Toys: How can we design moving toys that other children can build?

Primary: (ages 7 – 11)	Interdisciplinary (STEM)

Students consider how objects in contact and at a distance exert forces on each other. They start by observing the movement of existing toys before building their own toy prototypes. They engage in activities prompted by the driving question, "How can we design moving toys that other children can build?" Plans for redesigning their prototypes are developed through investigations and scientific models. By the end of the unit students incorporate all they have learned about the forces that cause their toy to move into a final design for their chosen toy.

Time allocation	About 9 lesson periods
Subject content	Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object. Make observations and measurements of an object's motion to predict future motion.
Creativity and critical thinking	This unit has a **creativity** and **critical thinking** focus: • Propose, produce, and revise a personally novel moving toy and a model of how unbalanced forces cause objects to start moving • Reflect on the strengths, weaknesses, and limits of prototypes and models according to different criteria
Other skills	Collaboration, Communication,
Key words	balanced; unbalanced; forces; engineering; modelling; observation

Products and processes to assess

Students develop their collaborative, creative, critical thinking, modelling and engineering skills by sharing ideas, constructing and revising models, and using models and ideas to explain phenomena. At the highest levels, students show a willingness to examine a range of ideas carefully, generate unusual ideas and push them to their limits, and demonstrate a clear understanding of the strengths and weaknesses of proposed prototypes and models.

Authors: Peek-Brown, D., Finnie, K., Fitzgerald, M., Palincsar, A., Miller, E., Codere S., Krajcik, J., *with literacy pieces co-authored by Linda Kucan* (2019). Multiple Literacies in Project-based Learning, Michigan State University, CREATE for STEM for the OECD for the CERI project *Fostering and assessing creativity and critical thinking skills*.

Teaching and Learning plan

This plan suggests potential steps for implementing the activity. Teachers can introduce as many modifications as they see fit to adapt the activity to their teaching context.

Step	Duration	Teacher and student roles	Subject content	Creativity	Critical thinking
	(Preparatory phase)	Gather materials for a toy prototype to be built by each group (2-3) of students.			
1	Lesson period 1	The teacher demonstrates a toy air rocket in motion and provides two or three other air rockets for students to try. Students are introduced to the unit driving question and are reminded that they will be designing their own moving toys in the next lessons. Students make observations about the motion of various air rocket toys and begin to generate questions about how and why they move. Students are asked to consider what might be increasing and decreasing the speed, and changing the direction and position of the rocket, recording their observations and ideas. Students add their questions and wonderings from what they have experienced so far to the Driving Question Board.	Making observations of patterns of motion and considering changes to motion	Observing and describing relevant experience	Developing their understanding of the context of the problem (i.e. what makes toys move in different ways)
2	Lesson period 2 and 3	Students review the Driving Question Board and continue to ask questions. Each group (2-3) of students brainstorms a number of ideas for moving toys they could design. Students consider what would be the most unusual or surprising toy they could build, what would be the most fun for different possible users, what moving toy would be easiest to make, and what would be very difficult or impossible and why (the teacher supports students to make connections between their previous observations and what is possible). Students consider which of these factors it is most important when deciding on a design for their toy. Through a process of discussion, the students arrive at a final idea for a moving toy that is both unusual and feasible given the different ways toys can be made to move and the materials and time-scale available to them. They draw or describe their planned design and add questions and ideas to the driving question board.	Considering different ways of making toys move and designing moving toys	Generating and playing with unusual ideas about possible and impossible moving toys and explaining why they are possible or impossible	Considering several perspectives on what makes a good design for a moving toy Developing, using, and revising different sets of criteria and comparing and evaluating the value of resulting decisions
3	Lesson period 4	Each group reviews their plan from the previous lesson and builds a simple prototype of a toy (e.g. a toy skimmer or bottle rocket). They can be provided with video or written instructions as appropriate to help them create the basic features of their toy.	Making toys that move	Proposing and producing a moving toy	

