Physics Fields TCG: Crafting a Deck-Building Game as a Mental Model for the Fundamental Interactions of Nature

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Spring 2024, John Jay College of Criminal Justice - CUNY

Abstract

Understanding the laws that govern the fundamental interactions of the natural world is no small feat, and various approaches exist to introduce such abstract concepts to science students. This raises the following questions: First, is adapting a game with mechanics based on real-life physics fields even possible in the first place? Second, if so, does playing the game serve as an effective mental model for individuals unfamiliar with said concepts [1-7]? We confidently answer the first part of this hypothesis, that yes, a game of this nature, adapted from the laws of nature, is possible.

Introduction & Aims

Introduction:

- The area of physics we are concerned with are those that govern particles within fields—as in protons, neutrons, electrons, etc. that make up all of the matter in the universe.

- A lot of the "players" and "movements" of physics fields can be translated well into the mechanics of a trading card game (TCG). Players collect and use cards representing various particles and strategize according to the game rules that are in harmony with real laws of nature, particularly the following relationships:

$$E = \frac{kQ}{r^2}$$

A source charge, (Q) creates an electrostatic field a certain distance away (r). The larger the magnitude of charge, the stronger the field is and vice versa.

$$F = qE$$

A test charge (q) experiences an electrostatic force from a field (E). The larger the magnitude of force, the stronger the field is and vice versa.

Note: For our game particularly, we use addition and subtraction to perform the functions that multiplication and division perform in nature, to make things simpler. Particle cards create fields that 'force' the opponent's cards forward or backward as predicted by our version of these equations.

- This is important because mental models—which are our internal representations and understandings of different concepts—are particularly hard to make effective in subjects that have a lot of abstract teachings like physics [1-3].

Hypothesis: Once a TCG can be crafted and played in a meaningful way with real outcomes and consequences, it is expected that players of the game will develop their own mental model of these field and particle interactions, therefore increasing physics cognition.

Research Approach

Brainstorm
- Gather ideas using inspiration from common TCGs like Pokemon and Yugioh
- Decide what particles/fields/laws to be included and built upon in the game

Game Mechanics
- Establishing movement, space, and forces of attraction and repulsion that agree with both particle physics as well as actual playability.
- Trial and error! The game was played over and over, tweaking details each time until we had a full, playable game (see Figure 2)

Backstory and Art
- Now it is easy to utilize the naturally created quirks and characteristics from the game thus far and integrate rich backstory, artwork, and fine tuning of any game major game mechanics.

Figure 2: EUREKA! Recording of the First Win + Transcript:

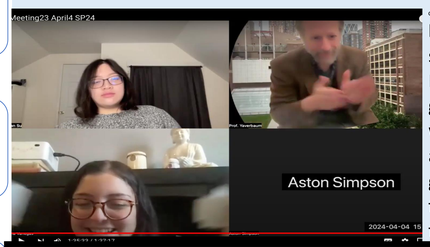

Figure 2: to the left is a screenshot of the moment Bri won the first-ever full game, as well as the written transcript. This was a major break-through in game development—the game actually comes to an end!

15:03:32 So that means I just used up my turn of grace and I didn't save myself from the danger zone.
15:03:38 But I'm in the danger zone. So my particles go into discard. I'm just like reviewing this to make sure I'm, so my particles go into discard and they take and they and they toss the field vector into the deck so my particles are gone then I go to my hands and the only thing in my hand is to beautiful Galileo pictures right here, buyers by Vivian.
15:03:58 So I have no particles in my hands, so I can't reset. So yes, I literally lose the game and the game is over.
15:04:07 Okay.
15:04:18 Okay.
15:04:10 And whoa, and you win. And so it, so my dream come true. We actually made a game that actually could go to completion and the student won but no that good no that's that really is exciting like like and you were literally thinking you were down for a lot of the game but then this crazy thing happened and just for the record the crazy thing that you did that turned the whole game and made me lose was crazy but it

