	1.06	0.27*	0.67
Questions													
1	32	5.62	1.26	5.74	1.34	5.69	1.35	0.13	1.28	-0.03	1.45	0.06	1.08
2	32	5.91	0.89	6.23	0.88	6.44	0.62	0.32	1.14	0.23	0.84	0.53***	0.76
3	32	6.19	0.97	6.32	0.83	6.44	0.76	0.13	1.26	0.13	0.99	0.25	0.92
4	32	5.47	1.48	6.00	1.21	5.75	1.41	0.58	1.65	-0.26	1.73	0.28	1.28
5	32	5.38	1.58	5.81	1.56	5.69	1.49	0.45	1.48	-0.06	1.57	0.31	1.35
6	32	5.72	1.14	5.94	1.34	5.97	1.36	0.26	1.09	0.10	1.33	0.25	1.41
7	32	5.38	1.48	5.81	1.42	5.84	1.42	0.48	1.59	0.10	1.66	0.47*	1.39
8	32	5.34	1.41	5.68	1.54	5.66	1.54	0.39	1.38	0.10	1.81	0.31	1.96
9	32	4.84	1.85	4.97	1.89	5.09	1.82	0.19	1.87	0.23	1.84	0.25	1.88
10	32	5.84	1.05	5.90	1.11	6.09	0.93	0.10	1.16	0.16	0.90	0.25	0.95
11	32	5.94	0.88	6.10	0.98	6.06	1.05	0.19	0.95	-0.06	0.93	0.12	0.87
12	32	6.06	0.88	6.06	1.00	6.00	1.05	0.03	1.02	0.00	1.10	-0.06	0.98
13	32	6.44	0.76	6.29	1.16	6.62	0.66	-0.13	1.15	0.32	0.98	0.19	0.64
14	32	5.97	1.31	5.81	1.66	6.09	1.06	-0.13	1.65	0.26	1.32	0.12	0.94
15	32	5.19	1.94	5.48	1.73	5.88	1.34	0.19	2.30	0.52	1.73	0.69**	1.53
16	32	6.06	1.32	6.19	1.05	6.16	1.17	0.16	1.10	-0.06	1.03	0.09	0.82
17	32	6.25	1.08	6.26	1.21	6.34	0.97	0.03	1.35	0.06	1.31	0.09	0.69
18	32	5.03	1.75	5.74	1.61	5.69	1.84	0.68	1.87	0.10	2.13	0.66**	1.47
Learning Styles													
Active	18	5.81	0.86	5.80	1.12	6.08	0.84	0.02	0.84	0.35	0.99	0.27	0.76
Reflective	14	5.56	1.07	6.03	1.04	5.83	1.03	0.47	1.09	-0.20	1.08	0.27*	0.56
Sensing	20	5.92	0.72	5.94	1.04	6.24	0.66	0.02	0.83	0.30	0.96	0.32*	0.58
Intuitive	12	5.33	1.19	5.84	1.18	5.52	1.13	0.61	1.12	-0.26	1.18	0.19	0.80
Visual	31	5.78	0.87	5.90	1.09	6.05	0.83	0.14	0.87	0.19	0.96	0.27*	0.68
Verbal	1												
Sequential	19	5.72	1.10	5.94	1.05	5.91	1.02	0.25	0.85	0.02	0.75	0.19	0.62
Global	13	5.68	0.73	5.86	1.14	6.07	0.78	0.19	1.15	0.21	1.41	0.39*	0.74
Year in College													
1	19	5.76	0.96	6.18	0.79	5.98	1.01	0.42*	0.94	-0.20	0.88	0.22*	0.44
2	9	5.57	1.12	5.36	1.58	5.94	0.93	-0.12	1.09	0.71	1.42	0.36	1.08
3	3	6.00	0.29	5.93	0.78	6.26	0.31	-0.07	1.06	0.33	0.51	0.26	0.60
4	1												
Rocketry Experience													
Yes	8	5.99	0.49	5.73	1.33	6.39	0.50	-0.26	0.97	0.66	1.43	0.40	0.70
No	24	5.61	1.05	5.97	0.99	5.83	0.99	0.39	0.93	-0.09	0.85	0.23	0.66
MOOC Experience													
Yes	21	5.97	0.64	6.07	0.97	6.23	0.66	0.11	0.93	0.16	1.11	0.26*	0.58
No	11	5.20	1.25	5.56	1.23	5.48	1.15	0.47	1.06	-0.02	0.98	0.28	0.84
Gender													
Female	11	5.20	1.24	5.39	1.38	5.75	1.09	0.19	1.26	0.36	1.54	0.55*	0.66
Male	20	5.96	0.67	6.25	0.73	6.09	0.84	0.30	0.78	-0.09	0.65	0.13	0.65
Other	1												

