Lunar Dash: A STEM Education Board Game

Stefanina Adrianza[1] and Sreenidhi Muppiri[2]
University of Georgia, Athens, Georgia, 30602, United States

Jonathan P. Squires[3]
University of Georgia, Athens, Georgia, 30602, United States

Ramana M. Pidaparti[4]
University of Georgia, Athens, Georgia, 30602, United States

A strong and innovative aerospace workforce is essential for addressing the challenges of the coming decades, from sustainable aviation and space exploration to national security. Building a workforce that is diverse, well-prepared, and forward thinking is not only vital for the aerospace sector but also critical for maintaining national and global leadership in science and technology. Middle school students represent a key part of this future pipeline. Research shows that students begin forming long term academic and career interests between grades 5 and 8, making this a crucial period to spark curiosity and confidence in STEM fields. Early engagement through hands-on activities, relatable role models, and creative learning experiences lays the foundation for the next generation of aerospace innovators, problem solvers, and explorers. In this context, our team at UGA is developing a space-themed educational board game, *Lunar Dash*, designed to introduce core STEM concepts in a fun and accessible way. The game is built on three design principles: creativity, collaboration, and systems thinking. Either by coordinating plans with one another, answering aerospace related prompts on cards, or designing rockets as given by their mission, students will experience a blend of storytelling with hands-on problem solving as they are exposed to the microcosms of how engineers approach real-world challenges. The game board, cards, and character pieces are currently being finalized, and we plan to conduct play tests with our target audience in the coming months. Based on our development process, we believe this game has strong potential to support teachers and inspire young learners by providing an engaging, interactive platform for exploring STEM and aerospace concepts.

[1] Undergraduate Student, College of Engineering, and Student Member, 1923898.
[2] Undergraduate Student, College of Engineering, and Student Member, 1923578.
[3] PhD Student, School of Computing, Young Professional Member.
[4] Professor, College of Engineering, 712B Boyd Research Center, Associate Fellow, Professional Member.

I. Introduction

In recent years, increasing emphasis has been placed on science, technology, engineering, and mathematics (STEM) education at the elementary and middle school levels, driven by the growing demand for a STEM-skilled workforce in US towards pursuing jobs focused in engineering industries[3]. Establishing a strong STEM foundation during the K–8 years is critical to sustaining the long-term growth and vitality of these fields. Further, preparing students at an early age to compete in a global economy further underscores the need to cultivate future STEM-oriented leaders capable of advancing technological and engineering innovation.

Early exposure to engaging and applied STEM learning has been shown to influence students' interest in pursuing STEM degrees and careers later in their schooling[4]. Game-based learning (GBL) offers a compelling instructional approach by combining competition, collaboration, and inclusivity to reinforce classroom concepts while increasing student motivation and engagement[2]. Integrating GBL, and other non-traditional pedagogical methods and techniques into K-12 aerospace education has been shown to enhance student experiential learning while fostering essential engineering competencies like design-thinking, resource management, and effective communication[6,7].

This educational opportunity coincides with a renewed public and student interest in aerospace engineering. The aerospace sector is experiencing a resurgence driven by frequent commercial launch activity such as SpaceX's relentless launch schedule and landmark exploration initiatives such as NASA's Artemis program, which marks humanity's return to the Moon. Advances and milestones anticipated in the 2030s signal a transformative era in space exploration that resonates strongly with the next generation of learners and engineers.

To leverage this momentum and strengthen STEM learning among elementary and middle school students, we developed *Lunar Dash*, a board game centered on a mission voyage to the Moon. Designed to introduce aerospace systems concepts through interactive play, *Lunar Dash* aims to reinforce STEM skills while sustaining curiosity and engagement. This paper presents the game's development process, including iterative prototyping, classroom-informed testing, and final design refinement.

II. Development, Evolution, and Iterations of *Lunar Dash*

A. Development

The inspiration for *Lunar Dash* stems from a clear gap in the tabletop game market. After researching several board game forums, we found that players consistently lament the lack of a "solid space game," particularly one that targets STEM development for the K-8 age range.

