NEZHA INVENTORS KIT V2

Lesson 04: Balancing Act — Building a Unicycle Robot

Enhanced Lesson Plan | Grades 6–8 | STEAM, Robotics, Computer Science

LESSON OVERVIEW

Lesson Title	Balancing Act — Building a Unicycle Robot
Subject Area	Science, Technology, Engineering, Art & Math (STEAM)
Grade Level	Grades 6–8 (Adaptable for Grades 5 and 9)
Duration	2 Class Periods × 45 Minutes (90 minutes total)
Key Themes	Robotics, Center of Gravity, Belt Drives, Balance, Stability, MakeCode Programming, Iterative Design
Framework	5E Instructional Model (Engage, Explore, Explain, Elaborate, Evaluate)

SMART LEARNING OBJECTIVES

By the end of this lesson, students will be able to:

#	Objective	Domain
1	Explain the concept of center of gravity and demonstrate how its position affects the stability of a structure by experimenting with mass distribution on the robot.	Science / Knowledge
2	Describe how a belt drive transfers rotational force and motion from a motor to a wheel, and identify the trade-offs between belt tightness, slippage, and speed.	Science / Knowledge
3	Design, build, and program a unicycle robot using the Nezha Inventor's Kit V2 that can balance and travel forward on a single wheel with minimal human assistance.	Design / Engineering
4	Write and upload a MakeCode program that controls the motor to drive the unicycle wheel, incorporating speed adjustment and directional control.	Programming / Technology
5	Apply an iterative design process: test the unicycle	Problem-Solving / Iteration

#	Objective	Domain
	robot, identify balance or motion problems, make targeted modifications, re-test, and document all changes and outcomes.	

SUCCESS CRITERIA (I CAN STATEMENTS)

Students will demonstrate success when they can:

- I can draw a diagram showing where the center of gravity is on my unicycle robot and explain what happens if it moves too far forward, backward, or sideways.
- I can identify the drive belt, driver pulley, and driven pulley on my robot and explain how the belt transfers motion from motor to wheel.
- I can build a unicycle robot with a single drive wheel that can travel at least 30 cm on a flat surface without toppling.
- I can write a MakeCode program that controls the wheel motor at a stable speed and can be adjusted using buttons.
- I can document at least two design iterations with specific changes made and measurements of improvement.
- I can explain the role of the center of gravity in keeping my robot balanced and one structural change I made to improve stability.
- I can present my final unicycle robot with a live demonstration and explain both the physics and the code behind its operation.

KEY VOCABULARY

Pre-teach these terms using a word wall or visual glossary before the lesson begins:

Term	Definition	Real-World Connection
Center of Gravity (CoG)	The point in an object where its total weight is considered to act; if CoG is above the support base, the object is stable; if it falls outside, the object tips.	Tightrope walkers, sports cars (low CoG), tall cranes
Belt Drive	A system that uses a flexible belt looped around two pulleys to transfer rotational force and motion from a driver to a driven shaft.	Bicycle chain drive, car alternator belt, conveyor belts
Stability	The ability of an object to resist tipping and return to its equilibrium position after being disturbed.	Wide-base furniture, sumo wrestlers, racing car spoilers
Equilibrium	A state where all forces acting on an object are balanced, resulting in no net movement; a	Balanced scales, hovering helicopter, stationary

Term	Definition	Real-World Connection
	balanced robot is in equilibrium.	tightrope walker
Gyroscopic Effect	The tendency of a spinning object to resist changes in its orientation; a fast-spinning wheel provides stability (like a bicycle).	Spinning top, bicycle wheel, spacecraft attitude control
Tension	The pulling force transmitted through a belt, rope, or cable; belt tension must be sufficient to prevent slippage but not so tight it causes excessive friction.	Guitar strings, suspension bridge cables, fan belts
Counterbalance	A weight placed on the opposite side of a pivot to balance a load; used in unicycle robots to lower the center of gravity.	Crane counterweights, balance scales, see-saws
Inertia	The tendency of an object to resist changes in its motion; a moving unicycle robot continues forward unless a force acts to stop it.	Seatbelts in cars, stopping distance of trains, spinning tops
Traction	The grip between the wheel and the surface that allows the wheel to drive the robot forward without slipping.	Tyre tread, non-slip shoes, climbing equipment
Feedback Control	A system that continuously measures output and adjusts input to maintain a desired state; advanced balance robots use sensor feedback to stay upright.	Segway, thermostat, autopilot in aircraft