$^*p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

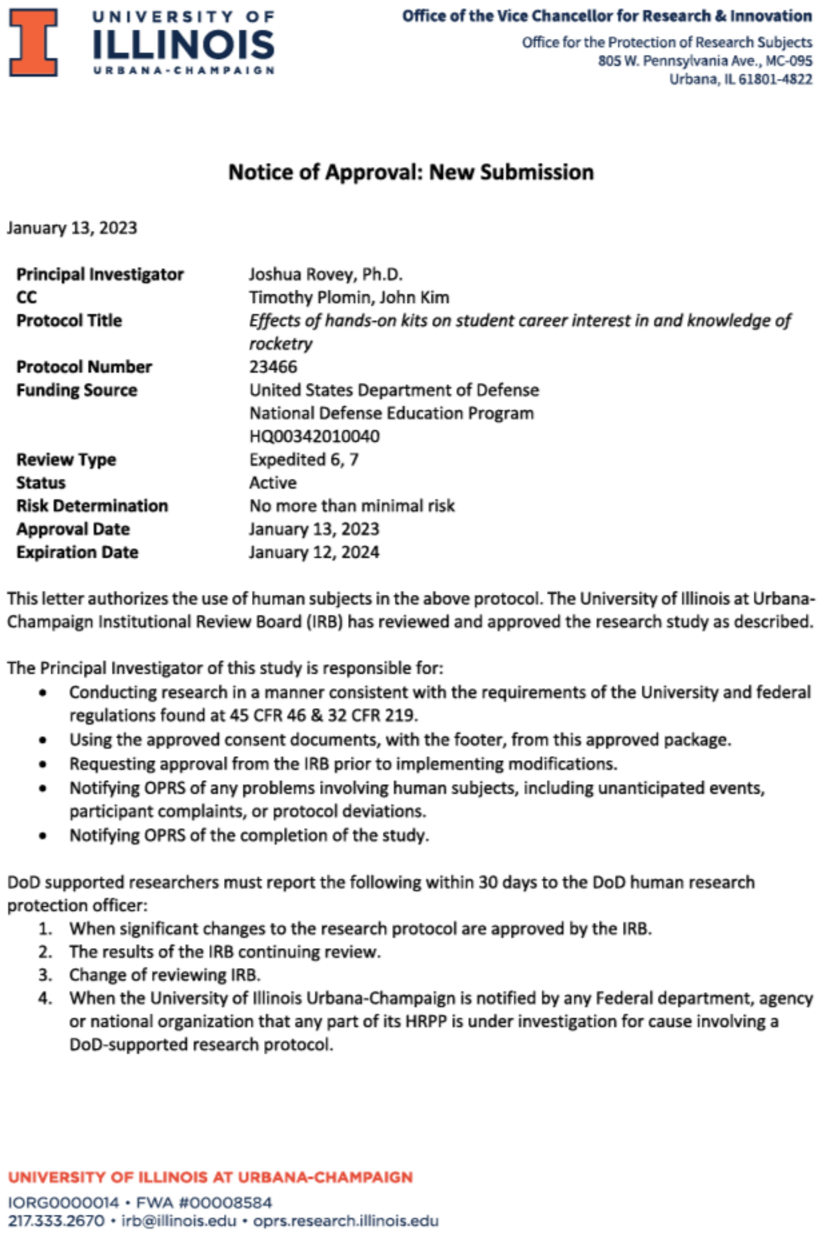
Assessment		**1**		**2**		**3**		**1 → 2**		**2 → 3**		**1 → 3**	
	n	μ_1	σ_1	μ_2	σ_2	μ_3	σ_3	$\mu_2 - \mu_1$	σ_{2-1}	$\mu_3 - \mu_2$	σ_{3-2}	$\mu_3 - \mu_1$	σ_{3-1}
Task and Skill Rocketry													
	32	2.68	1.36	5.44	1.02	6.09	0.79	2.72	1.46	0.66	1.06	3.41***	1.35
Questions													
1	32	2.91	1.61	3.97	1.70	5.56	1.37	1.03	2.17	1.61	1.93	2.66***	1.54
2	32	3.09	1.61	5.74	1.00	6.34	0.60	2.61	1.91	0.61	1.09	3.25***	1.63
3	32	2.53	1.85	6.19	1.08	6.28	0.68	3.61	1.78	0.10	1.04	3.75***	1.88
4	32	2.19	1.65	5.84	1.19	6.16	0.92	3.61	1.61	0.32	1.14	3.97***	1.71
Learning Styles													
Active	18	2.74	1.47	5.50	0.96	6.29	0.61	2.69	1.51	0.82	1.09	3.56***	1.54
Reflective	14	2.61	1.25	5.36	1.12	5.82	0.93	2.75***	1.46	0.46	1.03	3.21***	1.07
Sensing	20	2.82	1.40	5.60	0.85	6.31	0.62	2.77***	1.42	0.71**	1.05	3.49***	1.54
Intuitive	12	2.44	1.30	5.14	1.27	5.71	0.92	2.61	1.61	0.57	1.12	3.27***	0.99
