

Virtual Roller Coaster Design

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JTILT
Competition
Honorable
Mention

This lesson received an Honorable Mention in the 2023 JTILT Technology-Rich Lesson Plan Competition. It was not peer-reviewed.

OVERVIEW

This lesson offers a technology-enriched educational experience for 10th grade students that focuses on applying geometry, trigonometry, and physics. Students design a virtual roller coaster by applying geometric shapes (e.g., circles, triangles, and polygons), trigonometric ratios (e.g., sine, cosine, tangent), and physics principles (e.g., forces, energy conservation, motion dynamics).

Students are challenged to make simulations that reach a height of 100 feet, a track length of 1000 feet, and incorporate one or more loops. They explore concepts like the Pythagorean Theorem, circular motion, and centripetal forces. Assessments focus on precision and creativity, presentation effectiveness, and depth of reflective discussions.

Topics: Collaborative Learning, Geometry, Physics, Technology Integration, Trigonometry

Time: Five 50-minute class sessions.

MATERIALS

- NoLimits 2 Roller Coaster Simulation Software compatible with Windows and Mac computers
- Computers and internet access
- Projector and screen
- Whiteboard and markers
- [Lesson Instruction Handout](#) (DOCX)
- [Safety Considerations Instructional Handout](#) (DOCX)
- [Geometric Shapes Instructional Handout](#) (DOCX)
- [Trigonometric Principles Instructional Handout](#) (DOCX)
- [Assessment Criteria Rubric](#) (DOCX)

CONTEXT-AT-A-GLANCE

Setting

This Virtual Roller Coaster Design lesson was created for a formal, urban public high school in the United States with a robust digital infrastructure, emphasis on experiential learning, and a student body that thrives on interactive, hands-on projects.

Modality

Hybrid (face-to-face instruction with online aspects)

Class Structure

This lesson was facilitated over five class sessions, lasting 50 minutes each, in a tech-oriented classroom. Instructors have flexibility in room setup tailored to the activities.

Organizational Norms

The institution should offer robust technological resources and support to promote technology-driven, collaborative learning.

Learner Characteristics

Learners were in 10th grade with diverse backgrounds and varying levels of prior knowledge regarding mathematics, physics, and roller coaster design. The optimal class size is 20-24 students.

Instructor Characteristics

Instructors should be tech-savvy and familiar with the NoLimits 2 Roller Coaster Simulation software (Steam, n.d.).

Development Rationale

The design rationale was to bridge mathematical concepts with real-world applications, enhancing engagement and understanding.

Design Framework

Project-Based Learning, promoting active learning through a hands-on project

SETUP

The following steps will ensure an effective learning environment for the Virtual Roller Coaster Design lesson.

TECHNOLOGY PREPARATION

Ensure all computers are equipped with the NoLimits 2 Roller Coaster Simulation software (Steam, n.d.), compatible with both Windows and Mac operating systems. Verify that each computer meets the software's system requirements for optimal performance. Arrange computers in a way that facilitates both individual work and collaboration among students.

CLASSROOM ARRANGEMENT

Set up the classroom to accommodate both lecture-style teaching and group discussions. Depending on the class session (see Learning Representation section), this may involve arranging desks in clusters or rows. Designate a space for the projector and screen for software demonstrations and student presentations.

MATERIAL DISTRIBUTION

Prepare the handouts and rubric:

- Lesson Instruction Handout (DOCX)
- Safety Considerations Instructional Handout (DOCX)
- Geometric Shapes Instructional Handout (DOCX)
- Trigonometric Principles Instructional Handout (DOCX)
- Assessment Criteria Rubric (DOCX)

The handouts can be distributed individually or bundled into a stapled packet for students.

INSTRUCTOR PREPARATION

Become familiar with the NoLimits 2 software to effectively guide students through the design and simulation process. As the lesson progresses, students can showcase more complex functions of the NoLimits 2 software in lieu of the instructor. Plan

the introduction of each session, ensuring a clear understanding of the day's objectives and activities.

TIME ALLOCATION

Allocate time for each lesson plan phase, balancing instruction, hands-on activities, group work, and presentations. Schedule brief intervals for class discussions and feedback sessions.

SAFETY BRIEFING

Although the lesson involves virtual simulation, emphasize the importance of safety in roller coaster design as a key learning objective. Discuss responsible use of technology and software within the classroom. By following these steps, instructors can create a dynamic and interactive learning environment conducive to exploring the principles of roller coaster design in a technology-integrated classroom.

STANDARDS

The Virtual Roller Coaster Design lesson aligns with several educational standards, ensuring a comprehensive and relevant educational experience. This lesson was designed in California, thus specific state standards were utilized.

MATHEMATICS CONTENT STANDARDS

The following Common Core State Standards (CCSS, n.d.) for Mathematics, adopted in California, align with this lesson.

CCSS.MATH.CONTENT.HSG.MG.A.1: "Use geometric shapes, their measures, and their properties to describe objects" in roller coaster design (Common Core State Standards Initiative, n.d., Modeling with Geometry section).

