Duel of Spin

a strategy game to facilitate learning rotational motion

Jianhao Ma

Games for Learning

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Dr. Maaike Bouwmeester

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Abstract

Battle tops like Beyblade used to be and still are a popular toy genre for teenagers globally. The play experience of customizing their tops to outperform competitors conveys significant potential for applying physics concepts that are often considered counterintuitive, which incubates the project *Duel of Spin*.

Duel of Spin is a 3D strategy game designed to teach players about rotational motion through engaging, physics-based gameplay. The context analysis identifies a key challenge: while strategy games are effective for STEM learning, they are not popular among teenagers. To address this, enhancements in visual appeal, feedback mechanisms, and thematic relevance are proposed to make the game more appealing to this demographic. The game covers learning contents that the target audience typically lacks life experience with, including torque, angular velocity, and moment of inertia.

The game design elaborates on two modes—Campaign and Sandbox—that provide both structured learning and free-form exploration. The instructional design choices are based on Digital Game-Based Learning (DGBL) principles, engaging players affectively, behaviorally, cognitively, and culturally.

As for the next step, various methods will be used for assessing and refining the game through user feedback and research. Ultimately, *Duel of Spin* aims to make learning physics accessible and enjoyable for teenagers, demonstrating the potential of combining educational content with engaging gameplay. By systematically addressing user engagement and learning outcomes, this project aspires to bridge the gap between educational effectiveness and game popularity.

Game Overview

"Duel of Spin" is a 3D strategy game set in a futuristic universe. In this game, players engage by customizing toy tops to compete against others. The primary gameplay involves adjusting tops for duels based on an opponent's design. Players start by examining the opposing top, then modify their own accordingly. After customization, they initiate a duel, watching as an animated simulation unfolds without further input.

During these clashes, tops are launched into a concave, bowl-shaped arena where they gravitate toward the center, colliding until one top depletes its energy and ceases to spin. Each top consists of five interchangeable parts: the cap, collision disk, kinetic disk, base, and friction tip, arranged from top to bottom. With over 25 different components available, players select variations that differ in shape, weight, and weight distribution, influencing the top's physical behavior.

The game enhances players' grasp of physics, particularly rotational dynamics, by encouraging experimentation with different component combinations and observing their effects in duels against tops with varied attributes and movement patterns.

"Duel of Spin" offers two gameplay modes: campaign and sandbox. The campaign mode features three tutorial levels that progressively guide players through game mechanics and underlying physics principles. These tutorials use text prompts from a narrating guide, focusing on calculating top attributes and predicting outcomes of duels against AI opponents. Completing a level unlocks additional components and progressively more challenging adversaries. In sandbox mode, players have unrestricted access to all components, allowing them to freely construct two tops and simulate their interactions in battle.

Analysis

The Problem

Strategy games are a significant genre in video games, renowned for their effectiveness in enhancing STEM learning and cognitive development through the engagement of complex thinking and real-world knowledge application (Glass, Maddox, & Love, 2013; Gui, Cai, Yang, Kong, Fan, & Tai, 2023; Dale & Green, 2017). However, despite these educational benefits, strategy games are notably less popular among teenagers—a critical demographic that could greatly benefit from these games (Brown, 2017; Uke, 2024). Understanding why these games do not appeal as much to teenagers is essential for designing educational games that are both effective and engaging for this age group.

Extensive research has confirmed the positive impact of video games on STEM education. A 2023 meta-analytic review in the International Journal of STEM Education analyzed 136 effect sizes from 86 studies and found a medium to large overall effect of digital game-based STEM learning compared to conventional methods (g = 0.624, 95% CI [0.457, 0.790]). Furthermore, the review highlighted that strategy games are the most effective genre, demonstrating a significantly larger effect size (g = 1.841) compared to role-playing games (g = 0.586) and action games (g = 0.394), suggesting their superior efficacy in promoting STEM learning (Gui, Cai, Yang, Kong, Fan, & Tai, 2023).

In addition to educational benefits, strategy games have been shown to enhance cognitive skills. A study conducted by the University of Texas at Austin demonstrated that participants who played the real-time strategy game *Starcraft* exhibited more significant improvements in cognitive task performance after 40 hours of play than those who played *The Sims*, a casual simulation game (Glass, Maddox, & Love, 2013).

Despite the proven advantages of strategy games in STEM education and cognitive development, their popularity among youth is not as high as expected, making it challenging to engage this audience outside controlled experiments and studies. Analysis of GameTree data on gamers' genre preferences by age group reveals that while the 13-17 age group shows a -5.6% preference for strategy games, preference increases with age, peaking at 13.6% among the 33-42 age group (Uke, 2024). Similarly, Pew Research Center surveys have indicated that strategy games are among the most favored genres among adults (Brown, 2017).

