Lunar Dash: A STEM Education Board Game

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Integration of STEM in elementary and middle school levels is receiving great attention from multiple perspectives including diverse workforce needs, especially in the aerospace engineering discipline. The National Academy of Engineering (NAE) and the National Research Council (NRC) indicate that design and computational thinking approaches to engineering innovation should be taught at K-8 levels. The goal of this study is to design and develop a fun and informative learning product that is based on a game concept and inspires students (grades K5-8) to develop an interest in aerospace engineering careers by emphasizing the theme of "Lunar Dash." The game concept fosters students learning and design thinking, and draws upon their knowledge of math, science, and technology. Multiple board game design concepts were designed and evaluated to arrive at a final design that involves a unique and 3D style board game in which players roll a die to progress from the earth to the moon. The implementation of Question and Chance cards in the game will provide historical context and assist students in understanding the STEM concepts. Currently, the design is being prototyped and will be tested to further improve the game elements. Finally, the utility of the game for enhancing the learning/educational experience will be evaluated after testing with students and teachers in the community.

I. Introduction

The current focus of many in education is increasing STEM (Science, Technology, Engineering, and Math) learning in elementary and middle schools due to the current push in the workforce towards jobs in STEM. This means that setting the foundation for STEM learning early for kids is crucial for the growth of the fields. Also, preparing students to be competitive in the global economy underscores the need for more STEM engineers to enter the field and further engineering innovation.

As noted in a report by the President's Council of Advisors on Science and Technology[1], motivating middle school students to learn STEM concepts will help them to ultimately pursue STEM degrees later in their schooling. Game-based Learning (GBL) offers a unique and innovative approach for students to learn and appreciate the STEM topics learned in the classroom and increase their academic engagement. Recently, there have been many studies related to introducing aerospace to K-12 students using non-traditional ways including board games and video games. [2-3] These GBL studies have shown that they contribute to enhancing student experiential learning in a variety of ways in

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engineering in particular, including problem solving, design thinking and learning concepts and skills. Due to recent space activities including 50th anniversary celebration of the first moon landing, and the attempts to land on the moon through a lander named "Odysseus" by a private company (Intuitive Machines), indicates there is a growing interest in aerospace engineering. Using nontraditional learning tools and we created a board game based on a voyage to the moon to boost STEM learning and skills of middle school students. Previously, a capstone design team from the UGA College of Engineering developed a game and presented it as part of the UGA AIAA Student Chapter community outreach project. [4] This paper presents an aerospace themed new board game developed for students in grades 5-8 students and the board game design goal, design, prototyping and testing are briefly described below.

II. Development of Lunar Dash Board Game

The goal of this game is to create a fun learning environment for K-8 students. The game aims to use design thinking principles to boost STEM learning and increase interest in STEM. There are two main principles that are used in this game to garner interest in STEM. The first principle is design thinking strategies to introduce the students to how engineers try to think when solving a problem. The second is simple STEM related questions to increase what the students know, and hopefully, make the students gain interest in STEM through learning more about the different areas. The use of a 3D board as well as requiring players to build their game pieces throughout the game also fosters creativity in the students.