Results

Table 1: Master List of all Cards

Name	Description	Type	Mass	Charge	Quark
Electron	Gravitational pull, electrostatic pull	Particle	1	-1	0
Proton	Gravitational pull, electrostatic push	Particle	2	+1	3
Neutron	Gravitational pull	Particle	2	0	3
Anion	Electrostatic push	Particle	0	-1	0
Cation	Electrostatic pull	Particle	0	+1	0
Protium	Gravitational pull	Particle	6	0	6
Protium ion	Gravitational pull, electrostatic push	Particle	6	+1	6
Tri-valent free chain	Gravitational pull, electrostatic push	Particle	3	-3	0
Alpha particle	Gravitational pull, electrostatic push	Particle	8	+2	12
E-field vector	- Force other card "d" spaces - "d" = (charge + charge) - (space + space) - +/- = pull; +/+ = push; -/- = push	Field Vector			
G-field vector	- Force other card "d" spaces - "d" = (mass + mass) - (space + space) - Always a pull	Field Vector			
Nuclear-field vector	- Force other card "d" spaces - "d" = (quark + quark) - (space + space) - Always a pull	Field Vector			
Einstein	Draw 5 from top of deck, discard 3, keep 2 in hand	Physicist			
Galileo	Discard 1 from hand, search deck for 1 field vector	Physicist			
Noether	If you discard two cards from your hand, you may replace one particle in your region. Replaced particle is shuffled into the deck.	Physicist			

Figure 3: Starting Play Conditions

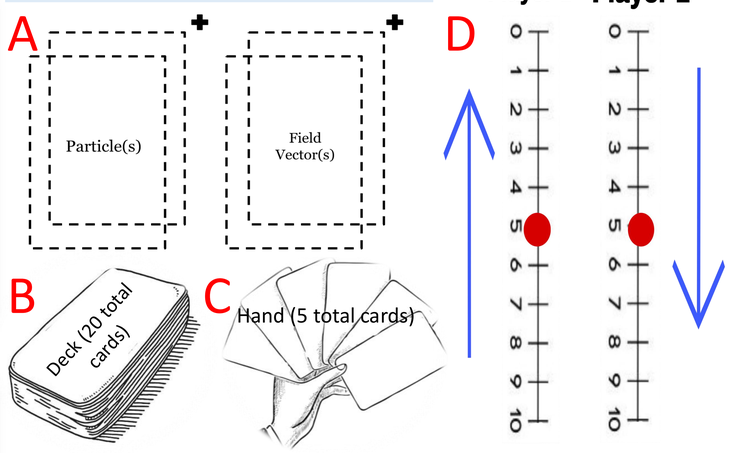

Figure 3: The above graphics depict the starting game setup: The play space includes two main areas to place/stack particles as well as field vector cards (A). The player's deck consists of 20 total cards: 10 particle cards of choice and 10 cards of any choice (B). The player then picks 5 total cards from the deck to place in hand (C). (D) is an experimental prototype of a visualization of particle movement for both players.

Figure 4: Some of our Favorite Cards

Figure 4. The above cards (generated with CardConjurer.com) are some of our favorites in terms of artwork, beautifully created by our one and only Vivian Su. We are very grateful for her artistic vision and contribution that ultimately gave our game life. Cards: Einstein (physicist), neutron (particle), electron (particle), Noether (physicist), tri-valent free-chain (particle), g-field vector (field vector)

Conclusions & Discussion

- Upon completion of these three phases of game development, we can report with confidence that developing a trading card game that is robust, playable, and consistent with the laws of physics is possible.
- Said game includes (and will not be limited to) particle, field vector and physicist cards with their own abilities and numeric attributes, a comprehensive rulebook, rich backstory, and captivating art on each of our cards. These features themselves speak to the amount of hard work and consideration that was required of us to make this game not only possible, but fun.

Future work:

- Now that we have established that the game is playable, future developments can be arranged to finalize the game and to test how well it works as a mental model for fundamental laws of the natural interactions being studied in physics classes. This can include launching student game trials with feedback and polls for players to assess understanding [1-7].

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Acknowledgements

Support for student stipends, supplies, and/or equipment used in this research was provided by the Program for Research Initiatives in Science and Math (PRISM) at John Jay College. PRISM is funded by the Developing Hispanic-Serving Institutions (DHSI) – Title V and the Hispanic-Serving Institutions – Science, Technology, Engineering, or Mathematics (HSI STEM) – Title III, Part F programs of the U.S. Department of Education; the Improving Undergraduate STEM Education: Hispanic-Serving Institutions (HSI Program) program of the National Science Foundation; and the New York State's Graduate Research Technology Initiative and New York State Education Department Collegiate Science and Technology Entry Program (CSTEP).