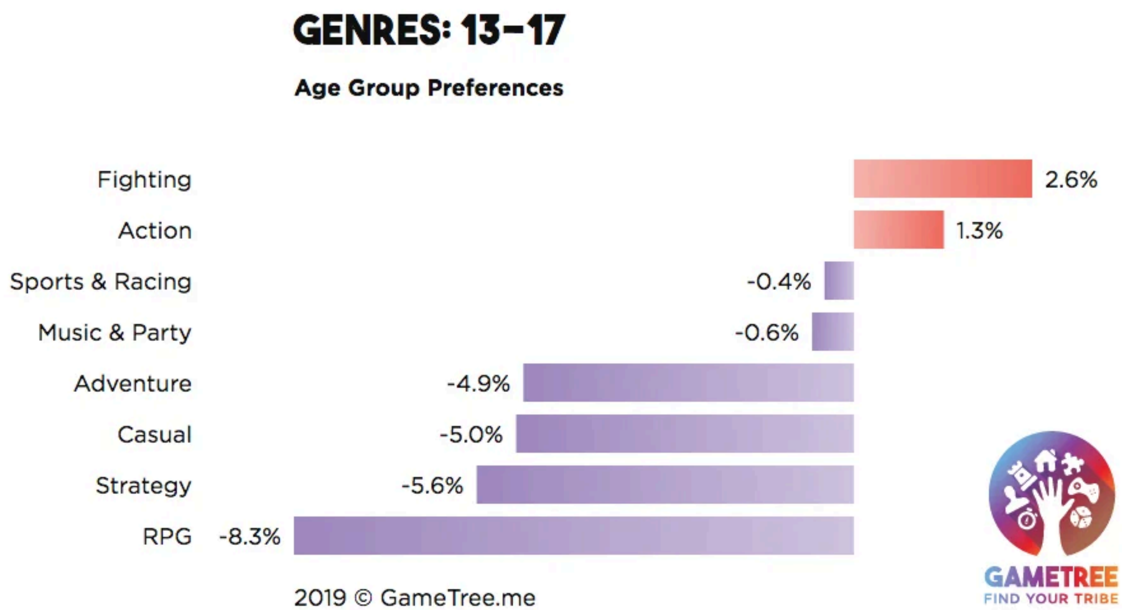


Fig. 6.1

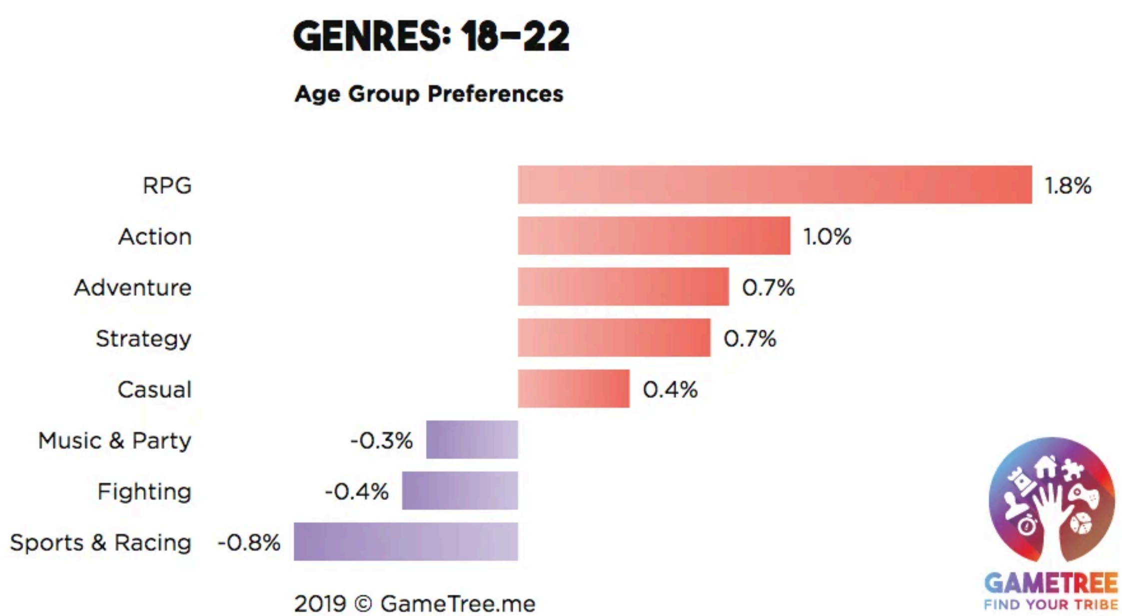
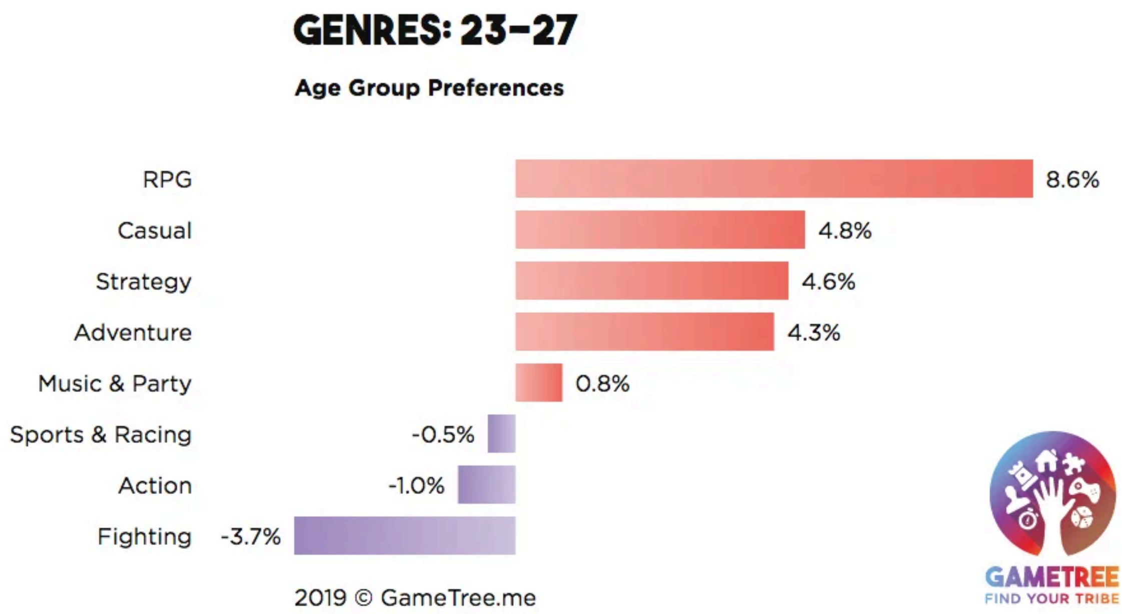


Fig. 6.2



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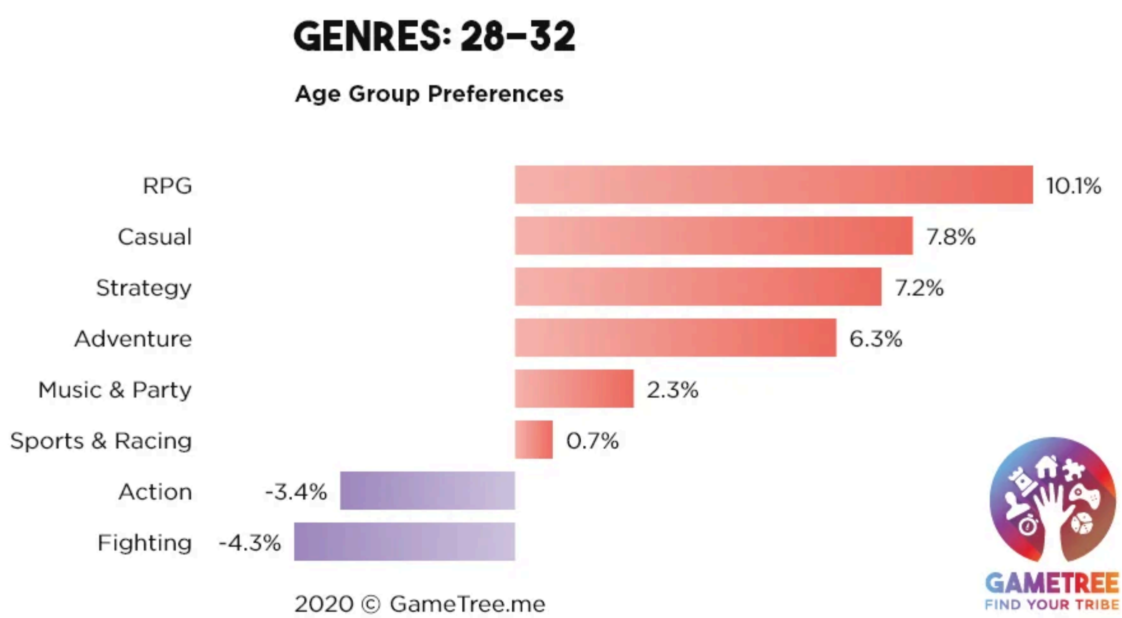

