Building Coherency in K–4: Forces, Motion, and Energy

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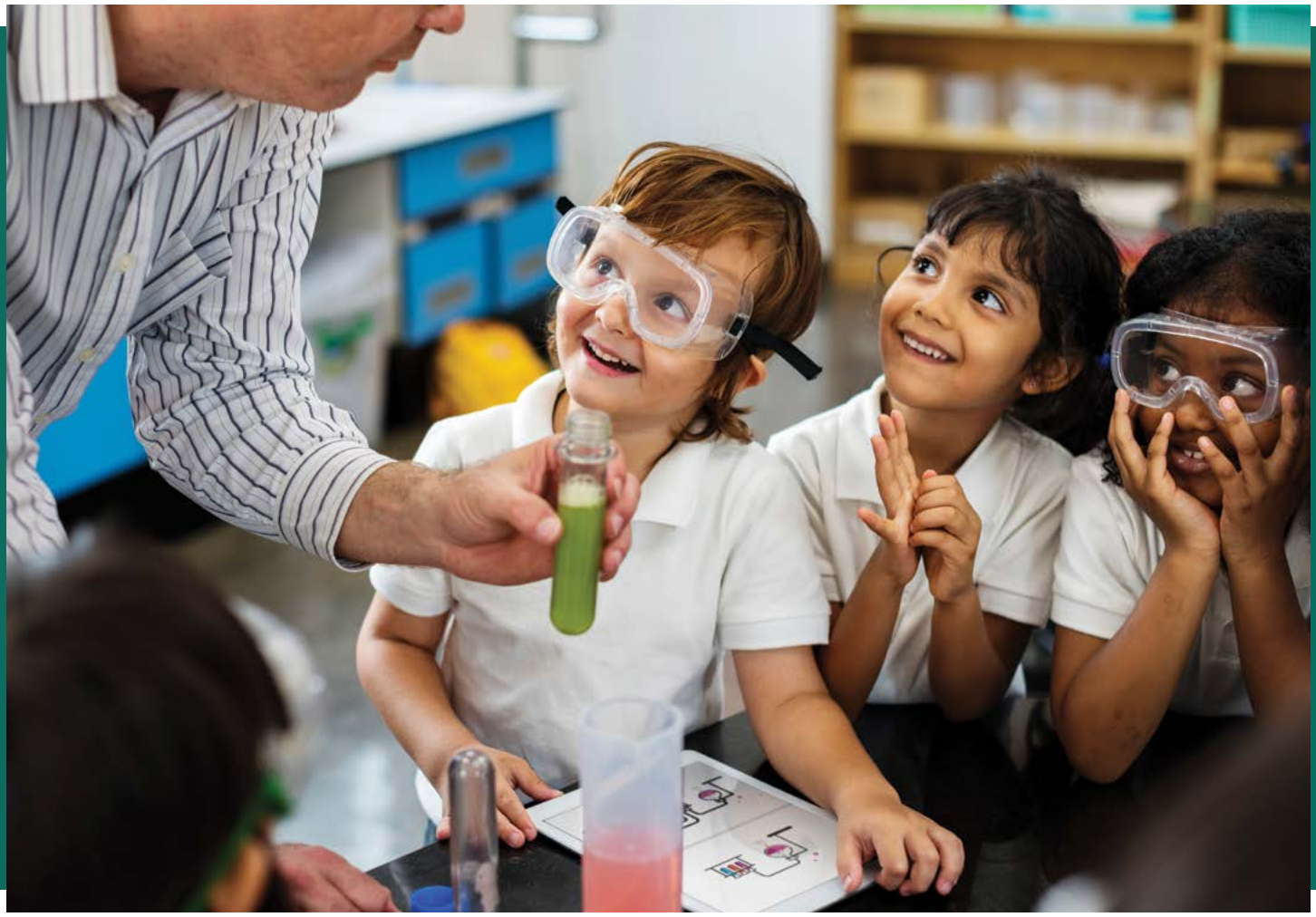

Learning progressions within the Next Generation Science Standards (NGSS) help students build on prior knowledge, make connections, and develop coherent understanding of science. "Building progressively more sophisticated explanations of natural phenomena is central throughout grades K-5, as opposed to focusing only on description in the early grades and leaving explanation to the later grades" (National Research Council, 2012, p. 26). The following describes a kindergarten, third grade, and fourth grade set of learning experiences to demonstrate how a learning progression can help students develop a coherent understanding of forces, motion, and energy.

Kindergarten – Motion and Stability: Forces and Interactions

Kindergarten learning experiences help students to understand that motion means going from one place to another and can be described in terms of distance and direction. Additionally, forces are pushes and pulls that can be described in terms of strength and direction. Understanding of these phenomena helps students meet the per-

formance expectation K-PS2-1. Plan and conduct an investigation to compare the effects of different strengths or different directions of pushes and pulls on the motion of an object.

The goal in science is to help students move from sensory/physiological experiences to quantifying their experiences in order to explain the how and why of phenomena. After connecting kindergarteners to phenomena of motion that they encounter, such as throwing or kicking a ball, remote control cars are used to help students understand that motion can be described as an object moving from one point to another and to demonstrate how students can measure the distance between the starting point and the ending point, thus comparing the motion of different cars to answer the question, "How far did each car travel?" Arrows are used to show direction of travel and to demonstrate how motion involves moving away or towards the students. This helps students understand that motion can be described in terms of distance and direction.