Initially, a foundational concept was first developed between 2020 and 2021 by a capstone design team from the University of Georgia's (UGA) College of Engineering[1] (Fig. 1) and a first iteration produced from 2023-2024 (Fig. 2) [8]. To further expand and build the concepts, we have significantly expanded on this idea to align with current STEM teaching standards through new testing data.

Lunar Dash provides an engaging STEM learning experience for K–8 students by incorporating design-thinking principles into gameplay. The game promotes interest in STEM through two core features. First, its rules are structured around design-thinking strategies, introducing players to how engineers approach problem-solving and decision-making. Second, progression through the game requires players to answer age-appropriate STEM questions, reinforcing conceptual understanding while maintaining accessibility across grade levels.

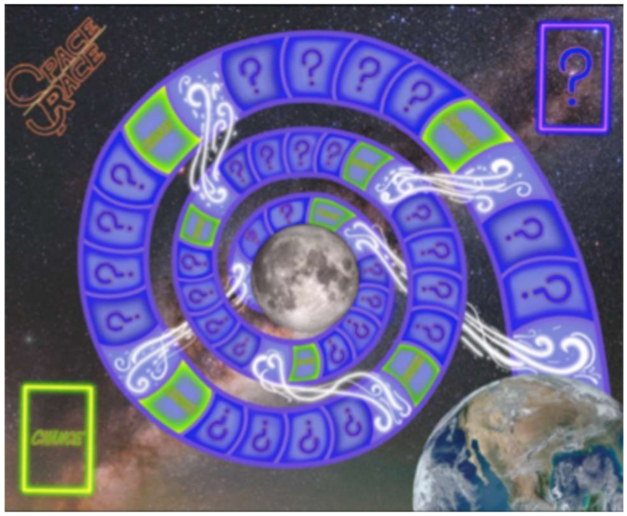

Fig. 1: First-Ever Conceptual Drawing of *Lunar Dash*, Initially Titled *Space Race*

The capstone group incorporated the use of Chance and Question cards, and Missions that players had to complete before successfully reaching the Moon, in their theoretical game board. These elements were later included in the first iteration of the game (Fig. 2). The board consisted of multi-colored squares forming a square spiral, leading to the moon. The path was made up of six different spaces: pink, blue, green, and orange Question spaces, Chance spaces, and STAR spaces. At the center of the board lies the Moon and a bright red rocket with *Lunar Dash* labeled on it (Fig. 2).

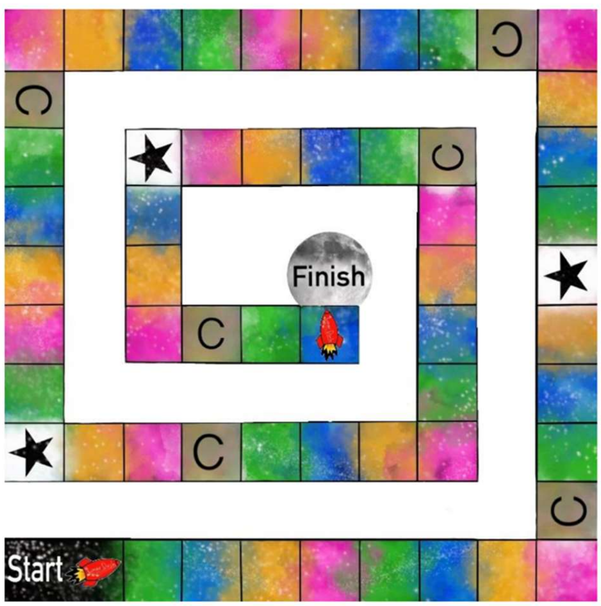

Fig. 2: *Lunar Dash*, First Iterative Design

The second iterative design (Fig. 3) features many of the same aesthetic changes incorporated in the first iterative design; the game board includes multi-colored Question spaces, Chance spaces, STAR spaces, and newly-added wormholes. The spiral at the end curls towards the Moon, featuring an enlarged, landed rocket. Select tiles include nebulas and galaxies to break up design monotony.