Visual	31	2.73	1.34	5.44	1.04	6.15	0.71	2.67	1.46	0.72	1.01	3.42***	1.37
Verbal	1												
Sequential	19	2.55	1.34	5.56	0.97	5.97	0.74	2.94	1.25	0.43	0.96	3.42***	1.39
Global	13	2.87	1.41	5.27	1.11	6.25	0.87	2.40***	1.72	0.98**	1.14	3.38***	1.34
Year in College													
1	19	2.76	1.39	5.53	1.04	6.16	0.80	2.76***	1.60	0.63**	0.97	3.39***	1.37
2	9	2.61	1.54	5.25	1.25	6.03	0.79	2.50	1.43	0.81	1.38	3.42***	1.27
3	3	2.58	1.18	5.50	0.00	5.83	1.13	2.92*	1.18	0.33	1.13	3.25	2.18
4	1												
Rocketry Experience													
Yes	8	3.53	1.59	5.38	0.92	6.25	0.73	1.84**	1.38	0.88	1.39	2.72**	1.65
No	24	2.40	1.17	5.46	1.07	6.03	0.82	3.02	1.39	0.59	0.94	3.64***	1.18
MOOC Experience													
Yes	21	2.80	1.34	5.57	1.11	6.31	0.60	2.77***	1.55	0.74**	1.07	3.51***	1.51
No	11	2.45	1.42	5.15	0.78	5.66	0.96	2.60	1.33	0.50	1.07	3.20***	1.02
Gender													
Female	11	2.32	1.23	5.36	1.24	5.89	0.90	3.05***	1.36	0.52	1.45	3.57***	1.25
Male	20	2.71	1.24	5.41	0.89	6.20	0.75	2.63	1.50	0.82	0.74	3.49***	1.23
Other	1												