CCSS.MATH.CONTENT.HSG.GMD.A.3: Apply "volume formulas for cylinders, pyramids, cones, and spheres" in practical contexts like roller coaster design (Common Core State Standards Initiative, n.d., Geometric Measurement & Dimension section).

CCSS.MATH.CONTENT.HSG.MG.A.3: Utilize "geometric methods to solve design problems," including roller coaster construction (Common Core

State Standards Initiative, n.d., Modeling with Geometry section).

CCSS.MATH.CONTENT.HSG.CO.A.1: Understand “precise definitions of angle, circle, perpendicular line, parallel line, and line segment” in the context of roller coaster tracks and structures (Common Core State Standards Initiative, n.d., Congruence section).

CCSS.MATH.CONTENT.HSG.CO.C.10: Explore theorems about triangles, such as angle sum and properties of isosceles triangles, in designing roller coaster tracks (Common Core State Standards Initiative, n.d.).

CCSS.MATH.CONTENT.HSG.SRT.C.8: Employ “trigonometric ratios and the Pythagorean Theorem” in solving real-world problems in roller coaster design (Common Core State Standards Initiative, n.d., Similarity, Right Triangles, & Trigonometry section).

CCSS.MATH.CONTENT.HSG.SRT.D.11: Apply the Law of Sines and the Law of Cosines in determining measurements in roller coaster design (Common Core State Standards Initiative, n.d.).

CONTEXT AND SETTING

The Virtual Roller Coaster Design lesson plan was implemented at a suburban public high school in a 10th grade classroom. This school is characterized by its diverse student population and a strong emphasis on integrating STEM (Science, Technology, Engineering, and Mathematics) education into the curriculum. When implementing this lesson, the school should support innovative teaching methods and the incorporation of technology in learning.

The classroom was designed to support both individual and collaborative learning experiences. The environment had modern computers, necessary for running the NoLimits 2 Roller Coaster Simulation software. This software was a crucial component of the lesson, facilitating an interactive and immersive learning experience for students. The classroom layout was adaptable, allowing for configurations that supported direct instruction, group discussions, and collaborative project work.

The school’s educational ethos strongly encouraged project-based learning and technological fluency, making it an ideal environment for implementing this lesson. The lesson was designed to align with the

objectives of fostering critical thinking, creativity, and collaborative skills among students. These objectives are reflected in the lesson's focus on applying mathematical and physical concepts to real-world scenarios.

Overall, the context and setting for the Virtual Roller Coaster Design lesson plan were integral to its success. The supportive, technology-rich environment and the school’s commitment to innovative and student-centered learning created an ideal backdrop for this experience.

LEARNING OBJECTIVES

Upon completion of the Virtual Roller Coaster Design lesson, students were able to:

- Utilize geometric shapes and trigonometric principles to design the structural elements of a roller coaster, including loops, curves, and slopes.
- Employ mathematical equations and physics concepts to calculate and predict the behavior of roller coaster elements, focusing on aspects like speed, force, and motion.
- Demonstrate proficiency using the NoLimits 2 Roller Coaster Simulation software to model and test roller coaster designs, ensuring compatibility with Windows and Mac systems.
- Create a roller coaster design that meets specific criteria, including a minimum height of 100 feet, a track length of 1000 feet, and at least one loop.
- Work effectively in teams to brainstorm, design, and simulate roller coasters, enhancing communication, cooperation, and problem-solving abilities.
- Recognize and integrate safety principles in roller coaster design, understanding the importance of structural integrity and rider safety.
- Prepare and deliver presentations that effectively communicate the roller coaster design process, challenges encountered, and solutions applied.
- Analyze and evaluate the roller coaster designs and simulations for accuracy and feasibility, applying critical thinking to optimize the design for safety and enjoyment.
- Understand the real-world applications of the mathematical, scientific, and engineering principles used in the lesson, identifying career paths and practical uses in various industries.

- Encourage creative and innovative thinking in designing roller coasters, allowing students to explore unique and imaginative designs.

LEARNING REPRESENTATION

The Learning Representation section is written to explain how to implement this lesson.

SESSION 1: INTRODUCTION TO ROLLER COASTER DESIGN (50 MINUTES)

Introduction to Roller Coaster Design (8 minutes): Provide a brief overview of the project, highlighting the integration of math, physics, and technology. Distribute the Lesson Instruction Handout and Assessment Criteria Rubric as a reference for students.

Basic Geometric Concepts (12 minutes): Discuss circles, angles, shapes, symmetry, balance, scale, and proportion. Distribute the Geometric Shapes Instructional Handout as a reference for students.

Basic Trigonometric Principles (12 minutes): Introduce the Pythagorean Theorem, trigonometric ratios, Law of Sines, and Law of Cosines. Distribute the Trigonometric Principles Instructional Handout as a reference for students.

Application in Roller Coaster Design (12 minutes): Explain how these principles are applied in designing loops, curves, and slopes.

Group Students (1 minute): Either create student pairs or have students select a partner.

Assignment (5 minutes): Have students brainstorm initial design ideas in their pairs for their roller coaster.