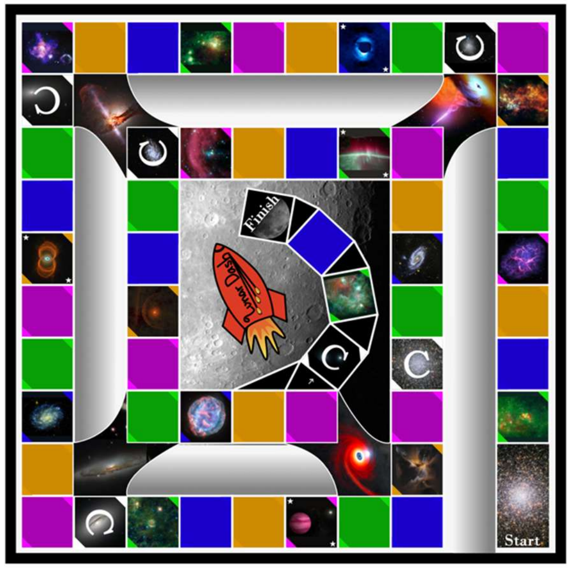

Fig. 3: *Lunar Dash*, Second Iterative Design

Several play tests were conducted using the second iterative design of *Lunar Dash*.

B. Methodology and Reiterative Process

The reiteration process of our design followed a design thinking process approach from Stanford University[5]:

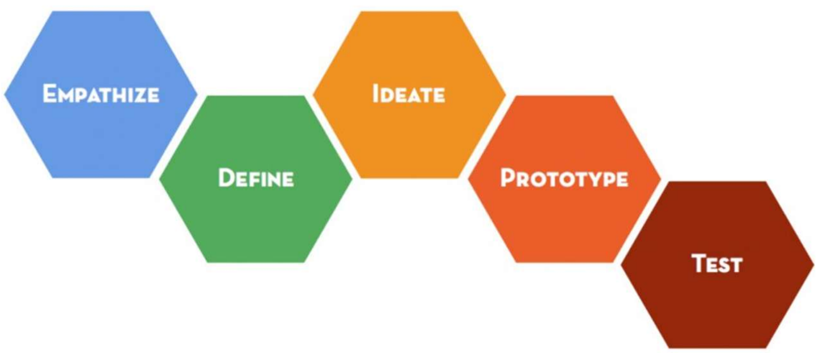

Fig. 4: Design Thinking Process

When completing the second reiteration of *Lunar Dash*, these steps were reevaluated from the first iteration:

Empathize: We reexamined the game's core influence to ensure maximum engagement for our target audience, focusing on sparking genuine excitement for STEM and aerospace concepts.
Define: Our mission was formalized: To develop an educational STEM experience that introduces foundational aerospace concepts to children aged 8–14 within the classroom.
Ideate: By analyzing previous testing data, a targeted brainstorming session was held to identify specific mechanical and aesthetic improvements for the game.
Prototype: We developed an updated prototype incorporating these enhancements. Design aspects, including the board layout and card faces, were refined in Inkscape, while the custom rocket pieces were modeled in Inventor for 3D printing.
Test: To validate the second iteration, we conducted testing with 12 distinct groups (six K–5 groups and six 6–8 groups) to gather comprehensive feedback.

Following this phase, a final iteration was performed to ensure all insights and data gathered during testing were fully integrated into the final design.

III. Game Components

A. Game Information

Objective of the Game:
The first player to complete their mission and reach the moon is the winner!

Game Board Contents:
Game board, rules sheet, rocket pieces, timer, dice, card deck including Chance cards, plum, indigo, magenta, and teal question cards, and STAR cards.

Preface:
This game is best played with two or more (up to 4) players that may compete individually, or in teams. To make this game suitable for students across K-8, we have created two sets of question cards for students in K-5 and 6-8, respectively. The questions formulated for each group have been created based on the Georgia Department of Education's STEM framework and standards for elementary and middle school curriculums, respectively.