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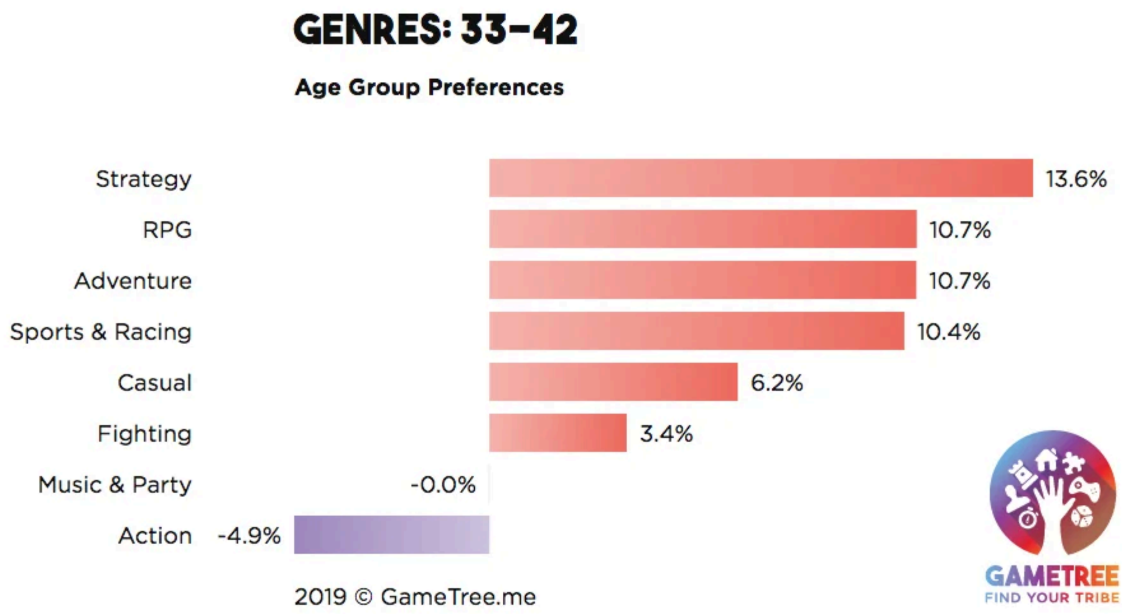


Fig. 6.5

While there is ample research on the psychological impacts of the time children and teenagers spend playing various video game genres, studies specifically examining the psychological factors influencing their genre preferences are limited. Hence, the following analysis predominantly relies on indirect evidence and theoretical assumptions:

1. Visual Appeal: Teenagers often gravitate towards action and fighting games rather than strategy games, which generally offer less dynamic and vibrant visuals. Action and hybrid genres typically prioritize high-quality, immersive graphics to enhance fast-paced gameplay and detailed environments, whereas strategy and puzzle games tend to focus more on mechanics and strategic depth over graphical fidelity.

2. Feedback and Gratification: Teenagers prefer games that offer immediate feedback and rewards. Strategy games, often inheriting turn-based elements from their board game predecessors, require long-term planning and deliver delayed gratification, which may not appeal to youths looking for quick outcomes.

3. Thematic Interest: The themes prevalent in strategy games, such as historical warfare and economic management, may not attract younger players as effectively as themes that are either more relatable or fantastical.

The analysis highlights a significant gap: strategy games are educationally effective but not popular among young players. Addressing this challenge in my project involves designing a video game that retains the educational benefits of strategy games—such as engaging with complex tasks and enhancing critical problem-solving skills (Gui, Cai, Yang, Kong, Fan, & Tai, 2023). At the same time, the game will need to improve upon traditional strategy games by offering more vibrant visuals, quicker feedback, and themes that resonate with younger audiences. This approach aims to make strategy games more appealing and accessible to this demographic.

Competitive Analysis

Besiege is a physics-based building game that challenges players to construct medieval siege engines to complete various objectives and destroy structures. The game stands out for its highly realistic physics simulation and inventive gameplay, where players creatively assemble machinery from a wide range of available parts. It offers a distinctive educational aspect by indirectly teaching principles of engineering and mechanics through trial and error in machine building and scenario solving (Besiege Wiki, n.d.).

Similarities

- Construction Mechanics: Like Besiege, my game allows players to build their own machines using a variety of available parts. This feature empowers players to experiment with different construction strategies and learn through practical engagement.
- Physics Simulation: Both games feature realistic physics simulations that add depth and realism to the gameplay. This not only enhances the gaming experience but also educates players on the dynamics of force, motion, and interaction between different materials and structures.

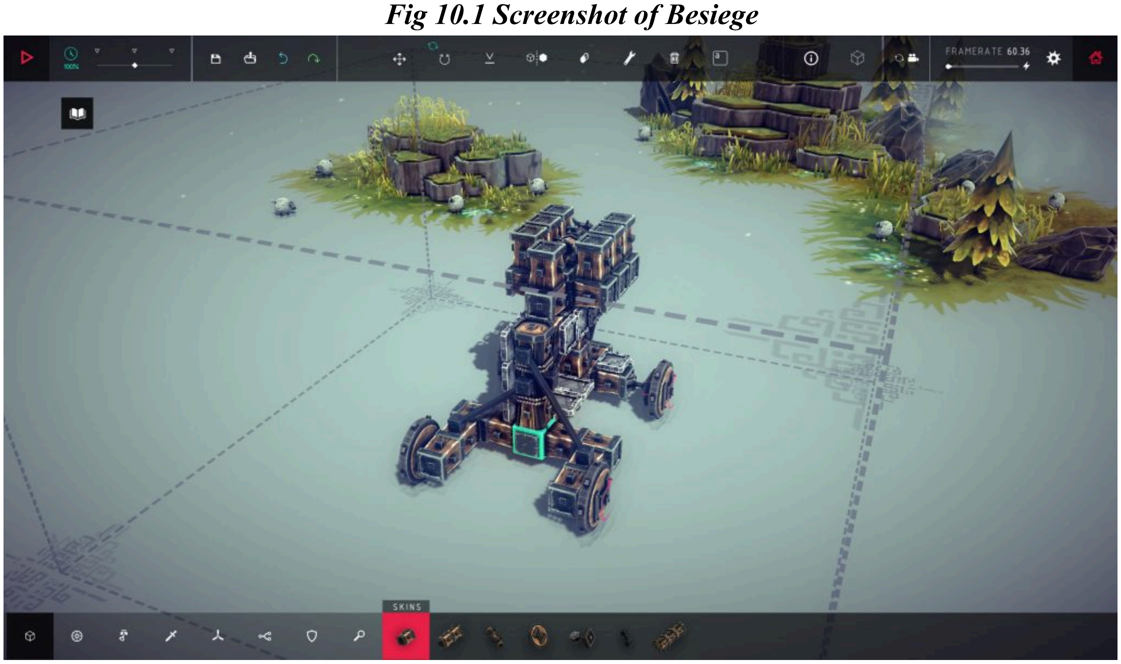
- Educational Value: Besiege has a strong educational component, particularly beneficial for teaching basic engineering concepts. My game will also harness this potential by incorporating design challenges that encourage players to think critically and apply rotational motion physics.

Differences

- Accessibility: While Besiege offers a complex challenge, my game will lower the entry barrier by simplifying the rules and streamlining the game objectives. This adjustment aims to make the game more approachable and enjoyable for beginners and younger players.
- Physics Complexity: Unlike Besiege, which simulates a broad range of physics aspects, my game will specifically focus on rotational motion and collisions. It will adopt a more realistic approach to these elements, allowing players to delve deeper into tactics focused on this particular area of physics.
- Thematic Appeal: To better connect with young adults, my game will incorporate themes that resonate more strongly with this demographic. By integrating popular toys and elements familiar to teenagers, the game seeks to engage and retain the interest of young players, enhancing its educational and entertainment value.

By addressing these key areas, my game aims to retain the core of what makes Besiege successful, while tailoring the experience to better suit younger audiences and those new to physics-based strategy games.

Fig 10.1 Screenshot of Besiege



Player Characteristics

The primary target audience for Duel of Spin consists of teenagers aged 13-17. A key challenge of this project is to make the strategy game a spontaneous choice for players in this age group, extending beyond educational and research settings. The game is designed to appeal to players with a budding interest in physics and engineering. With its simple and intuitive interactivity and controls, Duel of Spin is accessible on various platforms, making it suitable for both novice and experienced gamers.