SESSION 2: SOFTWARE INTRODUCTION AND INITIAL DESIGN PHASE (50 MINUTES)

Software Demonstration (10 minutes): Show basic functions and features of NoLimits 2 software.

Initial Design Phase (35 minutes): Have students start designing their roller coasters in pairs. The

instructor should float between pairs supporting as needed.

Wrap-up (5 minutes): Summarize progress and set goals for the next session.

SESSION 3: ADVANCED DESIGN TECHNIQUES AND SAFETY CONSIDERATIONS (50 MINUTES)

Advanced Design Techniques (10 minutes): Cover more complex aspects of NoLimits 2 software like vertical loops, corkscrews, and banking turns.

Safety in Roller Coaster Design (10 minutes): Discuss the importance of safety, G-forces, and structural integrity. Distribute the Safety Considerations Instructional Handout as a reference for students.

Design Continuation (25 minutes): Have students apply advanced techniques and safety principles in their designs.

Debrief (5 minutes): Have students refine their designs and think about presentation structure.

SESSION 4: FINALIZING DESIGNS AND PREPARING PRESENTATIONS (50 MINUTES)

Design Finalization (20 minutes): Have students make final adjustments to their roller coaster designs.

Presentation Guidance (5 minutes): Provide guidance on structuring presentations and effectively communicating designs.

Presentation Preparation (20 minutes): Have student pairs prepare their presentation plans.

Review (5 minutes): Facilitate a peer-review session for feedback on designs and presentation plans.

SESSION 5: PRESENTATION AND REFLECTION (50 MINUTES)

Student Presentations (30 minutes): Have pairs present their designs, highlighting the application of mathematical and safety principles.

Reflective Discussion (15 minutes): Discuss what was learned, the challenges faced, and how concepts were applied.

Closure (5 minutes): Summarize key learning points and distribute the assessment rubric.

ASSESSMENT

Roller coaster designs were evaluated for mathematical accuracy, physics application, and safety. Presentations were assessed for clarity, organization, and understanding. Reflections were analyzed for depth of understanding and application in real-world scenarios. The Assessment Criteria Rubric was used in the assessment of this project.

DIFFERENTIATION

For students who require additional support, offer them a pre-made roller coaster design as a starting point. This design could include fundamental elements like the roller coaster's structural frame and initial track layout. Instructors may choose to leave out specific details, such as the arrangement of loops, twists, or special features, allowing students to focus on modifying and enhancing these aspects. Alternatively, they could simplify the design by reducing the complexity of the roller coaster's layout. The provided design may also include basic measurements and angles, providing a foundation for students to work from and build upon.

Encourage students seeking an extra challenge to design and simulate a roller coaster that meets specific advanced criteria, such as achieving a certain maximum speed or incorporating a predetermined number of inversions. Instructors can specify complex criteria that require students to apply advanced physics and engineering principles in their design. For instance, they might require the roller coaster to achieve a specific G-force or include unique features like corkscrews or multiple launch sections. Instructors should provide additional resources, such as advanced physics equations or engineering guidelines, to support students in meeting the elevated challenge criteria.

EXTENSION ACTIVITIES

Instructors could extend the lesson with the following activities:

- Have students research the engineering principles behind roller coaster design.
- Have students design and build a physical model of their roller coaster.
- Have students create a video or presentation about the history of roller coasters.

CRITICAL REFLECTION

For a comprehensive analysis, the virtual roller coaster design lesson should be implemented at least three times within different class groups or even different academic terms. This will provide a holistic view of its efficacy and adaptability to varying student cohorts.

If executed well, this lesson holds the potential to meet its goals of bridging the gap between theoretical trigonometry and real-world application. Its integration into the larger mathematical curriculum provides a refreshing practical application highlighting math's significance in real-world scenarios.

From preliminary observations, instructors may find that while students are enthusiastic about design, some might stray from mathematical precision. A challenging balance could be between fostering creativity and ensuring rigorous adherence to mathematical principles. Some implementation tips include beginning with a robust introduction to core mathematical concepts essential for design. Be sure to emphasize the importance of accurate calculations for safety and functionality. And allocate time for group discussions, allowing students to share challenges and solutions, fostering collaborative problem-solving.

Depending on feedback, instructors might want to integrate more advanced mathematical concepts or even expand the project's scope to include a physics segment. An additional session could be introduced where students compare their virtual designs with real-world roller coasters, analyzing any discrepancies and fostering an understanding why certain designs might not be feasible in real life.

In conclusion, while the project is a rich learning experience, its success lies in its execution, emphasizing the blend of creativity and mathematical rigor. Continuous reflection and adjustment is key to its perennial relevance and effectiveness.

REFERENCES

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ABOUT THE AUTHOR

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Frank's career spans roles as an Associate Software Developer at Broadridge Advisor Solutions, military service as an Electronic Warfare Systems Helper and Multichannel Communication Systems Operator, and leadership positions in educational organizations. He holds a Master of Science in Information Technology and is pursuing a Master of Education in Inspired Teaching and Learning and a Single Subject Teaching Credential in Mathematics from National University.

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