Game Rules:

1. Each player/team will select a colored rocket base piece and place it at the START position.
2. Each player will select a Mission card corresponding to the color of their rocket base.
3. To determine which player will go first, all players will roll the dice. Whoever rolls the highest number will begin the round, and players will continue in clockwise order.
4. The first player rolls one die and moves forward the number of spaces rolled.
    1. If the player lands on a colored question space, the player to their left will select a Question card from the pile of Question cards of the corresponding color as the space. If the initial player answers the question correctly, they will move their piece the designated number of spaces forward. If they answer incorrectly, they will not move their piece forward.
    2. If the player lands on a Chance tile (C), they must select a Chance card and follow the instructions on the card.
    3. If the player lands on a STAR tile, or moves over a STAR tile during their turn, they must select a STAR card and follow the instructions on the card.
5. The game ends when a player successfully rolls a perfect number of tiles to reach the Moon. For example, if the player is exactly two spaces away from the FINISH tile, only a 2 rolled with the dice will allow the player to reach the FINISH tile. Whoever reaches the Moon first while completing their mission wins!

B. Mission Cards

Each player is randomly assigned a Mission card according to their selected colored rocket base piece before the game starts. The Mission cards provide students with a unique goal for designing and building their rocket. Players will build their rockets according to mission-specific criteria. These cards encourage and develop design thinking skills and demonstrate to students that choosing different design elements can vastly alter the entire mission for the rocket. The Mission cards also demonstrate that different combinations of design choices will result in different maximums and minimums in rocketry criteria such as thrust, payload, velocity, and range.

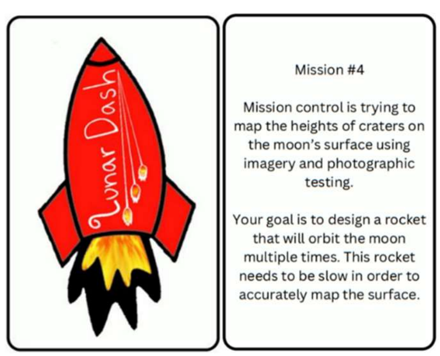

Fig. 4: Example of a Mission Card

C. Question Cards

The use of Question cards incorporates STEM education in the game. Questions were developed for the elementary mode (K-5), the middle mode (6-8), and the hard mode. Each mode features questions in science, technology, aerospace, and math; there are 15 questions in each category, individually, totaling 60 questions per mode. Successfully answering "easier" questions in the chosen mode allows the player to move ahead 1 space; answering "harder" questions allows the players to move ahead 2 spaces. When a player answers a question incorrectly, they are not penalized, and instead stay in the same spot they were at initially.

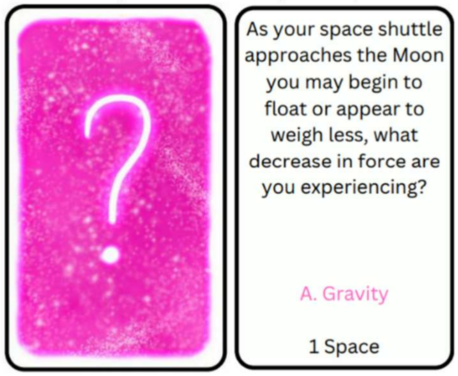

Fig. 5: Example of a Question Card

D. Chance Cards

When players land on spaces with 'C' markings, they draw a Chance card from the stack. Each Chance card showcases a real-life scenario or fact related to lunar travel and has an action for the player to complete. The actions range from skipping the player's next turn, rolling again, switching spaces with another placer, moving forward a specific number of spaces, or moving all the way back to start. These cards provide some unique challenges for students, and provide them with unexpected events, good or bad, and require them to make rapid decisions.

Fig. 6: Example of a Chance Card

E. STAR Cards

Landing on a STAR space requires the player to choose a STAR card and follow the instructions listed on the card. All STAR cards have instructions for selecting and building a component of a player's final rocket. STAR cards prompt players to skillfully choose one of three parts on the final rocket, a fin, body tube, and nosecone, according to the player's unique mission criteria.