Persona A:

- Name: Jeff
- Age: 17
- Location: Seattle, Washington
- Education: Attends a private high school
- Physics Knowledge: Enrolled in AP Physics
- Hobbies: Video games, RC cars, trading card games
- Gaming Habits: Spends 20 hours per week gaming
- Preferred Platforms: PC, PlayStation
- Favorite Games: Call of Duty, Rocket League

Persona B:

- Name: Pete
- Age: 14
- Location: Tucson, Arizona
- Education: Attends a public middle school
- Physics Knowledge: Recently learned about kinetic energy and simple mechanical systems
- Hobbies: Soccer, social media, Nerf guns
- Gaming Habits: Games less than 4 hours per week
- Preferred Platforms: Mobile
- Favorite Games: Fortnite, Roblox

Learning Contents Outline

Duel of Spin is a strategy game that actively integrates physics education, enabling players to explore physics concepts through strategic top customization and battles that are annotated in real-time. This approach not only introduces physics knowledge but also reinforces learning through observable dynamics during gameplay. Physics knowledge involved in the tutorial and gameplay of Duel of Spin are:

1. Newton's Laws of Motion: (Chakrabarty et al., 2016)
    - First Law (Law of Inertia): Explains that an object at rest stays at rest, and an object in motion continues in motion with the same speed and in the same direction unless acted upon by an unbalanced force.
    - Second Law (Force and Acceleration): States that the acceleration of an object depends on the net force acting upon it and the object's mass.
    - Third Law (Action and Reaction): For every action, there is an equal and opposite reaction.
2. Torque: (Chakrabarty et al., 2016)
    - A measure of the force that causes an object to rotate. The effect of the force depends on the location where it is applied, which influences the object's rotational motion.
3. Angular Momentum: (Chakrabarty et al., 2016)
    - Defines the quantity of rotation of a body, which is the product of its moment of inertia and angular velocity.
4. Mass Distribution and Moment of Inertia: (Chakrabarty et al., 2016)
    - Focuses on how the distribution of mass affects the rotational dynamics of an object. Moment of inertia is a critical factor in determining how an object will rotate when force is applied, impacting the stability and behavior of the tops in gameplay.

5. Gyroscopic Effects: (Chakrabarty et al., 2016)
    - Precession: The movement of the axis of a spinning object, such as a top, describing a circle around a vertical axis due to an external torque.
    - Nutation: A secondary motion where the axis of a spinning object wobbles around its mean precessional path.
6. Rigid Body Dynamics: (Chakrabarty et al., 2016)
    - Analyzes the motion of solid objects under the influence of external forces and torques, disregarding any deformations.
7. Elasticity and Plasticity: (Chakrabarty et al., 2016)
    - Elastic Collisions: Where the total kinetic energy post-collision is equal to the total kinetic energy pre-collision.
    - Inelastic Collisions: Collisions in which some kinetic energy is converted into other forms of energy.
8. Friction: (Chakrabarty et al., 2016)
    - The force opposing the relative motion between surfaces in contact.
    - Static Friction: Prevents the relative motion between two surfaces at rest.
    - Dynamic (Kinetic) Friction: Occurs between surfaces in relative motion.
9. Conservation Laws: (Chakrabarty et al., 2016)
    - Conservation of Energy: The principle that the total energy in an isolated system remains constant over time.
    - Conservation of Momentum: The total momentum of a closed system remains constant, assuming no external forces interfere.

Learning Objectives

By playing Duel of Spin, players can potentially achieve the following educational outcomes:

1. Reinforce Understanding of Newton's Laws of Motion: Players will deepen their grasp of how objects interact and move according to these fundamental laws.
2. Learn About Torque: Players will understand torque and its role in initiating rotational motion.
3. Familiarize with Angular Momentum: While players are not expected to calculate angular momentum, they will learn to anticipate its general effects in rotational motion.
4. Understand Moment of Inertia: Players will become familiar with the concept of moment of inertia and learn to estimate its value based on an object's shape and mass distribution.
5. Explore Gyroscopic Effects: Players will be introduced to gyroscopic phenomena and understand their implications in real-world applications.
6. Introduction to Rigid Body Dynamics: Players will gain a basic understanding of how forces affect the motion of rigid bodies.
7. Anticipate Collision Outcomes: Players will learn to predict the results of collisions based on the elasticity of the objects involved.
8. Reinforce Knowledge of Friction: Players will enhance their understanding of how friction influences the movement of objects.
9. Deepen Understanding of Conservation Laws: Players will solidify their knowledge of energy and momentum conservation laws and their applications in physical systems.

Game Design

Overview

Duel of Spin is a 3D strategy game set in a futuristic universe, where players engage in spinning top battles driven by physics and strategic design. The game includes two primary modes: a campaign mode that progressively teaches physics principles through guided gameplay, and a sandbox mode that allows for unlimited creative exploration of game mechanics. Central to both modes is the customization feature, where players choose from over 25 different components to construct tops with varying shapes, weights, and mass distributions to counter their opponents' designs effectively. Once the customization is complete, the tops are launched into automated battles within a concave, bowl-shaped arena. Here, the tops converge and collide without player input, but with real-time annotated details displayed, allowing players to observe the impact of their design choices as the battle unfolds. This setup not only reinforces the game's educational goals but also keeps players engaged by visually demonstrating the physics at play.

Rules and Control

In *Duel of Spin*, each level represents an independent battle against a pre-scripted opponent. During the battle preparation phase, players use mouse clicks to inspect the opponent’s top and customize their own top by swapping components and adjusting parameters. Pressing the “DUEL” button initiates a battle simulation powered by the NVIDIA PhysX system, providing real-time calculated animations. Players observe and analyze these simulations to receive feedback on their application of physics concepts. Victory is achieved when the opponent's top is either knocked out of the arena or stops spinning, unlocking new parts and subsequent levels.