$^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

Assessment		**1**		**2**		**3**		**1 → 2**		**2 → 3**		**1 → 3**	
	n	μ_1	σ_1	μ_2	σ_2	μ_3	σ_3	$\mu_2 - \mu_1$	σ_{2-1}	$\mu_3 - \mu_2$	σ_{3-2}	$\mu_3 - \mu_1$	σ_{3-1}
Task and Skill Online													
	32	5.64	1.19	5.97	1.27	6.28	0.79	0.24	1.24	0.33	1.04	0.65**	1.19
Questions													
1	32	5.97	1.26	6.16	1.32	6.34	0.94	0.13	1.61	0.19	1.17	0.38	1.39
2	32	5.41	1.46	5.94	1.46	6.13	1.28	0.45	1.43	0.20	1.67	0.71	1.79
3	32	5.53	1.48	5.81	1.49	6.38	1.01	0.13	1.57	0.61	1.38	0.84***	1.19
Learning Styles													
Active	18	5.61	1.39	5.90	1.22	6.41	0.70	0.12	1.13	0.55	1.17	0.80**	1.18
Reflective	14	5.67	0.91	6.05	1.38	6.12	0.88	0.38	1.39	0.07	0.83	0.45	1.22
Sensing	20	6.13	0.74	6.05	1.19	6.37	0.82	-0.08	1.04	0.32	1.11	0.23	0.97
Intuitive	12	4.81	1.34	5.82	1.46	6.14	0.74	0.82	1.41	0.36	0.97	1.33**	1.24
Visual	31	5.67	1.19	5.93	1.28	6.26	0.79	0.17	1.20	0.34	1.06	0.59**	1.17
Verbal	1												
Sequential	19	5.61	1.17	6.26	1.05	6.35	0.66	0.48	0.87	0.13	0.85	0.74**	1.03
Global	13	5.67	1.26	5.56	1.47	6.18	0.96	-0.10	1.60	0.62	1.25	0.51	1.43
Year in College													
1	19	5.98	1.03	6.04	1.26	6.35	0.76	0.05	0.98	0.32	0.95	0.37	0.96
2	9	4.93	1.30	6.08	1.22	6.33	0.60	0.87	1.28	0.33	1.51	1.41**	1.19
3	3	6.00	1.00	5.22	1.95	5.67	1.53	-0.78	2.04	0.44	0.51	-0.33	1.53
4	1												
Rocketry Experience													
Yes	8	5.96	0.49	5.62	1.57	5.96	1.01	-0.33	1.32	0.33	1.51	-0.00	1.21
No	24	5.53	1.33	6.09	1.17	6.39	0.69	0.43	1.17	0.33	0.87	0.86***	1.13
MOOC Experience													
Yes	21	6.03	0.95	6.08	1.21	6.44	0.66	0.05	0.90	0.37	1.16	0.41*	0.92
No	11	4.88	1.26	5.73	1.44	5.97	0.94	0.63	1.75	0.27	0.80	1.09*	1.54
Gender													
Female	11	6.00	1.01	6.12	1.24	6.42	0.63	0.12	1.21	0.30	1.45	0.42	1.04
Male	20	5.42	1.27	5.86	1.34	6.22	0.88	0.30	1.31	0.39	0.79	0.80**	1.29
Other	1												

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

APPENDIX C: PROTECTION OF RESEARCH SUBJECTS



UNIVERSITY OF ILLINOIS
URBANA-CHAMPAIGN

Office of the Vice Chancellor for Research & Innovation
Office for the Protection of Research Subjects
805 W. Pennsylvania Ave., MC-095
Urbana, IL 61801-4822

Notice of Approval: New Submission

January 13, 2023

Principal Investigator	Joshua Rovey, Ph.D.
CC	Timothy Plomin, John Kim
Protocol Title	*Effects of hands-on kits on student career interest in and knowledge of rocketry*
Protocol Number	23466
Funding Source	United States Department of Defense National Defense Education Program HQ00342010040
Review Type	Expedited 6, 7
Status	Active
Risk Determination	No more than minimal risk
Approval Date	January 13, 2023
Expiration Date	January 12, 2024

This letter authorizes the use of human subjects in the above protocol. The University of Illinois at Urbana-Champaign Institutional Review Board (IRB) has reviewed and approved the research study as described.

The Principal Investigator of this study is responsible for:

- Conducting research in a manner consistent with the requirements of the University and federal regulations found at 45 CFR 46 & 32 CFR 219.
- Using the approved consent documents, with the footer, from this approved package.
- Requesting approval from the IRB prior to implementing modifications.
- Notifying OPRS of any problems involving human subjects, including unanticipated events, participant complaints, or protocol deviations.
- Notifying OPRS of the completion of the study.

DoD supported researchers must report the following within 30 days to the DoD human research protection officer:

1. When significant changes to the research protocol are approved by the IRB.
2. The results of the IRB continuing review.
3. Change of reviewing IRB.
4. When the University of Illinois Urbana-Champaign is notified by any Federal department, agency or national organization that any part of its HRPP is under investigation for cause involving a DoD-supported research protocol.