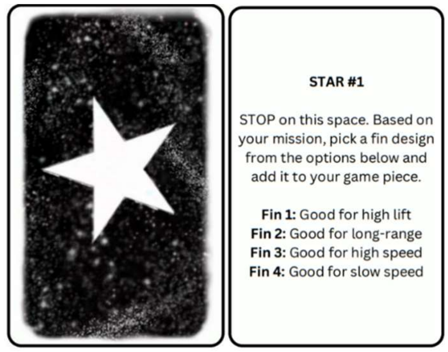

Fig. 7: Example of a STAR Card

F. Game Pieces

The game pieces were designed to bring an interactive element to the game. Each player will build up their game piece starting with a base whose color corresponds to their mission. When the players reach the STAR spaces, they choose and add on the rocket's fins, a body tube, and a nose cone to fully build their rocket. There are four designs of fins, body tubes, and nose cones. Each design serves a different purpose, based on the mission the part was designed for. The process of building the game pieces to match the mission based on the given characteristics exposes the students to design thinking strategies. After all players have reached or surpassed all STAR spaces, they will have built their full rockets and are ready to reach the moon!

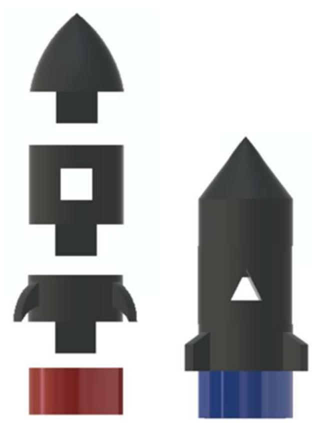

Fig. 8: Example of Unassembled and Assembled Rocket Game Pieces

IV. Testing

A. Round 1 of Testing (2024)

The first iterative model of *Lunar Dash* was piloted at Dove Creek Elementary School in Oconee County, Georgia in 2024. To protect student privacy, no pictures were taken during testing. The game was rated positively by the 12 students that played, with the game receiving an average overall rating of 4.5 out of 5. The feedback was generally positive, as the players were engaged throughout the game and particularly enjoyed building their own rockets as per the unique mission statements they received. All participants filled out a post-test survey to record their opinions on the game, game design, and whether question difficulty was appropriate. Testing with elementary school students revealed the need to simplify the questions offered to this age range. After playing *Lunar Dash*, many students indicated their increased curiosity in learning more about aerospace and STEM related careers, and 7 of the 12 participants asked the testers about their career plans after graduating from college. The final consensus was that the game was entertaining, beneficial to STEM education, and vital in introducing design thinking challenges that match that of the skill required for standard K-5 curriculum.

B. Round 2 of Testing (2026)

In the testing process, we first rolled out the game with groups of family friends. To make for a controlled testing environment, we grouped select family friends in advance, based on collective availability, and maintained the testing environment the exact same when playing the game each time around with new players. This included playing with exactly 4 players each game, 2 boys and 2 girls, playing on the same table, reading out the same start-up instructions, and setting up the game the exact way. The data collected included the total play time, observations made by hosts, and we conducted a 5-question pre/post survey to get feedback from the target audience. The feedback from the participants was extremely helpful, as it gave us a better understanding of their overall rating for the game based on how many questions were answered positively. For example, if 3 out of 5 questions were answered a 3 or above, it was counted as a point for positive feedback.

Guidance was offered whenever players were confused. For the most part, the players collaborated to understand what a question was asking of them and how they were meant to solve a question when one of them was confused. They seldom needed further support from the hosts' end.

For the sake of maintaining players' privacy, each player is denoted by the initials of their first and last names. The table below includes the time each group spent playing a single round of *Lunar Dash*, their average rating of the game on a scale of 5, where a score of 1 indicates a poor playing and testing experience, and a score of 5 signifies enjoyment while playing the game, and recommendation of the game to a player's peers. General observations of play time and explanations for outlying play-time lengths were recorded.