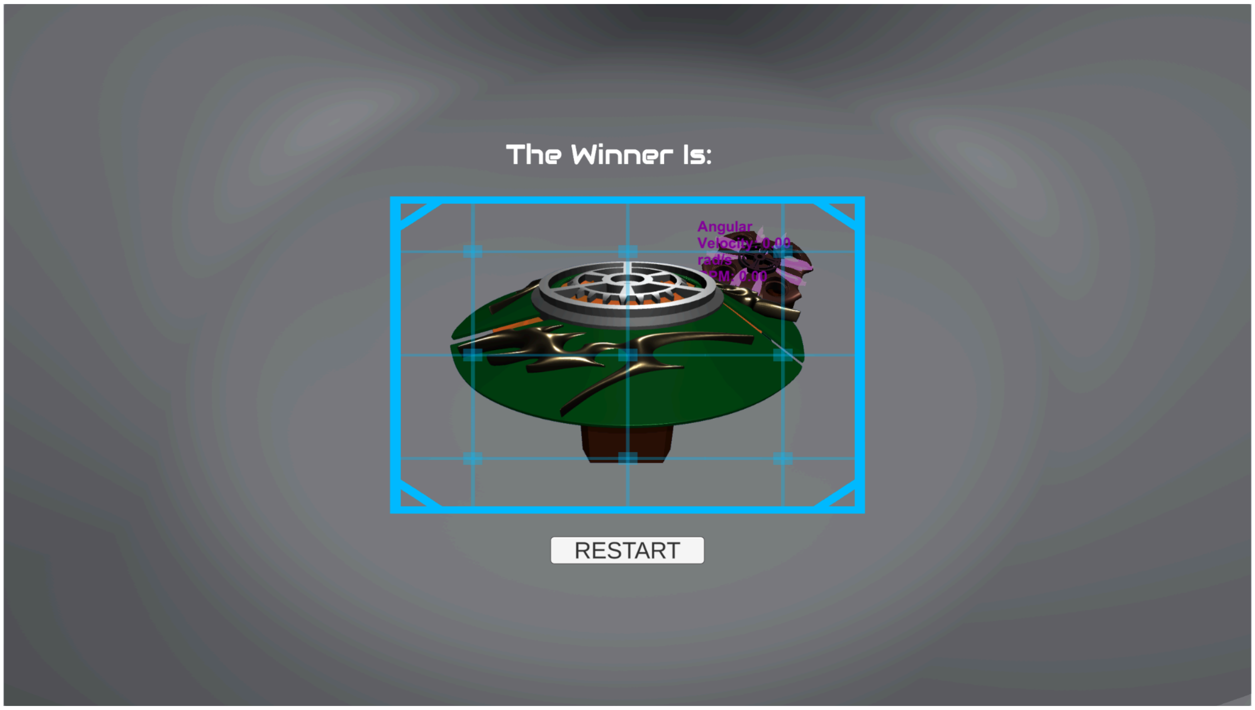
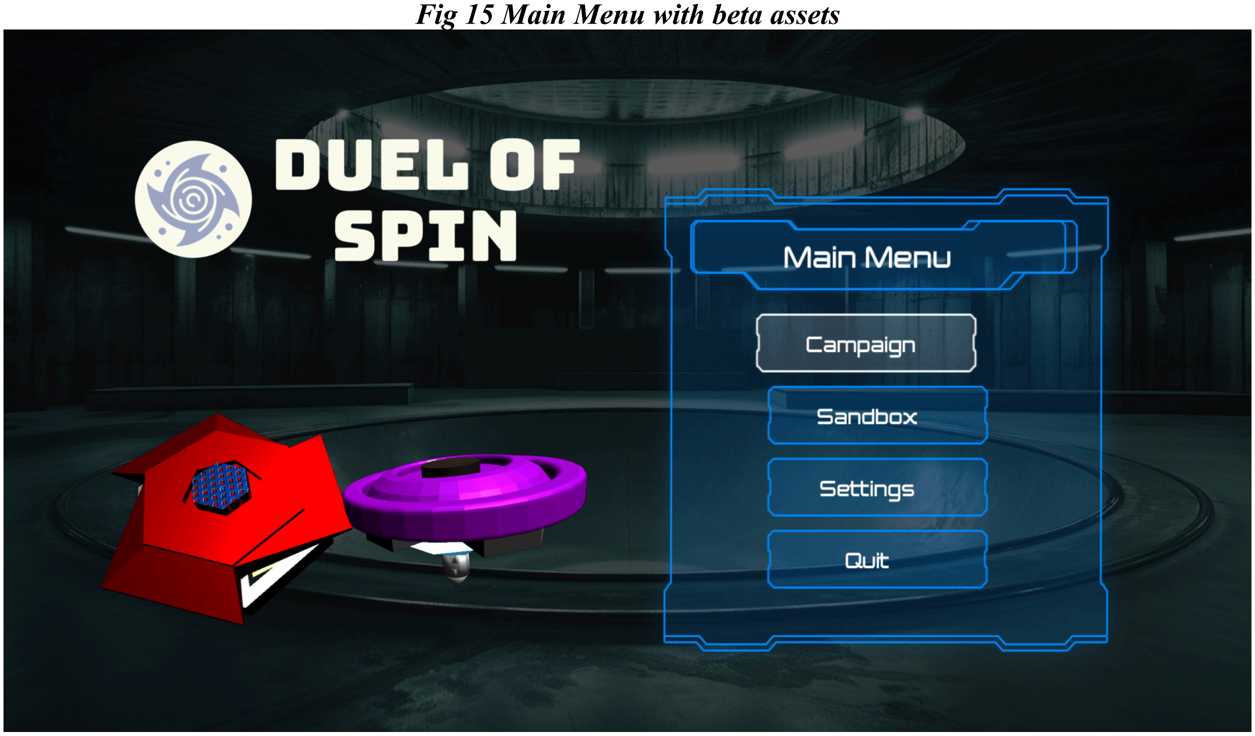


Fig 14 Winner Announcement Scene *- in this scene the player lose to its opponent therefore they can challenge the opponent again by pressing RESTART to start from the preparation phase*

Modes

Duel of Spin features two distinct modes accessible from the home menu: "Campaign" and "Sandbox."

Fig 15 Main Menu with beta assets



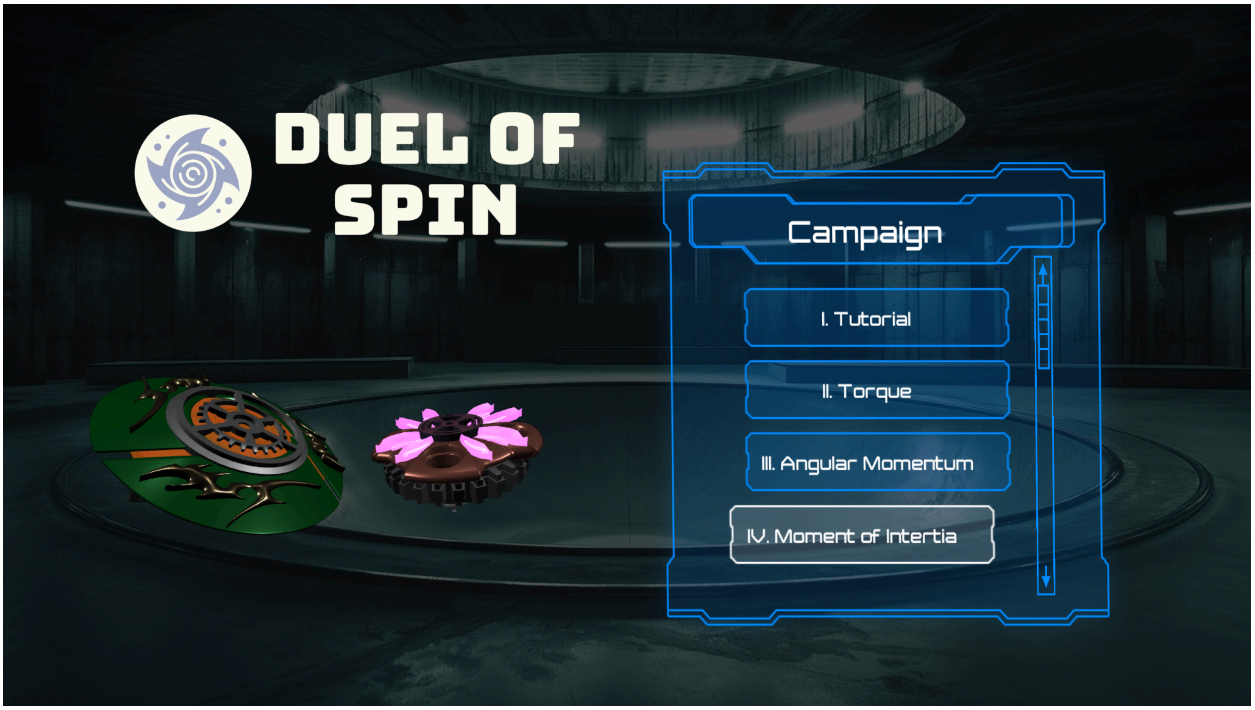


Fig 16.1 Campaign Menu, Level Selection

Campaign Mode

There are ten levels in the "Campaign" mode, each has a distinctive opponent top players need to defeat. The first level is "Tutorial", which uses pop-up text windows to teach players the basic controls including how to navigate through each UI panel in the game, how to swap components during customization, and which button to click to enter the battle. Subsequent levels focus on specific physics concepts: torque, angular momentum, moment of inertia, gyroscopic effects, rigid body dynamics, elasticity, friction, and conservation laws. Each level is themed around these concepts, where pop-up text windows not only introduce their relevance in top battle scenarios but also guide players in strategically customizing their tops using the newly acquired knowledge. Completing each level unlocks additional parts that enhance customization options, broadening strategic possibilities. Successfully completing all 10 levels grants access to "Sandbox" mode.