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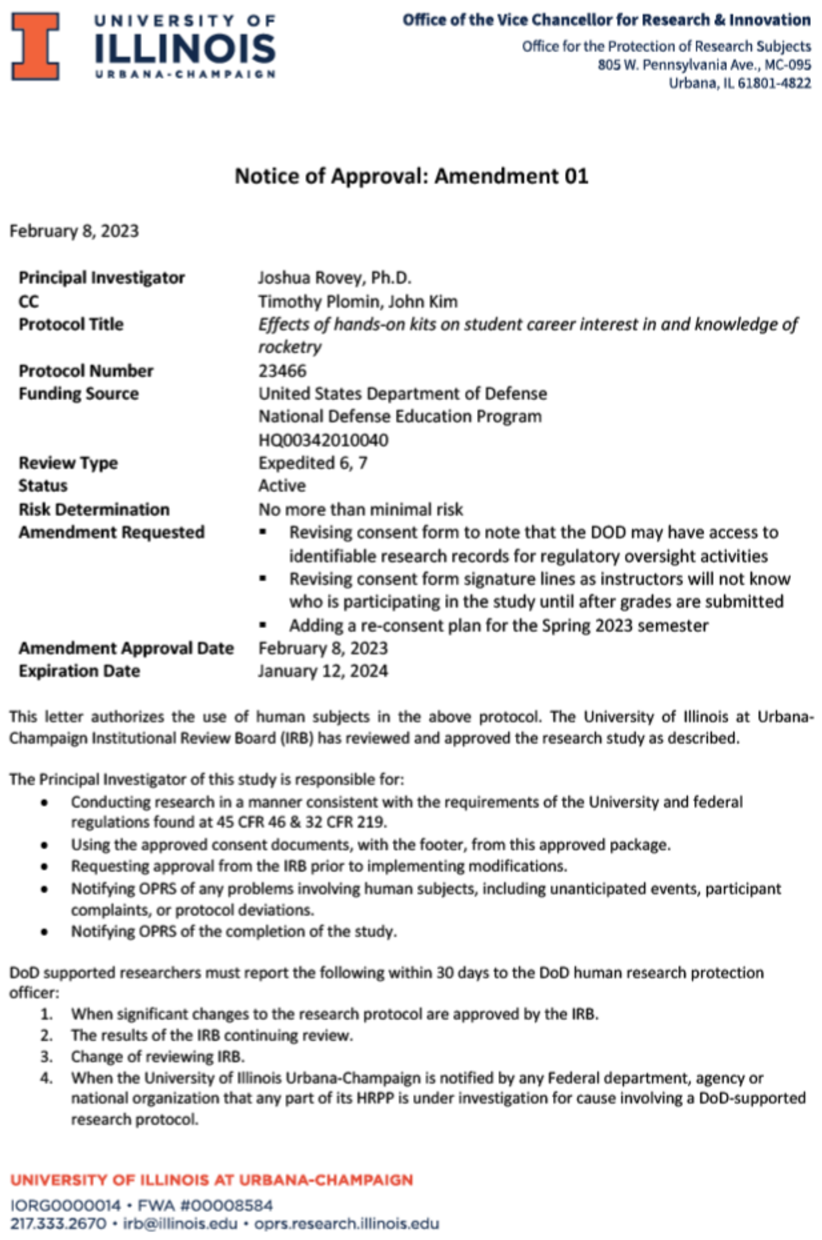

UNIVERSITY OF ILLINOIS
URBANA-CHAMPAIGN

Office of the Vice Chancellor for Research & Innovation
Office for the Protection of Research Subjects
805 W. Pennsylvania Ave., MC-095
Urbana, IL 61801-4822

Notice of Approval: Amendment 01

February 8, 2023

Principal Investigator	Joshua Rovey, Ph.D.
CC	Timothy Plomin, John Kim
Protocol Title	*Effects of hands-on kits on student career interest in and knowledge of rocketry*
Protocol Number	23466
Funding Source	United States Department of Defense National Defense Education Program HQ00342010040
Review Type	Expedited 6, 7
Status	Active
Risk Determination	No more than minimal risk
Amendment Requested	▪ Revising consent form to note that the DOD may have access to identifiable research records for regulatory oversight activities ▪ Revising consent form signature lines as instructors will not know who is participating in the study until after grades are submitted ▪ Adding a re-consent plan for the Spring 2023 semester
Amendment Approval Date	February 8, 2023
Expiration Date	January 12, 2024

This letter authorizes the use of human subjects in the above protocol. The University of Illinois at Urbana-Champaign Institutional Review Board (IRB) has reviewed and approved the research study as described.

