LESSON 07

The Crawling Robot

Gearing, Motor Control & Crawling Locomotion

LESSON OVERVIEW

Subject Area	STEM, Robotics, Computer Science, Math
Grade Level	Grades 6–8
Duration	3 Class Periods × 45 Minutes = 135 Minutes Total
Framework	5E Instructional Model (Engage → Explore → Explain → Elaborate → Evaluate)
Key Themes	Gear Ratios • Motor Control • Crawling Locomotion • Optimization • MakeCode
Materials	NEZHA Inventor's Kit V2 • MakeCode • Whiteboard/Projector • Markers • Rulers

LEARNING OBJECTIVES

01	Design and build a crawling robot using the NEZHA Inventor's Kit V2 that achieves consistent forward locomotion.
02	Understand the working principles of electric motors: electrical energy → magnetic field → rotational force.
03	Understand the basic principles of gearing: how gear ratio affects speed, torque, and efficiency of movement.
04	Explore the effect of different gear configurations on the crawling action and make data-driven optimizations.
05	Develop creativity, problem-solving skills, and collaborative teamwork through iterative design challenges.

KEY VOCABULARY

Term	Definition
Gear Ratio	Ratio of input (driver) gear teeth to output (driven) gear teeth; governs speed vs. torque.
Locomotion	The ability of a robot or organism to move from one location to another

	under its own power.
Crawling	A low-to-ground movement pattern using multiple contact points for stability and propulsion.
Optimization	The process of making systematic adjustments to improve performance toward a goal.
Motor Control	Regulating motor speed, direction, and duration through programming commands.
Mechanism	An assembly of parts that transmits or transforms motion and force.
Traction	Friction between surfaces that allows a robot's contact points to grip and propel forward.
Iteration	Repeating the design-test-improve cycle using data from each test to guide changes.

⚡ 5E MODEL — LESSON PLAN

⎕ ENGAGE

Step	Activity	Key Focus
1	Introduce crawling robots and their real-world applications: search & rescue, pipe inspection, disaster response.	Connect robotics to practical industries and real-world impact.
2	Show 90-sec video of crawling robots in action (Boston Dynamics, NASA rovers, rescue bots).	Spark curiosity, provide visual context, inspire student imagination.
3	Class brainstorm: 'How could a crawling robot navigate a collapsed building?' Discuss design challenges.	Encourage critical thinking and problem-centered engineering mindset.

⎕ EXPLORE

Step	Activity	Key Focus
1	Divide students into groups of 2–3; provide each group with a NEZHA Inventor's Kit.	Foster collaboration, distributed roles: builder, coder, tester.
2	Have students build a basic crawling robot using kit materials following their own sketches.	Facilitate hands-on exploration of robotics components and assembly.
3	Encourage experimentation with different gear sizes and ratios; record speed observations.	Promote creativity and systematic engineering thinking.
4	Have students test their robots on 3 different surfaces and observe how they move.	Analyze the impact of gear choice and surface traction on performance.

⎕ EXPLAIN

Step	Activity	Key Focus
1	Discuss experiment findings: which gear ratio produced the fastest vs. smoothest crawl?	Build understanding of gear ratio outcomes through student data.
2	Formal lesson: motor control (speed %, direction, duration) and gearing principles (ratio = teeth_driven/teeth_driver).	Provide foundational knowledge of motor-gear mechanics.
3	Demonstrate programming robot movements in MakeCode: variable speed, multi-phase crawl sequences.	Teach coding skills relevant to locomotion control.

ELABORATE

Step	Activity	Key Focus
1	Encourage students to modify gear ratio and leg design to achieve their personal speed/stability goal.	Apply problem-solving and iterative design with quantitative targets.
2	Guide students in adding a sensor (ultrasonic) to stop the robot before hitting obstacles.	Expand creativity and explore advanced sensor-driven functionality.
3	Have students document their optimization process and create a 90-second video or live presentation.	Promote engineering communication, reflection, and pride of authorship.

EVALUATE

Step	Activity	Key Focus
1	Groups present robots to class: explain design rationale, gear ratio choice, and performance data.	Assess understanding of robotics concepts, teamwork, and communication.
2	Facilitate Q&A: 'Why did you choose that gear ratio?' 'What would you change if you had more time?'	Develop critical thinking and the ability to defend engineering decisions.
3	Rubric assessment: design quality, crawling functionality, creativity, and data documentation.	Evaluate overall project outcomes against established criteria.