Tug of war is an engaging learning experience that is used to help students physiologically understand pulling forces. The parameters of the tug of war game are changed to demonstrate various strengths of pulls, and students use arrows to predict the direction the rope will travel in each of the different scenarios. For example, the teacher chooses six children to be on one side of the rope and three to be on the other side of the rope. The teacher asks, "In which direction do you predict the rope will travel and why?" The students predict that the rope will move towards the six students because the six students can pull with more force than three students.

Students are then asked to throw bean bags of the same mass with a small, medium, and a large force so that they make the connection between strength of force and distance the bean bag travels. Students measure the distance the bean bag travels with each force to make the connection that the larger the force, the further the bean bag will travel. Students are challenged to explain, "How can I make the second bean bag land farther away than the first?"

Third Grade – Motion and Stability: Forces and Interactions

Third grade learning experiences focusing on motion and stability: forces and interactions build on kindergarten understanding of pushes and pulls and motion to help students understand the effect that balanced and unbalanced forces have on the motion of an object in order to be able to meet the performance expectation 3-PS2-1. Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.

The tug of war activity is used to extend prior physiological experiences of pulling to physiologically experience no movement of the rope and movement of the rope in one direction or another. Asking students, "How can we create balanced forces on the rope? How can we create unbalanced forces on the rope?" requires them to apply their understanding of forces to the system to describe the effect of forces on the motion of the rope. To extend student thinking, four students are challenged to lower a ring with resistance bands over a cone – this requires students to work together to create balanced and unbalanced forces to move the ring over the cone without touching the cone.

To move the students from the physiological (qualitative feeling of force) to quantifying the forces in the system, a fifth student records the forces applied on spring scales attached to each resistance band. By quantifying the forces generated, students come to understand that measuring a force using Newtons is the same principle as any measurement comparing to a standard. When a student stretches the spring and reads the numerical quantity (in Newtons) from a calibrated spring, it is the same as placing a ruler on an object and measuring the quantity of length units.

Fourth Grade – Energy

Fourth grade connects the concept of energy to forces and motion. Energy is both a disciplinary core idea and a crosscutting concept in the NGSS. Students engage in a series of investigations to be able to explain, "How are energy and motion related?" This series of lessons prepares students to meet the performance expectation 4-PS3-1. Use evidence to construct an explanation relating the speed of an object to the energy of that object. A motion machine which has a spring launcher that propels balls (brass, steel, acrylic, wood and rubber) down an eight foot long clear tube is used to answer the question, "Where does the energy come from to propel the ball through the tube?" to help students understand that the compressed spring stores energy that is transferred to the ball when the spring is released. Students are divided into groups of four to conduct investigations with the motion machine and the assorted balls to generate an understanding that balls with different masses (same volume) will travel at different speeds when the same energy is applied to the balls (the compressed spring, when released, applies the same force every time). Students determine the speed of the balls qualitatively by noting which ball traversed the tube the fastest. Students answer the questions, "How do we store more energy inside the motion machine?" and "If we compress the spring more, once we release it will the ball will go faster or slower?" To help students understand the difference between qualitative versus quantitative data and to show students how quantitative data can be used as a tool to understand science, students quantify the speed by using a stopwatch to measure the time it takes for each ball to travel down the eight foot clear tube. Students organize this data to reveal patterns that suggest relationships between mass and speed. Ultimately, the students will use the evidence/data gathered during their investigations to construct an explanation relating speed to energy.

Coherency

The K-4 learning progression described in this article depicts how learning experiences surrounding physical science disciplinary core ideas (motion and stability: forces and interactions and energy) build K-4 coherency in understanding forces, motion, and energy, while also building student mathematical

and computational skills (the role of qualitative and quantitative data in producing patterns and showing relationships in science). Learning progressions that build coherency help students apply their understanding to novel situations, in order to solve real-world problems (Fortus and Krajcik, 2011).

References

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About the Authors

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William Banko, M.D. established Knowing Science in 2009 with the goal of working with leading educators around the country to make early introduction of science education a top priority. Dr. Banko authored "Starting a Science Education" in *Education Week* (2010) and was the lead author on NSTA's best-selling, award-winning book *Science for the Next Generation: Preparing for the New Standards* (2013). Most recently, he co-authored "Drawing for Meaning" in the February 2018 edition of *Science & Children.* Dr. Banko will be receiving the Atkins Award from the New Jersey Science Teachers Association (NJSTA) in May 2019 in recognition of his cooperation with and service to science teachers in NJ.

Dario Capasso, Ph.D. received his Ph.D. in Physics from the Graduate Center of the City University of New York (CUNY) in 2011. At Knowing Science, Dario's expertise has been instrumental to the development of our NJSLS-aligned curriculum and other resources for science educators. His publications include the chapter "What is Science?" in *Science for the Next Generation: Preparing for the New Standards* by NSTA Press; and *Physics, Life Science, Earth Science, and Data,* a set of review books by Knowing Science.