MATERIALS & RESOURCES

Category	Item	Purpose
Hardware	Nezha Inventor's Kit V2 (1 per team)	Building blocks for unicycle frame, wheel mount, and belt drive system
Hardware	PlanetX Smart Motor (1 per team)	Drives the unicycle wheel via belt drive mechanism
Hardware	Belt and Pulleys (from kit)	Transfer motor rotation to the wheel; demonstrate belt drive principles
Hardware	micro:bit v2 + Nezha Breakout Board	Programmable controller for wheel speed and direction
Hardware	USB Cables (1 per team)	Upload MakeCode programs to micro:bit

Category	Item	Purpose
Measurement	Ruler and Tape Measure	Measure travel distance and robot height (for CoG analysis)
Software	MakeCode (makecode.microbit.org)	Program motor speed, direction, and button-controlled adjustments
Classroom	Flat test surface (desk or floor)	Consistent testing surface for balance and travel trials
Classroom	Iteration Log Sheet (printed)	Document design changes, measurements, and outcomes for each iteration
Optional	Small additional weights (coins, clay)	Experiment with counterbalancing the robot's center of gravity

LESSON STRUCTURE — 5E MODEL

Total time: 2 × 45-minute class periods. Students explore the physics of balance and belt-drive mechanisms, then design and program a unicycle robot that can balance and move on a single wheel.

ENGAGE — Introduction & Hook (Period 1 | 15 min)

Time	Activity	Teacher Actions	Student Actions
0-5 min	Balance Challenge	Give each student a ruler and a pencil. Challenge: 'Balance the ruler flat on one finger. Now: can you balance it on the pencil point?' Ask: 'Why is it harder to balance on a point than on a flat surface?'	Attempt balance challenges. Discuss with partner: 'What determines whether something balances or falls? Where is the heaviest part?'
5-15 min	Video Hook	Show a 2-min video of a unicyclist balancing on a tightrope, then a Segway robot. Ask: 'How does a unicyclist stay upright? What would a robot need to do the same thing?'	Watch; jot 2 differences between human balance and robot balance. Share in Think-Pair-Share.
15-20 min	Design Brainstorm	Pose the design challenge: 'Build a robot that travels on a single wheel without falling over. Where will you put the heavy parts? How will you	Sketch a unicycle robot concept. Label where they would place the motor, battery, and frame to keep it balanced.

Time	Activity	Teacher Actions	Student Actions
		drive the wheel without tipping the robot?' Students sketch initial ideas.	

Key Misconception to Address in Engage

- Students often think 'heavier = more stable.' The key insight is position matters more than weight: a heavy object high up is LESS stable than a lighter object low down.
- Demonstrate with a toy or block: place a heavy eraser high on a narrow base vs. low on the same base. Show which tips more easily.
- Pre-assign team roles: Frame Engineer (structure), Drive Engineer (belt and motor), Coder, and Balance Tester.

EXPLORE — Design, Build & Belt Drive Investigation (Period 1 | 30 min + Period 2 | 15 min)

Time	Activity	Teacher Actions	Student Actions
0-10 min	Belt Drive Exploration	Distribute kits. Guide teams to first assemble ONLY the belt drive (motor + belt + pulley + wheel) WITHOUT the full robot frame. Ask: 'What happens if the belt is too loose? Too tight? What if the pulleys are different sizes?'	Assemble belt drive; test with hand-spinning the motor shaft. Record observations about belt tension and wheel speed.
10-35 min	Full Robot Build	Circulate with CoG prompts: 'Where is the heaviest component on your robot right now? Is the CoG above the wheel contact point? What could you move or lower to improve stability?'	Build full unicycle robot frame. Attach belt drive. Test balance before connecting to micro:bit. Make structural adjustments to lower CoG.
35-50 min	First Code & Roll Test	Demonstrate: motor forward at 50% speed; test. Ask: 'Does the robot travel straight? Does it tip? Adjust speed and observe what happens at different speeds.'	Write and upload motor code. Run first travel test on flat surface. Data Recorder measures distance traveled before tipping.
50-60 min	Iteration Round 1	Guide teams to make ONE specific change based on the first test. Ask: 'What caused the tipping — speed, weight distribution, belt slippage, or	Identify the primary cause of tipping. Make one targeted change. Run 3 more travel tests and compare results to original trials.

Time	Activity	Teacher Actions	Student Actions
		frame instability?'	

Guided Inquiry Prompts for Exploration Phase

- 'Your robot tips backward when it starts moving. What does that tell you about where the CoG is relative to the wheel contact point?'
- 'If the belt is slipping, should you increase belt tension or change motor speed? What is the difference between these solutions?'
- 'If you made the base wider (added a stabiliser), you would change the CoG stability. But the challenge requires a SINGLE wheel. What else can you adjust?'
- 'How fast does the unicycle wheel need to spin for the gyroscopic effect to contribute to stability? How would you test this?'

