

Empire of the Rolling Spheres:
 board game essay

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January 2026

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1 Introduction

Empire of the Rolling Spheres is a 2-6 player serious board game developed to introduce 16+ year old students to astrophysics in a fun and memorable way. The game takes 45-90 minutes to play and is an asymmetrical strategy game where each player controls one of the terrestrial planets or gas giants. Strategy, forward thinking and social manipulation are key to taking their planet to victory amidst the solar system.

2 Learning objectives

The game has two main learning objectives. Through playing this game students should:

- (LO1) Know and understand the relative scale of the solar system and the rotation of the terrestrial planets and gas giants.
- (LO2) Know and recall the key identifiable characteristics of the terrestrial planets and gas giants.

Appreciation of the relative size of the solar system is crucial for astrophysics. Depending on the calculation physicists may approximate the masses of planets as negligible (Physics LibreTexts 2025) or the distance between planets as infinite. However, “people have difficulty reasoning about magnitudes outside of human perception” (Resnick et al. 2017, p. 1020) and when dealing in the scale of 10^{11}m , for the radius of planets’ orbits, or 10^7s , for the orbit length, it is difficult for students to gain an intuitive appreciation of the different magnitudes. Therefore, understanding when an approximation is appropriate and necessary is challenging.

Each planet has a range of interconnected properties and characteristics which are necessary for an understanding of the solar system as a whole. The breadth of required knowledge is a challenge for students.

These learning outcomes are well addressed in the context of a serious game. By playing the game and physically interacting with the ratios of distances of the solar system and the different planets’ properties students get a tangible context for the numbers given within astrophysics.

3 Gameplay

The game is a race between players to hold 7 victory points; these are collected as a player progresses through the game with the largest rewards being given when a player ventures into the solar system and onto another planet. Each player chooses a home planet which all have different strengths and limitations imposed by the properties of the real life planet.

Players juggle the three core currencies (metal, fuel and science) as well as their worker number. They must improve their resource production, explore

space and interact with other players to accomplish victory. Players may cooperate or attempt to invade their opponents as they fight for the resources and benefits that the planet gives.

4 Game design

4.1 General design choices

According to Blooms taxonomy achieving the “most important goals of education”, the synthesis and evaluation, require “mastery of each simpler category as a prerequisite of the next more complex one” (Krathwohl 2002, p. 47–48). Since this game sets out to be an introduction to the subject of Astrophysics, it focuses on providing players with a thorough knowledge and understanding of the topic to form a solid foundation which they may build upon with further study.

Molnar & Kostkova (2013), states that it is overall beneficial for material to be integrated into the mechanics of the game, rather than stated as text. Therefore, this game aimed to embed material into the mechanics of the game where possible but present the information as text whenever useful or necessary.

Repeating information is key to remembering material (Hintzman 1976) and so this game aims to repeatedly present the player with the material. Therefore, the game was designed to have multiple rounds, leading to a longer play time and increased repetition of the key information. The average play time of an hour also means that the game can be played within a school or college lesson.

4.2 Specific design choices

The gameboard, and movement around it, is the key area where **(LO1)** is addressed. The board represents the solar system, with sections of the board divided by coloured lines (blue, black and red. (This choice maintains accessibility for the colour blind). Each line corresponds to a distance; In this way the game shows the distance between planets and across the solar system, allowing it to be to-scale while having a linear, and so less cognitively taxing design.

Blue	1/3 AU	$5 * 10^{10}\text{m}$
Black	1 AU	$1.5 * 10^{11}\text{m}$
Red	3 AU	$4.5 * 10^{12}\text{m}$

Table 1: distances represented by different colours

For a player to move between two tiles on the board they pay fuel per line crossed and so proportional to the distance travelled.

A game round represents 6 months and so each round the planets rotate around the board the appropriate relative distance. Therefore, in order to

move across the board, players must plan around the distance between and movement of the planets, helping them to learn and understand this.