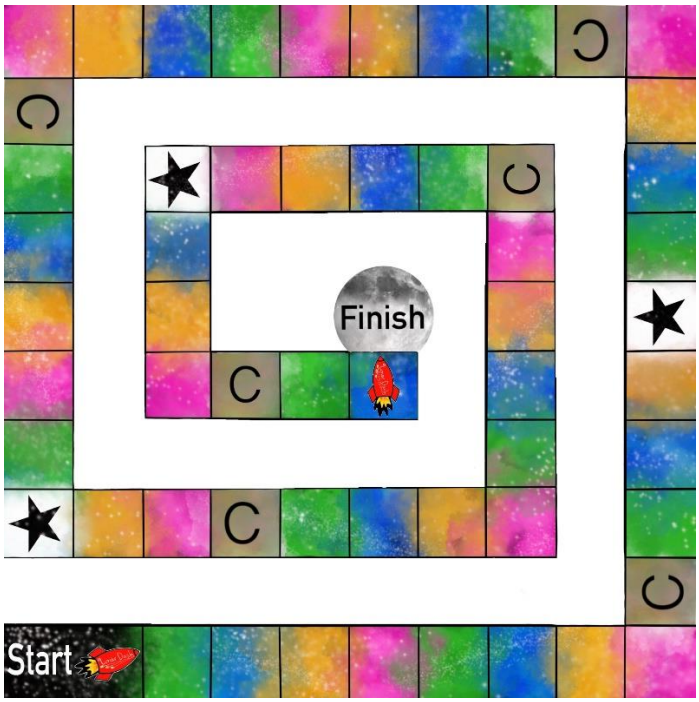

Fig. 1 An overview of the Lunar Dash game board

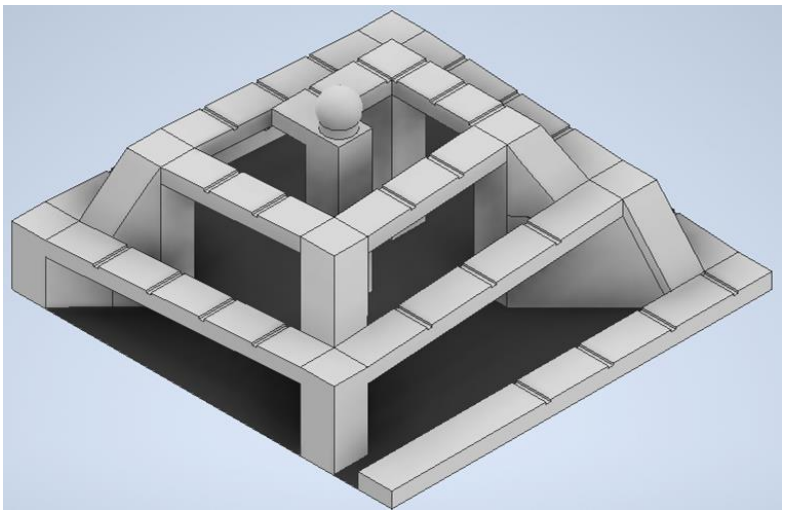

Fig. 2 Board game design CAD model

The idea behind the design is a race to the moon. Following that idea, the finish space is designed to look like the moon and the base of the board has an image of the Earth to give the feeling that the board is going up from Earth to the moon. The board is a single spiral that gets smaller as it reaches the finish. The board is made up of six different spaces: pink, blue, green, and orange question spaces, chance, and STAR spaces.

A. Rules

It is a four-player game, but students can play together in teams if the teacher wants more students to participate. The game starts with each player choosing a base for their game piece. Each of the four different game pieces are a different color, and each color corresponds to a different mission that the player will be trying to complete throughout the game. The players use these missions to build their game pieces throughout the game when they reach the STAR spaces.

To decide which player goes first, each player rolls the two dice, and the highest number goes first with play proceeding on the clockwise direction. When it is a player's turn, they roll the dice and move forward that number of spaces. If the player lands on a colored space, then they draw the corresponding color's question card. The player to the left will read the question off the card for the current player to answer. If the question is answered correctly, the player moves forward the number of spaces said on the card. However, if the question is answered incorrectly, the player stays on their square. The player's turn ends after the question is answered. If the player lands on a Chance tile (C), then the player draws a Chance card and follows the instructions on the card.

If the player moves over a STAR space while moving their rocket piece on their turn, they must stop immediately and not go further on that turn. The player who lands on a STAR space will read the directions on STAR card #1. The player will follow the directions on the card and stay on the STAR space until their next turn. Each time the player stops on a STAR space, the player will read the following STAR card number. The game ends when a player successfully rolls a high enough number to reach the finish spot.