EXPLAIN — Concepts, Demonstrations & Code Sharing (Period 2 | 20 min)

Time	Activity	Description
0-8 min	Physics of Balance Mini-Lecture	Teach: Center of Gravity definition and position diagram; stability triangle concept (why wider bases are stable); belt drive diagram with driver/driven pulley labelled; gyroscopic effect explained with spinning top demo. Students annotate a printed diagram.
8-16 min	Code Sharing Round	Each team displays their MakeCode project for 90 seconds. Coder explains: 'We set motor speed to X because at lower speed Y happened, at higher speed Z happened.' Class asks one question per team.
16-25 min	Class Balance Analysis	Teams share their CoG adjustment: 'We moved the battery lower because...' Build a class table: Design Change vs. Stability Improvement. Identify the most effective CoG adjustment strategy across all teams.

ELABORATE — Advanced Testing & Creative Extensions (Period 2 | 20 min)

Time	Activity	Description
0-12 min	Obstacle Course & Precision Test	Set up a simple 3-marker slalom course (30 cm between markers). Teams test whether their robot can navigate it without tipping. Record: markers completed, tipping events, distance traveled.
12-20 min	Enhancement Challenges	Choose one: (A) Button A = slow speed, Button B = fast speed — test which is more stable; (B) Add a counterbalance weight and measure the change in

Time	Activity	Description
		stability; (C) Research Segway technology and write 3 sentences comparing it to their robot; (D) Program the robot to stop automatically after 100 cm.

Balance Testing Protocol

- Stability Score: 0 = tips immediately on start; 1 = travels 0-10 cm; 2 = travels 10-30 cm; 3 = travels 30+ cm without tipping. Record scores before and after each design change.
- Ensure all travel tests are on the same flat surface — carpet vs. hard floor dramatically changes traction and results.
- For the obstacle course, define a consistent starting position and measure from that point for every team to ensure fair comparison.

EVALUATE — Robot Demonstrations & Reflection (Period 2 | Final 10 min)

Phase	Time	Description
Demonstrations	2 min / team	Each team demonstrates their unicycle robot traveling on the flat surface and (if ready) the obstacle course. Presenter explains: (1) how they adjusted the CoG, (2) how the belt drive works, (3) one code decision and why they made it.
Peer Feedback	1 min / team	2 Stars & 1 Wish: two specific observations (e.g., 'your CoG is clearly low because...' 'the belt looks well tensioned because...') + one specific suggestion for improving balance or distance.
Reflection Exit Ticket	5 min	Students write: (1) What is Center of Gravity and how did it affect your robot? (2) What is one change you made between iterations and what did the data show? (3) Name one real robot that uses balance technology and explain how it works.

DIFFERENTIATION STRATEGIES

Learner Group	Strategy	Concrete Example
SEN / Beginning	Pre-built drive system	Provide a pre-assembled belt drive and wheel. Student focuses on attaching it to a pre-cut frame and writing the basic motor forward code.
SEN / Beginning	Simplified success criterion	Robot must travel 10 cm without tipping. Student records 3 trial distances and identifies which run was best and why.

Learner Group	Strategy	Concrete Example
ELL Students	Visual physics support	Provide CoG diagram with arrows showing tipping direction; balance vocabulary card with illustrations; allow labelled diagrams instead of written explanations in reflection.
Average Learners	Full core task	Complete design, build, belt drive assembly, base code, flat surface travel test (3 iterations), and full written reflection.
Advanced Learners	Quantitative stability analysis	Measure robot height, CoG height (estimated), and base width; calculate stability ratio; compare across 3 design configurations.
Gifted / High Ability	Sensor integration	Research and implement a tilt sensor or accelerometer using micro:bit's built-in accelerometer to detect and respond to tipping — creating a basic feedback control system.

ASSESSMENT — FORMATIVE & SUMMATIVE

Formative Assessment (Ongoing)

Method	When	What to Look For
Balance Challenge Observation	Period 1 opening	Students correctly identify that the ruler is unstable on the pencil point because the support is under the CoG with minimal base area.
Belt Drive Assembly Check	Period 1, first 10 min	Teams correctly assemble driver pulley, belt, and driven pulley; can explain what happens with too much or too little belt tension.
CoG Adjustment Review	During build phase	Students can identify where the CoG is on their current robot and name one change that would lower it.
Stability Score Tracking	During testing	Teams record consistent stability scores across iterations; changes between iterations are deliberate and documented.
Code Sharing Observation	Period 2, Explain phase	Coders can articulate why they chose their motor speed value based on observed stability outcomes.