The Principal Investigator of this study is responsible for:

- Conducting research in a manner consistent with the requirements of the University and federal regulations found at 45 CFR 46 & 32 CFR 219.
- Using the approved consent documents, with the footer, from this approved package.
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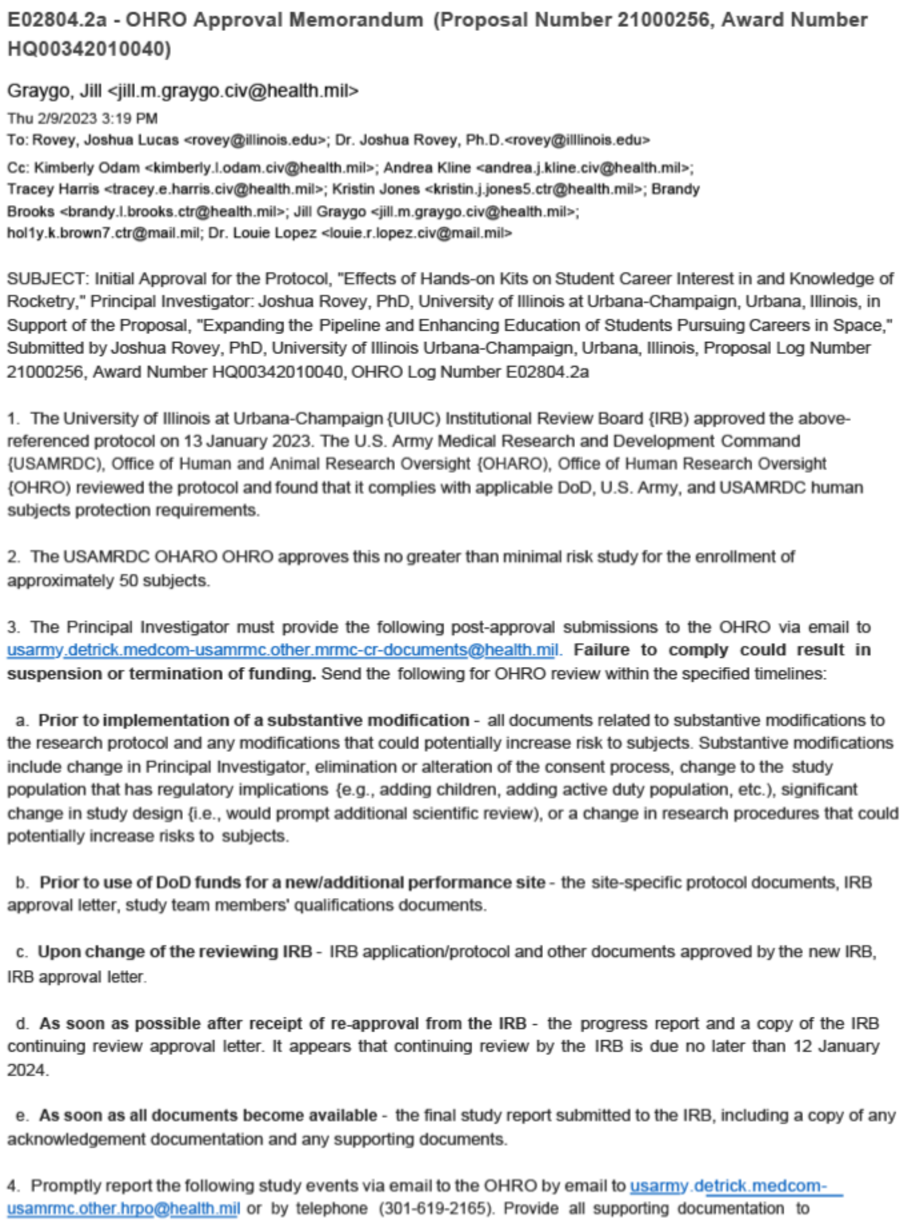
APPENDIX D: U.S. ARMY RESEARCH APPROVAL LETTER



E02804.2a - OHRO Approval Memorandum (Proposal Number 21000256, Award Number HQ00342010040)