Sandbox Mode

Accessible from the main menu once unlocked, "Sandbox" mode offers a free-form play environment without explicit objectives. Here, players can experiment with endless combinations of parts. They have the flexibility to set the torque values, time acceleration, and simulate battles between two constructed tops. This mode encourages both individual exploration of the game's physics engine and competitive play, where players can either challenge themselves or partner up to see whose top dominates.

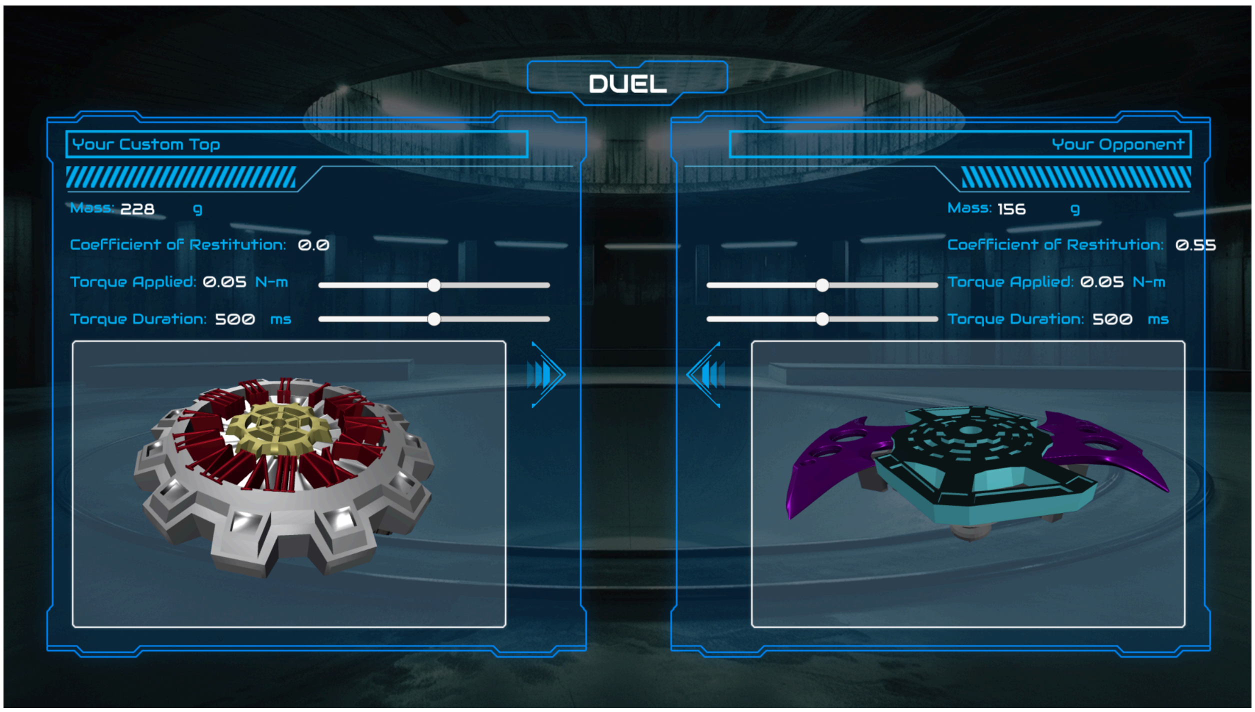


Fig 18 Tops Information Panel

Gameplay Experience Walkthrough

The gameplay experience of Duel of Spin consists of two main stages. In the first stage, customization, players first inspect their own top and the opponents' top. Based on the information given they can modify their tops by swapping parts to adjust the top's mass, ground friction, moment of inertia, and elasticity. This setup stage is crucial as it defines the physical properties that will influence the top's performance in the arena.

Fig 19 Swap Parts

Originally, the second stage was envisioned as the launching of the top, where players would apply torque to accelerate the top's angular velocity and strategically launch it into the arena, controlling its position, angle, and translational velocity. However, to keep the game straightforward and focused on strategy, this direct interaction has been simplified. Now, all necessary inputs such as torque application and initial velocity are predetermined during the customization stage or entered manually in the sandbox mode, based on the level design.

The actual gameplay in the second stage involves spectating a battle simulation. Once the tops are in motion, they move autonomously based on their configurations and the physics of the game, including collisions and gyroscopic effects. This stage is purely observational, with players watching the real-time, annotated simulation unfold. This annotation provides instant feedback on changes like angular velocity, helping players understand the battle dynamics as they occur. (see figure 20)

When significant collisions happen, particularly those that drastically alter the energy levels of the tops, the game displays these moments in slow-motion with a close-up view. This not only adds excitement but also allows players to closely analyze the physics behind the collision. Watching how their strategically built tops perform, and seeing if their physics predictions were accurate, keeps players emotionally invested in the outcome. This engagement is further enhanced by real-time annotations that help players track the action and refine their strategies for future battles.

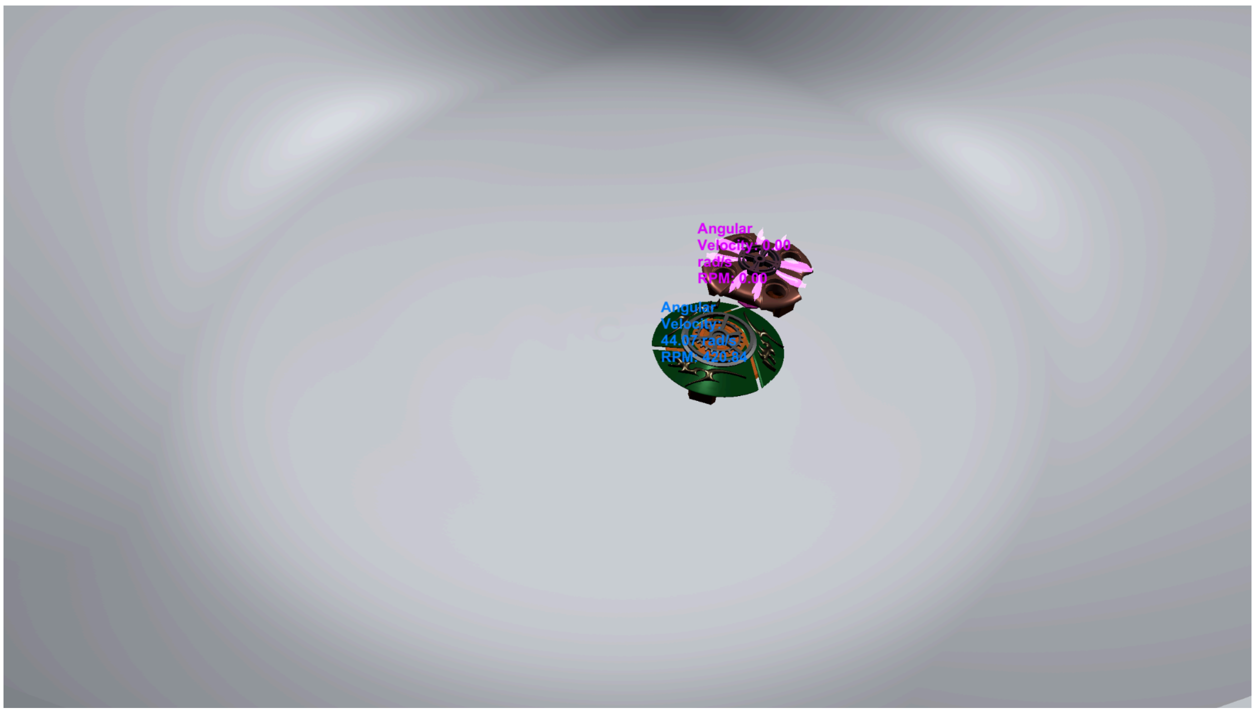


Fig 20 Annotated Battle Simulation - this part of the game is still under development therefore looks raw. The playback feature has not been added into it yet.