B. Mission Cards

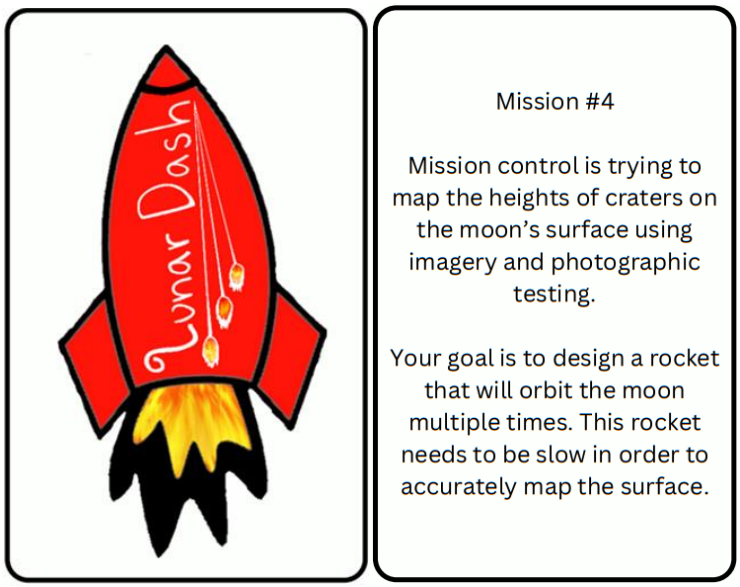

Fig. 3 Example of the Mission Cards

Each player is assigned a mission card according to their colored tile before the game starts. The mission cards provide students with a unique goal for their rocket design and help them later in the game when they land on STAR spaces. A player will use the cards to compare against the key and slowly build their rocket according to the mission criteria. These cards encourage design thinking skills and show the students that different designs on parts such as fins, body tubes, and nose cones will end up changing the entire mission for the rocket, and a different combination of designs will result in different maximums and minimums in rocketry criteria such as thrust, payload, velocity, and range.

C. Question Cards

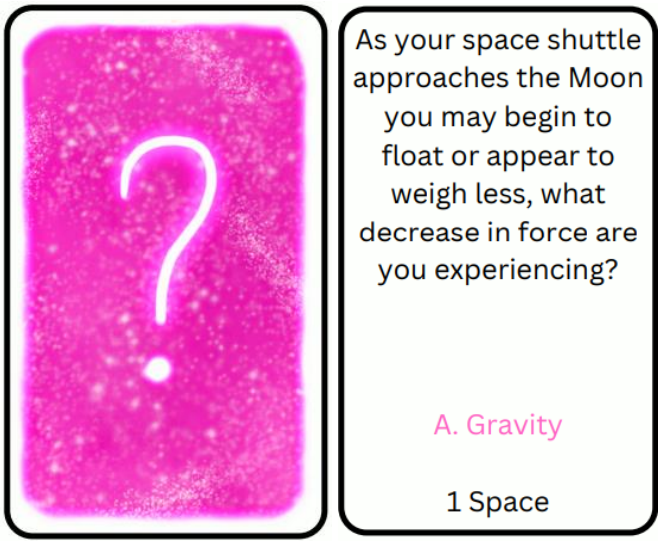

Fig. 4 Example of the Question Cards

The question cards are how STEM education is incorporated in the game. The questions on the cards vary between the different STEM topics of science, engineering, and math. When designing the questions cards, the difficulty level had to be such that the game could be played and enjoyed by every student in the age range. This added a level of difficulty to choosing the questions as the difference in a third-grade student and eighth grade student in what they

have learned in STEM is large, which is why the choice was made to have easy cards which move players forward one space and hard cards which move players forward two spaces. This gives a proper range of question difficulties for the age range, and because there are no negatives to getting a question wrong, the game does not penalize the players for getting a question about something they have not yet learned in their classes.