4	Lesson period 5	Each group of students in turn demonstrates their toy to the class, explaining what is unusual about the toy and what they have learned in the process of making the toy. They receive feedback from peers. What is the most surprising thing about the toy and why is it surprising? What are its strengths? What could be improved? Would it be easy for other students to replicate? They add questions and ideas to the driving question board and can be given the opportunity to revise their toy design if time allows.	Articulating what they have learned from the process of building toys that move		Considering different perspectives and reflecting on the strengths and limitations of their toy relative to possible alternatives
5	Lesson period 6	Students are now asked to develop an explanation of why their toys start and stop moving. They investigate applying different forces to start their toy moving and make observations of differences in the patterns of motion that occur. Students share their findings, then add their new ideas and any new questions about the phenomenon to the Driving Question Board. For example, they might notice "my car started off fast and then slowed down and stopped. I wonder what will happen if I start it moving slower?" The teacher helps students identify balanced and unbalanced forces, seeing that only unbalanced forces change the motion of their toy. Students add ideas about balanced and unbalanced forces and new questions to the Driving Question Board.	Using observations from their investigation as evidence that unbalanced forces cause a change in the motion of their toy.	Inquiring and generating ideas about why toys start and stop moving	Justifying their reasoning about why toys start and stop moving
6	Lesson period 7	Selected students use their prototype toys to demonstrate the effect of balanced and unbalanced forces on each type of toy. Students review their questions on the Driving Question Board and then work in pairs or individually to develop models based on their previous investigation that show how unbalanced forces cause objects to start moving.	Modelling the causal relationship between unbalanced forces and the motion of toys.	Producing models to solve a scientific problem in a personally novel way	
7	Lesson period 8	Students share and explain what steps they took to produce their model and use feedback from their peers and their own reflections to revise their models. Students reflect on and discuss the process of developing scientific models and the necessary components of a model. Why do we make scientific models? Why is it important to keep checking and revising our models? What makes models useful or not useful?	Considering why we need models and what makes a good scientific model	Reflecting on steps taken to produce models	Checking accuracy, and acknowledging potential uncertainty or bias in scientific models
8	Lesson period 9 This could extend to a 10th lesson	Students review their questions on the Driving Question Board and discuss models of the forces causing motion of their toys. Students use teacher demonstrations and an interactive computer model of balanced and unbalanced contact forces to predict how objects will move. Students revisit their models from the previous lesson and identify and label balanced and unbalanced forces. They can then be asked to re-assess the moving toys that	Predicating how objects will move using simulated models and their own models to	Reflecting on and assessing the relevancy and novelty of their chosen moving toy	Evaluating and acknowledging the limits of their chosen design for a moving toy

	period, if time allows	they have made in light of everything they have learned. What are the strengths, limitations, and novelty of their suggested designs relative to alternatives and what advice would they give to other students who want to design and make moving toys?	identify balanced and unbalanced forces.	

Resources and examples for inspiration

Web and print

- Investigation and observations sheets for students
- Student directions for building toy prototypes (written or video)
- Driving Question Board to keep track of class and student questions
- Interactive simulation model of balanced and unbalanced forces

Other

Household items for building toy prototypes (milk cartons, soda bottles, straws, paper clips, small disks for wheels, cardstock)

- Air rocket toys
- Materials (pens, post-it notes etc.) to enable students to post questions and ideas to the driving question board.

Opportunities to adapt, extend, and enrich

- This mini-unit is based on portions of the first two learning sets in a sequence of four learning sets. Remaining learning sets have students examine other forces (e.g., frictional, gravitational, electrical, magnetic) and design engineering solutions to improve their toy.
- Remaining learning sets, along with additional STEM project-learning units and related resources can be found at https://sprocket.lucasedresearch.org/portal and https://create4stem.msu.edu/

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Creativity and critical thinking rubric for science

- Mapping of the different steps of the lesson plan against the OECD rubric to identify the creative and/or critical thinking skills the different parts of the lesson aim to develop

	CREATIVITY Coming up with new ideas and solutions	Steps	CRITICAL THINKING Questioning and evaluating ideas and solutions	Steps
INQUIRING	Make connections to other scientific concepts or conceptual ideas in other disciplines	1,5	Identify and question assumptions and generally accepted ideas of a scientific explanation or approach to a problem	1,7
IMAGINING	Generate and play with unusual and radical ideas when approaching or solving a scientific problem	2,5	Consider several perspectives on a scientific problem	2,4
DOING	Pose and propose how to solve a scientific problem in a personally novel way	3,6	Explain both strengths and limitations of a scientific solution based on logical and possibly other criteria (practical, ethical, etc.)	2,4,5,7
REFLECTING	Reflect on steps taken to pose and solve a scientific problem	7,8	Reflect on the chosen scientific approach or solution relative to possible alternatives	7,8

Annex

A sample scoring rubric

A description of levels of achievement on a given dimension of the rubric that sets clear expectations, introduces a vocabulary to explain evidence, and serves to describe progression

This scoring rubric addresses one of the sub-dimensions of the general rubric described above (DOING), as a means of illustrating how teachers can define and base judgements on student work for this unit.

CRITICAL THINKING	Level 1	Level 2	Level 3	Level 4
INQUIRING • Envision / Express / Produce / Prototype new product / solution / performance • Appraise / Base / Justify opinion/products on logical, ethical or aesthetic criteria/reasoning	Student does not express an opinion / does not consider evidence to support their opinion / does not justify the validity of their evidence with reasoning	Student expresses an opinion / considers evidence but may not support their opinion / does not justify the validity of their evidence with reasoning	Student expresses an opinion / considers evidence that supports their opinion / provides reasoning to justify some but not all evidence as valid	Student expresses an opinion / considers evidence that supports their opinion as well as evidence that conflicts with their position / provides reasoning to justify all evidence as valid

Examples described in relation to lesson 3 (Construct a scientific explanation of the phenomenon).	Students' claim is not stated or does not answer the investigation question / Evidence does not support claim and/or no evidence is given	Students' claim is stated and answers the investigation question / some evidence supports claim and/or expected evidence is missing	Students' claim is stated and answers the investigation question / Most evidence supports claim and most expected evidence is present	Students' claim is stated and answers the investigation question / Evidence clearly supports claim and all expected evidence is present