Design Rationale

The instructional design of *Duel of Spin* is grounded in Digital Game-Based Learning (DGBL) principles, which emphasize the integration of educational content into engaging gameplay to enhance learning outcomes. DGBL categorizes engagement into four key areas: affective, behavioral, cognitive, and cultural (Plass, Mayer, & Homer, 2020; Plass, Homer, & Kinzer, 2015). The design of *Duel of Spin* leverages these categories to create an immersive and educational experience.

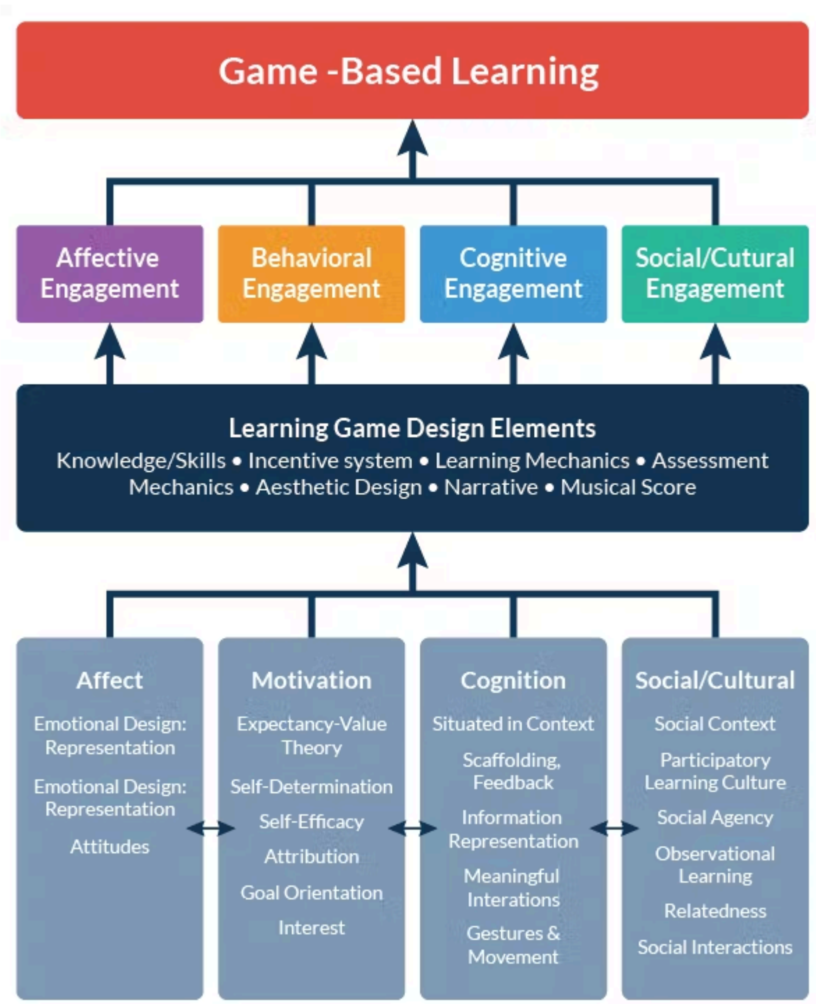


Fig 21 DGBL Diagram

Affective Engagement

Affective engagement focuses on the emotional connection and motivation players feel towards the game. In *Duel of Spin*, this is achieved through visually appealing 3D graphics and vibrant colors, which make the game visually stimulating and enjoyable. Additionally, the faster game pace keeps players actively engaged and excited, maintaining their interest and encouraging prolonged play (Plass, Mayer, & Homer, 2020).

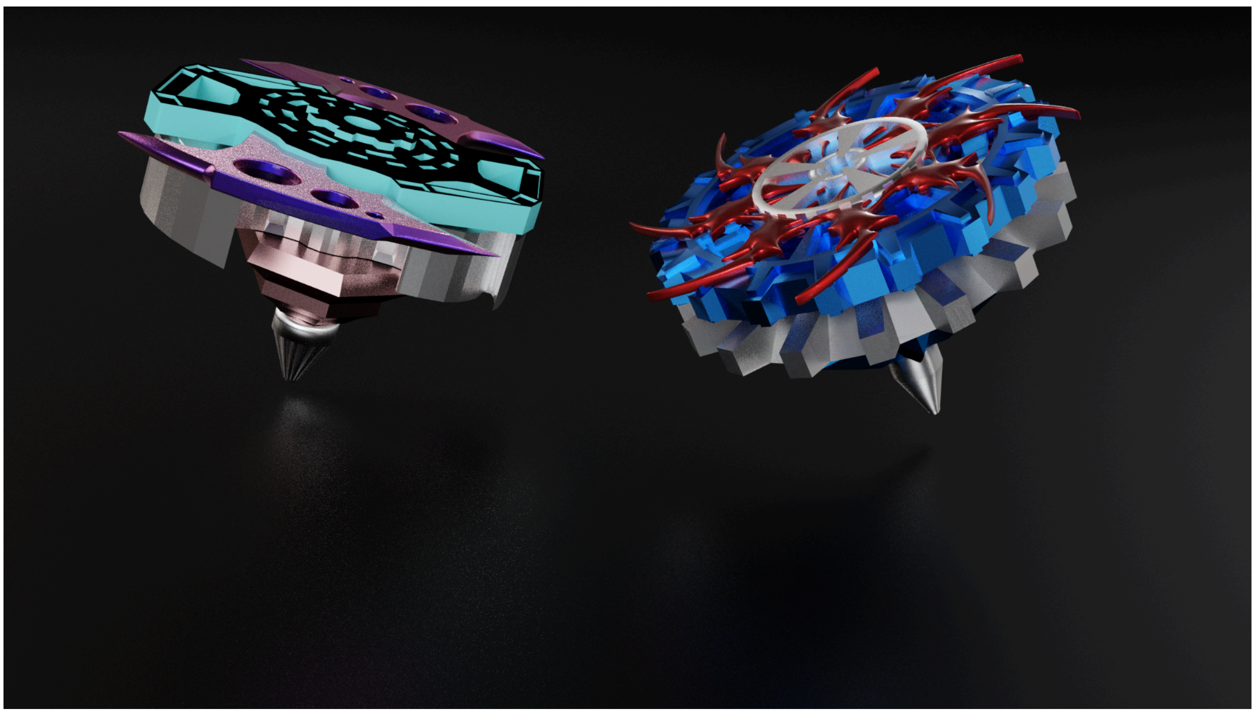


Fig 22 HD Rendering of the tops

Behavioral Engagement

Behavioral engagement involves the actions and participation of players within the game. *Duel of Spin* incorporates several design elements to enhance behavioral engagement:

- Unlockable Parts: Players unlock new components as they progress through levels, providing a sense of achievement and encouraging continued play.
- Key Moment Playback: Significant events in battles are highlighted with slow-motion replays, allowing players to analyze and learn from these critical moments.
- Competitive Play: The sandbox mode offers a competitive element where players can challenge themselves or others, fostering a sense of competition and replayability (Plass, Mayer, & Homer, 2020; Plass, Homer, & Kinzer, 2015).