D. Chance Cards

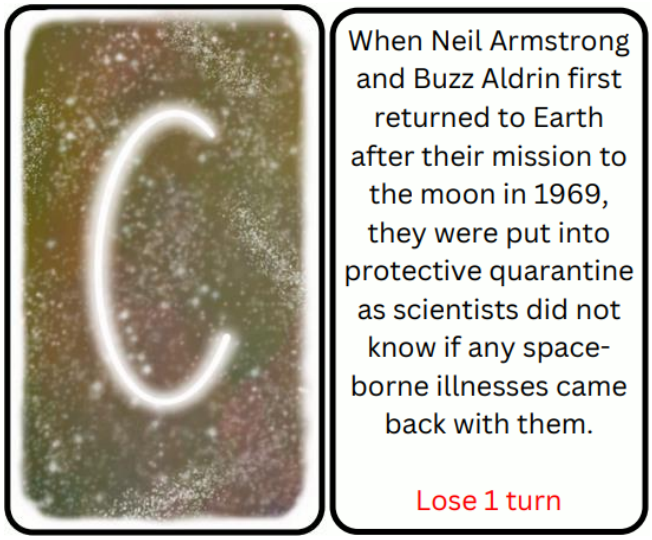

Fig. 5 Example of the Chance Cards

When players land on spaces with 'C' markings, they draw a chance card from the stack. Each chance card has a different 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, whether good or bad, and require them to make decisions in some situations such as switching spaces with another player.

E. STAR Cards

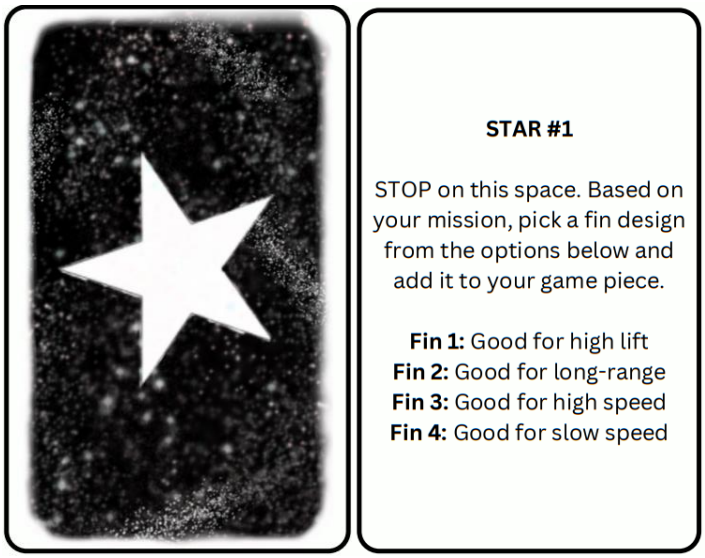

Fig. 6 Example of the STAR Cards

The STAR spaces require all players to immediately stop no matter what they rolled on the die on that space. They then choose the matching STAR card to their space and follow the instructions on the card. All STAR spaces have instructions to one of three parts on the final rocket, a fin, body tube, and nosecone. Students use the key on the STAR cards to pick a rocket part to add to their game piece and confirm that it matches their mission criteria. The instructions on each STAR card correlate to a picture of a rocket part design on the back of the rules sheet.