PERIOD-BY-PERIOD TEACHER & STUDENT SCRIPTS

PERIOD 1 — ENGAGE (40 min)

Time	Teacher Actions	Student Actions	Key Questions
0–8 min	Show rescue robot video. Ask: 'What challenges does a crawling robot face that a	List 3 challenges for crawling vs. wheeled robots in notebooks.	Why would crawling be better than wheels in some environments?

	wheeled robot does not?'		
8–20 min	Gear ratio demo: turn a small gear driving a large gear. Measure rotations. Calculate ratio.	Sketch two gear configurations; calculate and label the gear ratio for each.	If the driver has 10 teeth and the driven has 20, what is the gear ratio?
20–35 min	Groups begin building basic crawling frame. Coach structural stability and leg placement.	Assemble base frame; attach legs or contact points based on sketch.	How will you attach the legs so they don't fall off under load?
35–40 min	First crawl test: push robot by hand to simulate motor. Observe leg motion and stability.	Record observation: does it crawl? Does it tip? What is the biggest problem?	What is the first thing you would change to improve the crawl?

PERIOD 2 — EXPLORE (45 min)

Time	Teacher Actions	Student Actions	Key Questions
0–15 min	Guide motor attachment and wiring. Demo MakeCode: motor on → pause → motor off sequence.	Mount motor, wire to Nezha board, download basic program, run first powered crawl.	How does the crawling motion differ from what you expected?
15–30 min	Gear ratio experiment: try 3 different gear configurations; time each over 50 cm distance.	Record gear ratio, time, and observation notes for all 3 configurations in data table.	Which gear ratio gave the smoothest crawl? The fastest? Are they the same?
30–38 min	Guided optimization: choose the best-performing gear ratio and refine the leg design.	Make one gear change and one leg adjustment; run 3 more timed trials.	Does your data show improvement? By how much?
38–45 min	Gallery walk: observe other teams' crawling robots. Note one feature you would borrow.	Write 1 strength and 1 improvement suggestion for each team on sticky notes.	Which design element from another team would most improve yours?

PERIOD 3 — EXPLAIN → ELABORATE → EVALUATE (45 min)

Time	Teacher Actions	Student Actions	Key Questions
0–15 min	Mini-lecture: gear ratio formula, torque-speed trade-off graph, traction vs. surface type.	Solve 3 gear ratio problems using real numbers from their own robot data table.	How would doubling the gear ratio change both speed and torque?
15–30 min	Final optimization sprint: 12 min to implement the best change identified in gallery walk.	Apply one final modification; run 3 timed trials and calculate average speed (cm/s).	How does your final average speed compare to your very first test?
30–42 min	Group presentations: show	Present 90-sec summary:	What is one thing your data

	robot, display data table, explain gear ratio choice and results.	initial design → problem found → change made → result.	proves about gear ratios and crawling speed?
42–45 min	Exit ticket: gear ratio calculation problem + one sentence explaining the optimization made.	Complete individually and submit before leaving.	How would you use a sensor to make a crawling robot navigate autonomously?

DIFFERENTIATION & SCAFFOLDING

SUPPORT — Struggling Students	EXTENSION — Advanced Students
• Provide pre-assembled crawling frame so students focus on gear selection and programming. • Offer a simplified gear ratio reference sheet with diagrams and example calculations. • Pair with a peer coach for the MakeCode programming phase. • Reduce data collection to 2 gear configurations instead of 3.	• Challenge students to design a crawling robot that can carry a 50g payload over 1 meter. • Have advanced students write a mathematical model predicting speed from gear ratio. • Incorporate an ultrasonic sensor for autonomous obstacle-stopping behavior. • Participate in a classroom crawling robot competition with speed and obstacle challenges.

ASSESSMENT BREAKDOWN

Assessment Component	Weight	Description
Exit Ticket	**20%**	Gear ratio calculation + one-sentence optimization explanation (individual)
Data Table	**25%**	3+ gear configurations tested with times, ratios, and average speed computed
Design Improvement	**20%**	Justified change with quantitative before/after comparison
Group Presentation	**20%**	Clear explanation of design rationale, data, and results
Engineering Notebook	**15%**	Sketches, gear labels, data notes, and reflection entry

TEACHER NOTES

- Adapt lesson complexity based on student abilities and available time.
- Encourage collaboration and peer support throughout the design process.

- Emphasize the value of iterative design: every 'failure' is data for the next attempt.
- Celebrate creativity, originality, and engineering effort regardless of final outcome.
- Provide regular formative check-ins using the engineering notebook as a formative tool.

REAL-WORLD CONNECTIONS

The engineering principles explored in this lesson appear throughout real-world industries:

- Robotics Engineering: Professional robots use the same motor control and sensor concepts in manufacturing, medicine, and exploration.
- Biomimicry Design: Engineers worldwide study animals to design better robots, vehicles, and structures.
- STEAM Integration: The connection between art, science, math, and engineering is a cornerstone of 21st-century innovation.
- Career Connections: Robotics engineers, software developers, mechanical engineers, and product designers all apply these skills daily.