K-5	
Group 1: Play time: 46.23 Average ranking: 4	Additional Notes: This was our first play test, hence the longer-than-expected play time. Was a little difficult for players to understand at first. Players understood the goal and layout of the game towards the middle of the play session. Found the concept of the wormholes confusing. Players suggested that we implement a chutes-and-ladders concept in place of the wormholes.
Group 2: Play time: 42.17 Average ranking: 3.25	Additional Notes: This group didn't have as difficult of a time understanding game concepts as Group 1. Probably helps that all of the players in this group play tabletop games with chance and question cards fairly often. They found the game fairly entertaining, but collectively wish that the visuals of the game board were more interesting. They thought the questions were fairly difficult and not frustrating to solve or answer to.
Group 3: Play time: 17.13 Average ranking: 2	Additional Notes: They were very restless. They are in the younger grades and found it hard to focus. Definitely needed outside guidance to stay on track. Didn't understand basics because they were restless and only 2/4 kids found the questions interesting and wanted to keep playing. Was not a great group to get postive results from. Did not get all the way through the game.
Group 4: Play time: 38.08 Average ranking: 4	Additional Notes: These players were K-5. The youngest player played well with the older players because they guided him. This test group showed that the game would not be suitable for younger children to play on their own. Seems as though students from 2nd grade and up could get through the game without guidance. Consider having a teacher/guiding figure present for students in kindergarten and 1st grade. They were very slow players, but played well. They thought for a long time.
6-8	
Group 5: Play time: 27.45 Average ranking: 4.25	Additional Notes: There is a severely stark difference in comprehension between K-5 groups and 6-8 groups. Testing with this group went smooth; the players in this group tend to think independently, and did not rely too much on me. Students in this group tended to help each other out when one player in particular was unable to answer a question. When none of them knew the answer, they continued on with the game, as per the game rules, and revisted the question at the end.
Group 6: Play time: 25.04 Average ranking: 4.5	Additional Notes: One of our fastest gameplays. Testing went incredibly smoothly. Everyone was engaged. They enjoyed the simplicity of the game overall. Players suggested that this game may be not ideal for lower-elementary grade students, indicating that this game was most beneficial to students in grades 3-8.
Group 7: Play time: 37.29 Average ranking: 4	Additional Notes: They had a lot of fun, they got distracted and fought a lot over the spots that are supposed to be wormholes. They thought the questions were enjoyable and fair. Overall, they offered less criticisms and had more positvie feedback compared to other groups. They wanted to play again.
Group 8: Play time: 44.47 Average ranking: 5	Additional Notes: Took a longer time because they were very competitve. Out of all groups, they were most engaged with the questions. Players found the questions challegening and fair, and found it fun to guess when they didn't know. Players had a lot of feedback to do with the physical board and game aesthetics. Overall, they were very intellectual kids who had a really fun time. The ideal play goal was achieved and they learned a lot.

Fig. 9: Testing Results Garnered from Play Tests Conducted with Family Friends

K-5	
Group 9: Play Time: 35.31 Average Ranking: 4	Additional Notes: This group consisted of upper-elementary school students (3-5). They did not need me around to play smoothly in any capacity. None of the players have played a space-themed game before, so they thought this was particularly interesting! They brought up the inconsistency in the spiral of the tiles on the board game, and suggested using a typical, circle spiral in its place.
Group 10: Play Time: 37.57 Average Ranking: 4.25	Additional Notes: Some members of this group needed a little assistance in understanding the questions they were being asked. They found the game unique and engaging. They wished there were different, more consisent colors used in the board game, not much more feedback was offered in that regard. One of the players expressed that the board did not need to be as big as it is.
6-8	
Group 11: Play Time: 28.43 Average Ranking: 5	Additional Notes: They loved the game! A majority of the players thought the length of a single round of playing *Lunar Dash* was shorter than other tabletop games, because *Lunar Dash* does not require too much effort on the players' part. They wished the game had a few different aesthetic changes, namely that pieces could have been more unique for each player.
Group 12: Play Time: 26.58 Average Ranking: 3.5	Additional Notes: The group found the game cute and perfect for elementary school students. They did not find the questions very difficult, and answered most questions with ease. The players shared that increasing game difficulty for the middle school category would make it more enticing to play again and recommend to others.