Graygo, Jill <jill.m.graygo.civ@health.mil>
Thu 2/9/2023 3:19 PM
To: Rovey, Joshua Lucas <rovey@illinois.edu>; Dr. Joshua Rovey, Ph.D.<rovey@illlinois.edu>
Cc: Kimberly Odam <kimberly.l.odam.civ@health.mil>; Andrea Kline <andrea.j.kline.civ@health.mil>; Tracey Harris <tracey.e.harris.civ@health.mil>; Kristin Jones <kristin.j.jones5.ctr@health.mil>; Brandy Brooks <brandy.l.brooks.ctr@health.mil>; Jill Graygo <jill.m.graygo.civ@health.mil>; hol1y.k.brown7.ctr@mail.mil; Dr. Louie Lopez <louie.r.lopez.civ@mail.mil>

SUBJECT: Initial Approval for the Protocol, "Effects of Hands-on Kits on Student Career Interest in and Knowledge of Rocketry," Principal Investigator: Joshua Rovey, PhD, University of Illinois at Urbana-Champaign, Urbana, Illinois, in Support of the Proposal, "Expanding the Pipeline and Enhancing Education of Students Pursuing Careers in Space," Submitted by Joshua Rovey, PhD, University of Illinois Urbana-Champaign, Urbana, Illinois, Proposal Log Number 21000256, Award Number HQ00342010040, OHRO Log Number E02804.2a

1. The University of Illinois at Urbana-Champaign (UIUC) Institutional Review Board (IRB) approved the above-referenced protocol on 13 January 2023. The U.S. Army Medical Research and Development Command (USAMRDC), Office of Human and Animal Research Oversight (OHARO), Office of Human Research Oversight (OHRO) reviewed the protocol and found that it complies with applicable DoD, U.S. Army, and USAMRDC human subjects protection requirements.

2. The USAMRDC OHARO OHRO approves this no greater than minimal risk study for the enrollment of approximately 50 subjects.

3. The Principal Investigator must provide the following post-approval submissions to the OHRO via email to usarmy.detrick.medcom-usamrmc.other.mrmc-cr-documents@health.mil. **Failure to comply could result in suspension or termination of funding.** Send the following for OHRO review within the specified timelines:

a. **Prior to implementation of a substantive modification** - all documents related to substantive modifications to the research protocol and any modifications that could potentially increase risk to subjects. Substantive modifications include change in Principal Investigator, elimination or alteration of the consent process, change to the study population that has regulatory implications (e.g., adding children, adding active duty population, etc.), significant change in study design (i.e., would prompt additional scientific review), or a change in research procedures that could potentially increase risks to subjects.

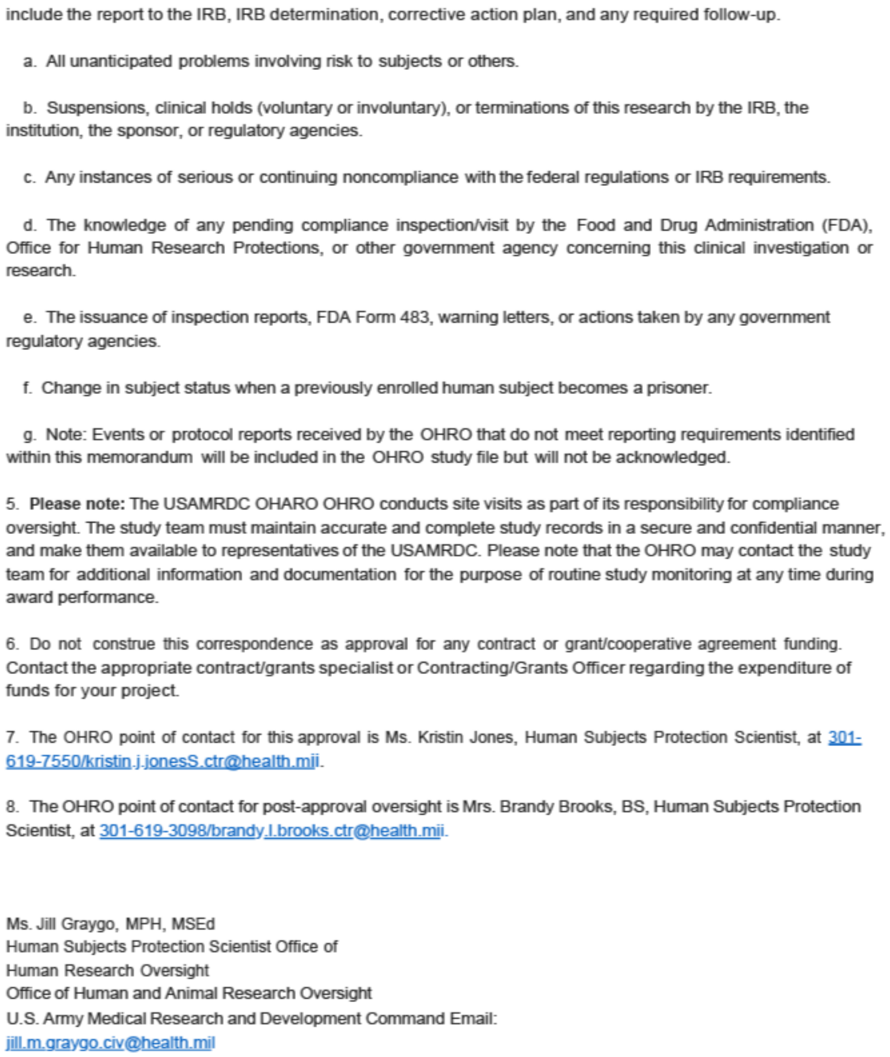
b. **Prior to use of DoD funds for a new/additional performance site** - the site-specific protocol documents, IRB approval letter, study team members' qualifications documents.