Method	When	What to Look For
Reflection Exit Ticket	End of Period 2	Students correctly describe CoG and at least one iteration with a documented outcome; real-world connection is relevant.

Summative Assessment Rubric

Criterion	Beginning (1)	Developing (2)	Achieving (3)	Exceeding (4)
Balance & Stability	Robot tips immediately and cannot travel any distance.	Robot travels 1-10 cm before tipping in most trials.	Robot travels 30+ cm consistently on a flat surface without tipping.	Robot navigates a 3-marker obstacle course and shows documented CoG analysis with before/after stability scores.
Belt Drive Assembly	Belt drive is incorrectly assembled; wheel does not spin.	Belt drive works but slips significantly under motor power.	Belt drive transfers motor rotation to wheel correctly with appropriate tension.	Belt drive is optimised; student can explain driver/driven ratio and demonstrate the effect of pulley size on speed.
Programming	Code does not run or motor does not respond.	Motor runs but at a fixed speed with no adjustment capability.	Code controls motor at appropriate speed; button A/B adjustments are implemented.	Code includes automatic stop, variable speed ramp, or sensor-based feedback response.
Iteration & Documentation	No design changes made after testing; no iteration log.	One change made but not documented with data comparison.	At least two documented iterations with specific change, rationale, and measured outcome.	Three or more well-documented iterations with quantitative stability data; clear evidence of systematic design thinking.
Presentation	No presentation or demo attempted.	Robot demonstrated but student cannot explain CoG or belt drive.	Clearly presents CoG adjustment, belt drive function, code logic, and travel test results.	Confident, data-rich presentation; connects balance physics to real-world examples (Segway, bicycle); responds fluently to questions.

TECHNOLOGY & AI INTEGRATION

Tool / Platform	How to Use in This Lesson
MakeCode (makecode.microbit.org)	Program wheel motor speed (0-100%), enable button-controlled speed adjustment (slow for stability testing, fast for performance), and implement auto-stop after set distance.
micro:bit v2 Built-in Accelerometer	Advanced extension: use the micro:bit's built-in tilt sensor to detect when the robot is tipping and auto-adjust motor response — introducing basic feedback control.
Nezha Breakout Board	Connect motor to micro:bit safely; provides stable power supply during balance testing where sudden motor starts and stops are common.
Ruler / Tape Measure + Timer App	Measure travel distance and record stability scores. Calculate speed (distance / time) as a secondary metric to compare optimised robot performance.
AI Chatbot (Claude / ChatGPT)	Students ask: 'How does a Segway stay balanced without falling?' or 'What is the difference between static and dynamic balance?' Evaluate AI responses for accuracy.
Video Recording (Slow Motion)	Capture belt drive operation and wheel spin at 120-240fps to observe belt slippage, pulley engagement, and the moment of tipping — supports visual analysis for physics explanation.

REAL-WORLD CONNECTIONS

Connection	Discussion Prompt
Segway Personal Transporter	'A Segway balances a human rider using gyroscopic sensors and feedback control. How does it know when to accelerate forward to prevent falling? How is this similar to and different from your unicycle robot?'
Self-Balancing Robots (Boston Dynamics)	'Boston Dynamics robots like Atlas balance on two legs in rough terrain. What sensors and processors make this possible, and why is balance harder for a robot than for a human?'
Bicycle Physics	'A bicycle is stable when moving but tips when stationary. How does wheel spin create gyroscopic stability? How does this relate to the belt drive and wheel speed in your robot?'
Aerospace: Satellite Attitude Control	'Satellites use reaction wheels (spinning gyroscopes) to control their orientation in space. How is this related to the gyroscopic effect we discussed, and why is it important that they can't use wheels on the ground?'

Connection	Discussion Prompt
Prosthetics & Wearable Robotics	'Powered ankle prosthetics must adjust to uneven terrain thousands of times per second. How does center of gravity management in those devices relate to what your unicycle robot does?'
Autonomous Vehicles	'Self-driving cars use sensors to detect road tilt and adjust wheel traction. How does the concept of center of gravity apply to a car taking a sharp corner, and why do SUVs tip more easily than sports cars?'