The learning objective (**LO2**) is embedded into the game mechanics through the different properties of the planets. Each planet has a distinct set of resource production values for metal and fuel as well as a unique population range. Metal represents heavy elements, fuel represents Hydrogen and Helium and the production rate corresponds to the relative abundance of each resource on the planet. The significance of these choices is explained on the back of each player shield and thus players are informed of the information and must plan around the properties of the planets. More explicitly, the player learns the properties of the planets through the planet cards. These detail a key fact about the planet, as well as a negative consequence for the player and are drawn and read at the beginning of each round. These cards introduce some input randomness into the game. Which varies the game each time it is played, leading to a more enjoyable experience.

This game can be used in a classroom setting and so must be appealing to all types of players (Louters 2021). This is achieved through the varied core gameplay. Throughout the game players will adventure through the solar system, achieve victory points and fight with other players in a conflict system inspired by the 2019 DUNE board game and designed to appeal to “killers” (Louters 2021). This game differs from dune, however, by introducing the option to cooperate and the closed player board. The ambiguity of players workers being hidden adds a layer of bluff and social manipulation during the player interaction phase of the round, appealing to the “socialisers” (Louters 2021).

5 Playtesting and feedback

5.1 (LO1) achievement success

Throughout the playtesting players fed back positively about the effectiveness of the game with teaching the learning objectives. Talking about the design of the board and the effectiveness of the design in teaching (**LO1**) one player remarked “Despite a linear representation visually, the scale of the solar system is embedded well into the mechanics. You feel the distance between planets when you spend fuel to travel between planets”. Players were given a scale before and after playing the game from 1-5 and asked to rank their current understanding and familiarity of both the scale of the solar system and the rotation of the planets. We saw an increase of 108% in their rankings after playing the game.

5.2 (LO2) achievement success

In an earlier version of the game planet cards were called occupation cards and drawn if a player had successfully invaded a foreign planet to signify the adaptation of species. These were a key source of information required

to achieve **(LO2)** but ended up being drawn infrequently. One player said: “The occupation cards help to develop understanding of the properties of each planet. They were both fun, interesting and informative but could have been used more.” To overcome this, occupation cards were renamed planet cards and changed to be drawn at the beginning of each round. This had a few effects: players read the key material more often and so became more familiar with the planets and players, had more use out of the “fun” cards and the increased randomness lead to a richer, more rewarding game. Having made this change this game the same player when asked to provide feedback said, “I feel like I learnt a lot more”.

Players were asked to complete a quiz on the characteristic properties of the planets before and after playing the game. Since players had no prior knowledge of the subject the initial average score was 1/12 and following the game the average score moved to over 11/12 showing the effectiveness of the game at achieving **(LO2)**.

5.3 Cognitive load

The initial feedback from playtesting highlighted a key flaw, both the rules and gameplay were rated 8/10 for complexity showing the game had too high a cognitive load. This was interfering with learning (Sweller 1988) and therefore addressed.

The rules were clarified and written to be more approachable, as well as an overview section was added to the beginning and examples were added to the end.

Players were also given a cheat sheet. This gave the player a simplified list of the key rules and information so eliminating the need to memorise the rules or refer to the rule book. This change was remarked as “really helpful” but still that “other ways to reduce cognitive load would help a lot”. With this second round of feedback in mind some other changes were made:

(LO1) a key was added to the game board

(LO2) the cheat sheet was made more comprehensive

(LO3) worker assignment cards had information on the use of each resource added to them

(LO4) the resource ladder was simplified and made clearer.

This collection of changes means that information on how to play the game is always close at hand and so reducing the cognitive load and thus “it frees you up to learn more”.

6 Conclusion

Empire of the Rolling Spheres is a serious game designed to teach students about the solar system. Its game mechanics were described as “unique”, “vi-

sually intuitive” and were shown to be successful in teaching students the desired material (**LO1**) (**LO2**). Given further time on this project, it would benefit from being made into a computer game helping to further reduce the cognitive load on players.

References

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- All images of planets used were taken by NASA. This game is not officially indorsed by NASA.