c. **Upon change of the reviewing IRB** - IRB application/protocol and other documents approved by the new IRB, IRB approval letter.

d. **As soon as possible after receipt of re-approval from the IRB** - the progress report and a copy of the IRB continuing review approval letter. It appears that continuing review by the IRB is due no later than 12 January 2024.

e. **As soon as all documents become available** - the final study report submitted to the IRB, including a copy of any acknowledgement documentation and any supporting documents.

4. Promptly report the following study events via email to the OHRO by email to usarmy.detrick.medcom-usamrmc.other.hrpo@health.mil or by telephone (301-619-2165). Provide all supporting documentation to



include the report to the IRB, IRB determination, corrective action plan, and any required follow-up.

a. All unanticipated problems involving risk to subjects or others.

b. Suspensions, clinical holds (voluntary or involuntary), or terminations of this research by the IRB, the institution, the sponsor, or regulatory agencies.

c. Any instances of serious or continuing noncompliance with the federal regulations or IRB requirements.

d. The knowledge of any pending compliance inspection/visit by the Food and Drug Administration (FDA), Office for Human Research Protections, or other government agency concerning this clinical investigation or research.

e. The issuance of inspection reports, FDA Form 483, warning letters, or actions taken by any government regulatory agencies.

f. Change in subject status when a previously enrolled human subject becomes a prisoner.

g. Note: Events or protocol reports received by the OHRO that do not meet reporting requirements identified within this memorandum will be included in the OHRO study file but will not be acknowledged.

5. **Please note:** The USAMRDC OHARO OHRO conducts site visits as part of its responsibility for compliance oversight. The study team must maintain accurate and complete study records in a secure and confidential manner, and make them available to representatives of the USAMRDC. Please note that the OHRO may contact the study team for additional information and documentation for the purpose of routine study monitoring at any time during award performance.

6. Do not construe this correspondence as approval for any contract or grant/cooperative agreement funding. Contact the appropriate contract/grants specialist or Contracting/Grants Officer regarding the expenditure of funds for your project.

7. The OHRO point of contact for this approval is Ms. Kristin Jones, Human Subjects Protection Scientist, at 301-619-7550/kristin.j.jonesS.ctr@health.mii.

8. The OHRO point of contact for post-approval oversight is Mrs. Brandy Brooks, BS, Human Subjects Protection Scientist, at 301-619-3098/brandy.l.brooks.ctr@health.mii.

Ms. Jill Graygo, MPH, MSEd
Human Subjects Protection Scientist Office of
Human Research Oversight
Office of Human and Animal Research Oversight
U.S. Army Medical Research and Development Command Email:
jill.m.graygo.civ@health.mil