Cognitive Engagement

Cognitive engagement pertains to the mental effort and strategies employed by players. *Duel of Spin* uses several principles to enhance cognitive engagement:

- Text Box Guidance: Instructional text boxes utilize the Temporal and Spatial Contiguity Principles, appearing simultaneously with relevant gameplay actions and placed near the game elements they describe. This minimizes cognitive load and helps players connect instructions with their actions (Mayer, 2009).
- Tutorial Levels: These levels employ the Pretraining Principle, introducing players to key concepts before they encounter them in gameplay, ensuring that they understand the basics before moving on to more complex tasks (Plass, Mayer, & Homer, 2020).

Cultural Engagement

Cultural engagement relates to how well the game's content connects with the players' interests and cultural background. *Duel of Spin* leverages the popularity of battle tops, inspired by the Beyblade series, to create a familiar and relatable theme. This cultural connection helps draw players in and makes the educational content more appealing and accessible (Plass, Mayer, & Homer, 2020).

Fig 24 "Beyblades, a Japanese Phenomenon, Invade American Homes" The New York Times

By integrating these DGBL principles into its design, *Duel of Spin* not only engages players across multiple dimensions but also provides a robust framework for learning complex physics concepts through play.

Theory of Change

The following theory of change diagram visually illustrates the context, purpose, and the development of effectiveness of Duel of Spin.

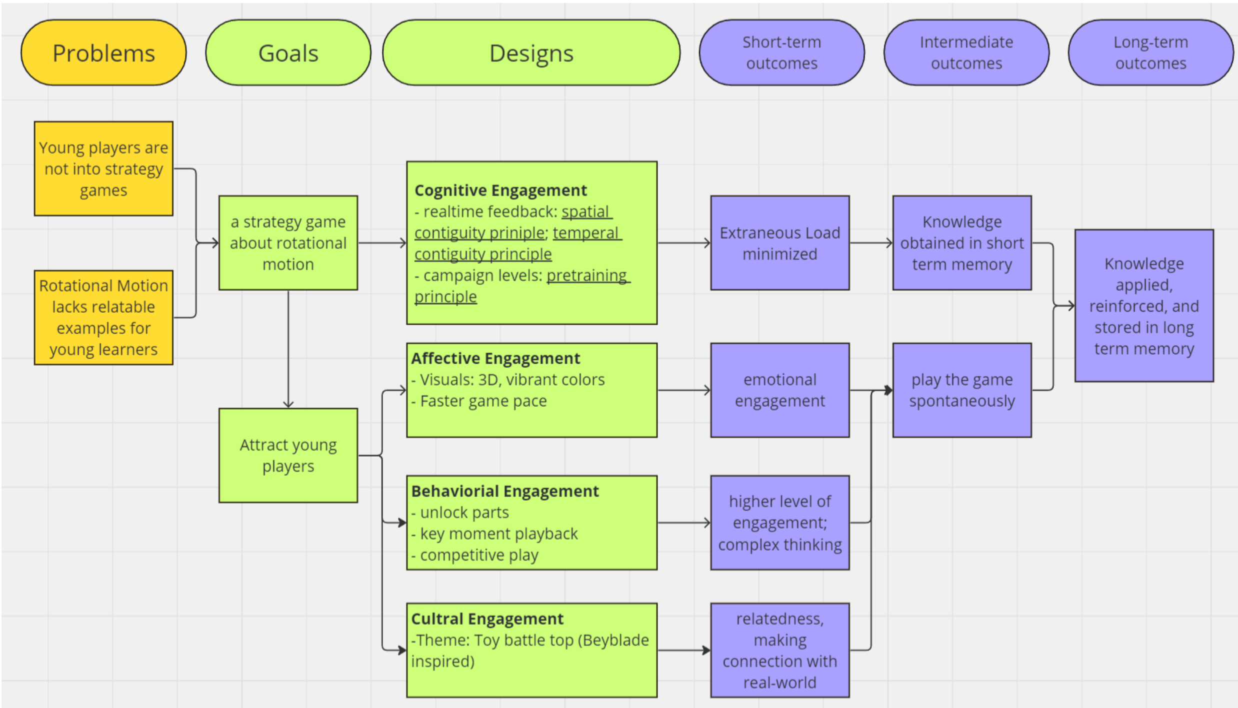


Fig 25 Theory of Change Diagram

Evaluation & Iteration

The sandbox mode of *Duel of Spin* is now in a playtest/user research-ready state. The next phase involves iterating the design of the UI, gameplay, and physics based on feedback gathered from these playtests. To guide this iteration process, we have developed three key research questions:

Research Question 1: Which UI interaction is more intuitive to players during the customization phase—a click-and-swap interaction or a drag-and-drop interaction?

- Research Method: Player Observation, Comparative Method

- Description: We will observe players as they interact with the customization phase of the game, comparing the intuitiveness and ease of use between the click-and-swap and drag-and-drop interactions. By analyzing player behavior and preferences, we aim to identify which method provides a smoother and more engaging user experience.
- Objective: Optimize the UI for better player interaction and satisfaction.

Research Question 2: How much "video game" satisfaction do players derive from this game?

- Research Method: Survey, Comparative Method, Player Observation

- Description: Participants will play *Duel of Spin*, *Besiege*, and *Bridge Designer from engineering.com*. After each game session, they will complete a survey rating their excitement and engagement levels on a scale chart. Additionally, we will observe their engagement and reactions during gameplay.
- Objective: Measure and compare the enjoyment and engagement provided by *Duel of Spin* relative to other physics-based games to identify areas for enhancement.

Research Question 3: Does playing this game facilitate players' learning of physics?

- Research Method: Controlled User Study

- Description: We will select participants who are scheduled to learn the rotational motion chapter in high school within the next week and divide them into two groups unbiasedly. Group 1 will play *Duel of Spin* for 15 minutes before their lesson. After they have completed the chapter in school, both Group 1 and a control group will take a test on rotational motion knowledge. We will compare the test results to determine the effectiveness of the game in enhancing learning.
- Objective: Assess the educational impact of *Duel of Spin* on players' understanding of physics concepts.

By systematically addressing these research questions, *Duel of Spin* can iteratively refine its design to ensure it is both an engaging game and an effective educational tool.

Conclusion

Duel of Spin represents a novel approach to STEM education, leveraging the immersive and interactive nature of video games to teach complex physics concepts. By incorporating Digital Game-Based Learning (DGBL) principles, the game engages players across multiple dimensions, making learning both effective and enjoyable. The iterative design process, guided by user feedback and research, ensures that the game remains accessible and appealing to its target audience of teenagers. Through strategic customization, annotated battle simulations, and a familiar cultural theme, Duel of Spin not only enhances players' understanding of rotational motion but also fosters a deeper interest in physics and engineering. This project demonstrates the potential of combining educational content with engaging gameplay, offering a valuable tool for both educators and learners in the pursuit of STEM education.

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