A Appendix



Figure 1: First round of playtesting

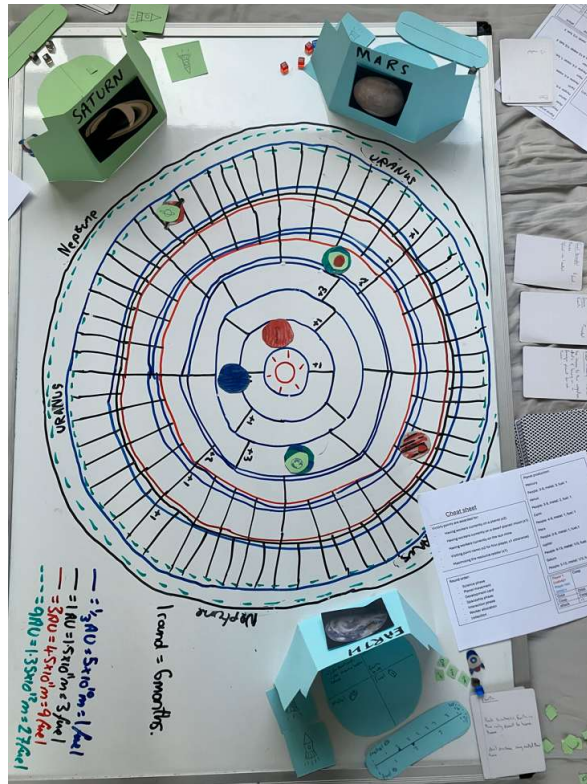


Figure 2: Final playtest with final board design



Figure 3: Original gameboard design

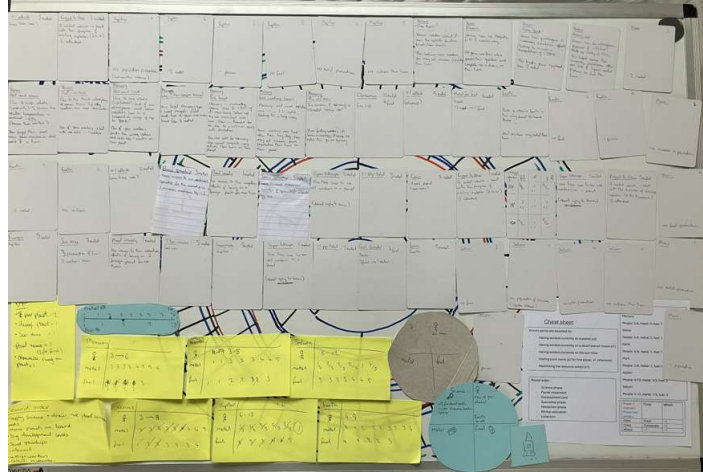


Figure 4: game elements and prototypes

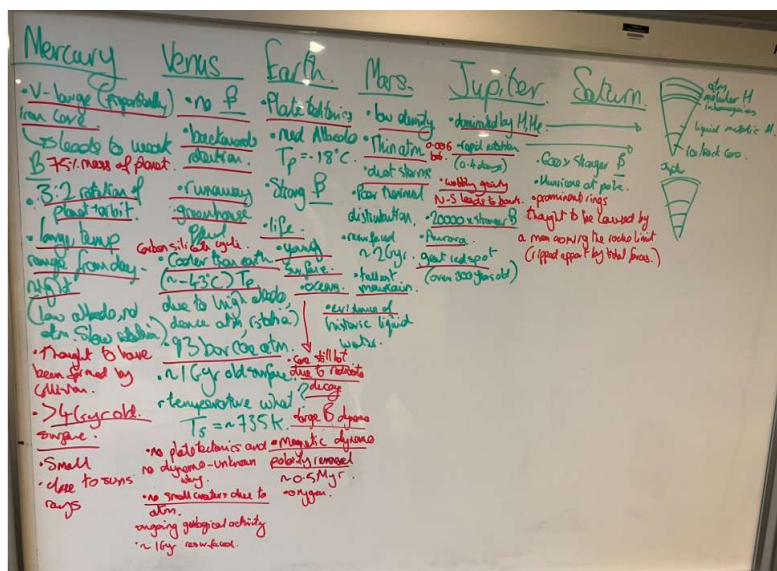


Figure 5: list of planet facts for the planet cards