F. Game Pieces

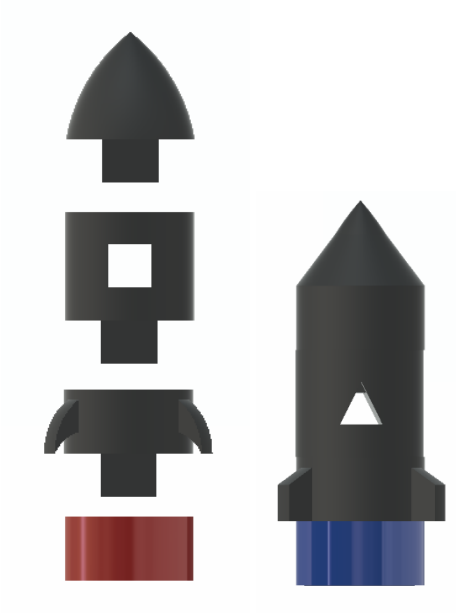

Fig. 7 Example of the Game Pieces

The game pieces were designed to bring an interactive element to the game, so that the players have to do more than just roll dice and answer questions. Each player will build up their game piece starting with a base that has a color corresponding to a mission. Then throughout the game when the players reach the STAR spaces, they will be adding fins, a body tube, and a nose cone to fully build their rocket. There are four types of fins, body tubes, and nose cones with each different design having different assigned characteristics based on the missions that the design is supposed to be best fit for. The process of building the game pieces to match the mission based on the given characteristics is how the students get exposed to design thinking strategies. As the players progress through the game, they get to add more parts to their game piece until they reach the top and have a fully completed rocket. At each STAR space, when the student is adding a piece to their rocket, they are supposed to look at the descriptions of each piece and choose the one that best fits their mission. After they have reached all three STAR spaces, the players will have built their full rocket and are ready to reach the moon.

III. Testing

The board game was piloted at a local elementary school in Oconee County, Georgia, Dove Creek Elementary. Due to student security, no pictures were taken while testing. The game was rated positively by the students that played, with the game getting an average overall rating of 4.5 out of 5. The feedback was mostly positive with the students being engaged throughout the game, and especially enjoying the process of building their own rocket as they played. Testing on the 5th grade students revealed that most of the critical feedback suggested making some question cards simpler for their age group. All students were asked to fill out a questionnaire to record their opinions and rankings on the game, how it was designed, and whether the question difficulty was appropriate. When asking students what they wanted to be when they grew up before the game, 100% of the 5th grade boys said some form of a pro sports player, from baseball to basketball to football. The girls had a greater variety of answers, with the majority at 35% as teachers and other answers including nurses, pop singers, and chefs. After playing the game many students indicated they were curious in learning more about aerospace and STEM related careers, and some

went on to ask the testers about their career plans after college. The final consensus described that the game was fun, entertaining, beneficial for learning, and introduced design thinking challenges that match those required for standard curriculum.

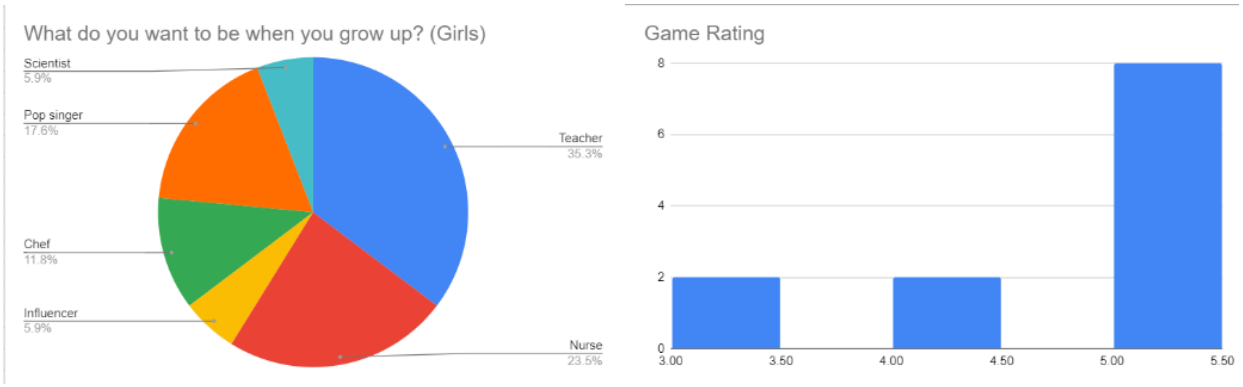

Fig. 7 Student Questionaire Results

IV. Conclusion

Based on the results from our testing we concluded that the board game is effective are helping kids learn STEM topics through a fun experience. However, through the testing, it was determined that there are still aspects of the game that can be improved. Further testing will help better identify the problems and refine the game into a better product. The purpose of designing the game was to use design thinking strategies to increase the interest in aerospace engineering and other related STEM topics. The board game is designed to be 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.

Acknowledgements

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