Fig. 10: Testing Results Garnered from Play Tests Conducted with Dancers at the Nataranjanatyanjali Dance Academy

Average play time for the K-5 groups was 36 minutes and 8 seconds. Average play time for the 6-8 groups was 31 minutes and 54 seconds. The average ranking the K-5 groups gave *Lunar Dash* is 3.58 out of 5. The average ranking the 6-8 groups gave the game is 4.38 out of 5. We received a variety of feedback from the 12 groups that were implemented in the latest iteration of *Lunar Dash*.

The current iteration of *Lunar Dash* focuses on a streamlined, high-engagement race mechanic. The previous "mission" system had players build physical rocket components, but further testing indicated that this added unnecessary complexity and led to confusion across various age groups. As a result, the Mission cards and STAR cards have since been removed.

Groups K-8 were tested to see how far the impact and engagement of Lunar Dash could reach. We found that children under 8 (3rd grade) required guidance when playing and became easily distracted. Symbols on the board were not intuitive without heavy reliance on instructions, which led these younger age groups to struggle to navigate. Additionally, the 3D-printed pieces were highly successful, though their "toy-like" nature occasionally distracted younger students from the core gameplay.

C. Testing Outcomes

Design changes were also executed to ensure the game would remain fun and clear. “Wormhole” spaces were corner spaces meant to move you up the board game. They were confusing, as the “wormhole” touched three spaces, but it was only meant for the corner space. It was also unclear if the player was traveling up or down the “wormhole”. We redesigned and resized the “wormhole” to be a rocket so that the direction of the jump/drop in spaces was clearer.

Significant modifications were also made to the mission system to address gameplay complexity. While the original design required players to build physical rocket components, testing revealed this added unnecessary confusion and slowed the game pace for all age groups. To maintain engagement, we removed the physical building requirements, missions, and the star spaces. This change ensures the core gameplay stays focused on STEM questions and the race to the moon without the frustration seen in testing,

Finally, we adapted some of the harder questions into a “Hard Mode” because it was observed that in specific group tests, certain questions were outside of the scope of knowledge, even for the older kids. We decided to leave them there as a challenge question on specific spaces.

V. The Future of *Lunar Dash*

The future development of Lunar Dash will focus on reconciling the high engagement of the mission-based design elements with the need for a more intuitive and streamlined gameplay experience. While the physical assembly of rocket components was a highlight for many students, testing indicated that a more simplified approach is necessary to maintain game momentum. We intend to reimagine the mission system by introducing a level-based progression. In this model, players who land on STAR spaces would earn specific mission tokens or status upgrades rather than performing complex physical assemblies. This keeps the design thinking framework where players must make strategic choices based on their mission criteria while ensuring that the game remains accessible to a broader range of ages and skill levels.

Furthermore, we aim to branch off and adapt a new version of *Lunar Dash*, specifically to better engage the K 3 demographic. Our research suggests that younger students are highly motivated by the 3D printed game pieces but are easily distracted by text heavy instructions and non-intuitive symbols. Future iterations will prioritize a visual first design, utilizing universal icons and a simplified board layout to reduce the reliance on external guidance. It is possible to also adapt a teacher-guided version so that it can be used as more of a guided classroom activity rather than a board game. By continuing this iterative design process, we believe Lunar Dash can become a staple in K 8 classrooms, effectively bridging the gap between play and the foundational principles of aerospace engineering.