EXTENSION ACTIVITIES

Activity	Description	Level
CoG Height Experiment	Build 3 versions: (1) motor high up, (2) motor at mid-height, (3) motor as low as possible. Test stability score for each. Create a bar chart comparing CoG height vs. stability score.	Average & Advanced
Pulley Size Ratio Investigation	Test with 3 different driver/driven pulley size combinations. Record wheel speed and stability for each. Identify the optimal ratio for balance and forward travel.	Advanced
micro:bit Tilt Detection	Use the micro:bit accelerometer to detect tipping angle. Program: if tilt > 15 degrees, increase motor speed to recover. Document whether this feedback system improves stability.	Gifted
Obstacle Course Design	Design a 5-marker slalom course. Time other teams on your course. Identify which robot design performs best and explain the engineering reasons why.	All levels
Segway Comparison Presentation	Research how a Segway's balance control system works (gyroscope + feedback loop). Create a 3-slide presentation comparing it to your unicycle robot. Identify 2 similarities and 2 differences.	Average & Advanced

HOMEWORK / FOLLOW-UP TASKS

Task	Instructions	Due
Balance Reflection	Write 200 words: Describe where your robot's center of	Next class

Task	Instructions	Due
	gravity was in your first design. What specific change did you make to improve stability, and how did the data show it worked? Use the term 'center of gravity' correctly at least 3 times.	
Gyroscopic Effect Investigation	Spin a bicycle wheel (ask a family member or friend) and try to tilt it. Write 3 sentences describing what you observe and how this connects to the stability of a spinning unicycle wheel.	Next class
Balance Technology Research	Research one self-balancing technology (Segway, drone, satellite reaction wheel, prosthetic ankle). Write: (1) How it detects imbalance, (2) How it corrects, (3) One similarity to our unicycle robot.	Next class

TEACHER NOTES & TIPS

Before the Lesson

- Prepare the balance challenge materials (rulers and pencils) before students arrive — this quick hands-on entry task is essential for building intuition about CoG before the formal definition.
- Test the belt drive assembly from the kit to ensure all belts have appropriate elasticity. Old or dry belts may slip excessively, which frustrates students unnecessarily.
- Pre-mark a flat 50 cm test track on desks or floor. A consistent, flat surface is critical for fair stability comparisons between teams.
- Prepare a stability score tracking sheet for the class — posting all teams' scores after each iteration motivates targeted improvements.
- If using the micro:bit accelerometer extension, test the tilt detection code yourself before the lesson; the built-in gesture blocks work reliably for this purpose.

During the Lesson

- The hardest conceptual shift: students believe making the robot heavier improves stability. Redirect: 'Heaviness doesn't matter — position of weight matters. A tall robot with heavy parts up high tips more easily than a short robot with heavy parts at the base.'
- Belt drive slippage is the most common technical frustration. If the belt slips, first check tension (slightly tighter), then check pulley alignment (must be coplanar), then check motor speed (reduce if too fast).
- Encourage teams to make ONE change between iterations and measure its specific effect. Multiple simultaneous changes make it impossible to know which intervention worked.
- If time is tight, skip the obstacle course and focus on the flat surface stability test with documented iterations — quality of iteration process matters more than quantity of activities.

After the Lesson

- Display a class stability score chart showing each team's improvement from first to final iteration — this celebrates progress and demonstrates the value of iterative design.
- Use the reflection exit tickets to identify students who still confuse weight with stability — address this explicitly at the start of the next lesson.
- This lesson builds directly toward more complex balance challenges. If a subsequent lesson involves sensors or feedback control, the CoG intuition built here is the essential foundation.

CURRICULUM STANDARDS ALIGNMENT

Standard Framework	Alignment
NGSS (Next Generation Science Standards)	MS-PS2-1: Apply Newton's Third Law to design a solution to a problem involving the motion of two colliding objects. MS-ETS1-4: Develop a model to generate data for iterative testing and modification of a proposed object to optimise function.
CSTA (Computer Science Standards)	Level 2 (Grades 6-8): Algorithms & Programming — students write programs with sequences, events, and conditionals; advanced students implement basic sensor-based feedback control using the micro:bit accelerometer.
ISTE Standards (Students)	Innovative Designer (4b): select and use digital tools to plan and manage a design process; (4c) develop, test, and refine prototypes iteratively. Empowered Learner (1d): understand fundamental concepts of technology operations.
Common Core Math (Supporting)	Ratios and proportional reasoning: analyse pulley size ratios; calculate speed from distance/time; interpret stability score data to identify trends across design iterations.
21st Century Skills (4Cs)	Critical Thinking (iterative design with documented evidence), Creativity (open-ended unicycle design challenge), Collaboration (team roles and division of engineering responsibilities), Communication (presentations connecting physics to real-world balance technology).