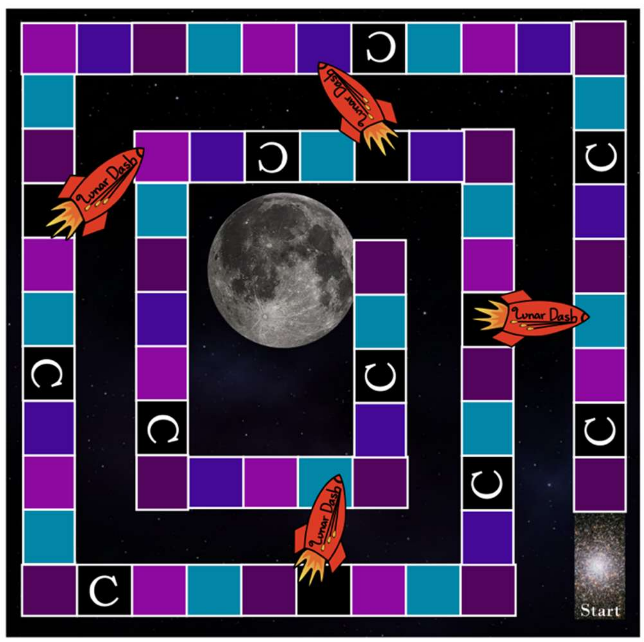

Fig. 11, Third Iteration of Lunar Dash

VI. Conclusion

Based on the results from our testing we concluded that the board game is effective at helping kids learn STEM topics through a fun experience. However, through testing, it was determined that there are still aspects of the game that can be improved. Further testing will help identify any remaining problems and refine the game into a better product. We applied design thinking to create a game that actively engages players with aerospace engineering and related STEM disciplines. The board game is a fun learning environment for teachers to incorporate to add to STEM education in their classrooms. Preliminary testing of the board game showed that the board game was entertaining for the students that played while also being informative, helping the students learn about the topics that are present in the game and quizzing them on knowledge learned in school.

Acknowledgments

The authors thank the previous UGA College of Engineering Capstone Design team (Alex Barrineau, Walker Nunes, Raj Patel, Jordan Winter) for their contributions related to some of the questions used in this study, and Brooklyn Schnupp and Jacob Pence for creating and testing the first iteration of *Lunar Dash*.

References

1. Barrineau, A., W. Nunes., R. Patel., J. Winter., and R. Pidaparti (2021) UGA Community Outreach Project – Space Race: A Voyage to the Moon Board Game. Presented at the 2021 AIAA Region II Student Conference (virtual).

2. Liu, M., Horton, L., Olmanson, J., & Toprac, P. (2011). A study of learning and motivation in a new media enriched environment for middle school science. *Educational Technology Research and Development*, *59*(2), 249–265. https://doi.org/10.1007/s11423-011-9192-7

3. Morana, L. C., Bombardier, J., Ippolito, C. V., & R.W. Wyndrum. (2012). *Future stem careers begin in the primary grades*. https://doi.org/10.1109/isecon.2012.6240514

4. President's Council of Advisors on Science and Technology (PCAST). (2010). Prepare and inspire: K-12 education in Science, Technology, Engineering, and Math (STEM) for America's future. White House Office of Science and Technology Policy (OSTP), Washington, DC.

5. Plattner , H. (2010). *An Introduction to Design Thinking Process Guide*. Stanford University. https://web.stanford.edu/~mshanks/MichaelShanks/files/509554.pdf

6. Rawat, K. S., E.E. Lawrence., R. R. Mangham., O.D. Gooden (2018) K-12 Aerospace Academy: An Out-of-School Authentic and Experiential STEM Learning Experience for College and Career Pathways to Aerospace/Aviation. Paper ID #22847. Paper presented at the 2018ASEE Annual Conference & Exposition, June 24-27, 2018, Salt Lake City, UT.

7. Sesma, F., E. Alao., H. Stroud., K. J. Shryock (2021) Bringing Aerospace to K-12 Students using Nontraditional Applications. Paper ID #34655. Paper presented virtually at the 2021ASEE Annual Conference & Exposition, June 26-29, 2021.

8. Schnupp, B., J. Pence., and R. Pidaparti (2024) Lunar Dash: A STEM Education Board Game. Presented at the 2024 AIAA Region II Student Conference, Kennedy Space Center, FL, April 4-5, 2024.