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The Authors

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Matt Heer is a graduate of UW Platteville in Math and Physics, and has been teaching high school physics at East Troy, WI for the past 7 years. He spends his summers working in Lake Geneva at a summer camp showing kids how to sail and wakeboard. His hobbies include sailing, wind surfing, wakeboarding, snowboarding, woodworking, and coaching track / cross country. His inspiration was Stuart Harper, who was his high school physics teacher with all the wonderful toys and demonstrations he would do, and for seeing the physicist within him.

Todd Everson was raised on a dairy farm in western Wisconsin (so much physics) and obtained a mathematics degree from UW – La Crosse, then moved to Milwaukee where he worked odd jobs, and attended UW Milwaukee to earn teaching licenses in Broad Field science, physics and eventually chemistry. He teaches physics and physical science at Milwaukee School of Languages where his “language” is mathematics (the language of science). He was recently recognized as an Outstanding Urban Educator after being nominated by a former student. He is still trying to figure out what he wants to do when he grows up.

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Michelle Sackerson currently teaches in the Franklin, WI school district, teaching AP Physics-B, Advanced Physics, and Advanced Chemistry. In 2006 she was awarded the Kohl Fellowship in teaching. She graduated Phi Beta Kappa with a BS in Chemistry, followed by working in industry for 10 years. Then she became certified to teach 6-12 in chemistry and physics, and now has a Masters in Curriculum and Instruction. With 13 years of teaching she finds that she is still learning many new ideas to help prepare students for success in the 21st century!

Craig Berg taught middle and high school science before pursuing an M.S. and Ph.D. in Science Education from the University of Iowa. His daily adventures now include directing the science teacher preparation program at the University of Wisconsin-Milwaukee, working with undergraduates, post-baccalaureates, and M.S. students in pursuit of exemplary science teaching. Research, writing, publishing and service to local school districts fills the rest of his calendar. He is truly blessed with being able to work with many of the exemplary teachers in the area on a variety of grants and projects such as this one. His twenty-four years of work in Milwaukee resulted in the 2011 UW-System Regents Excellence in Teaching Award. He draws inspiration from his wife Kathleen who is an NBCT of science and a creative wizard in the science classroom. Until his battery runs out he plans on continuing to work at something he truly loves doing on a daily basis - pursuing excellence in science education.

Contributors: Greg Bisbee, Dwight Osmon

Introduction

In my thirty plus years as a science teacher and science-teacher educator, I find that the great ideas for teaching science stem from researchers studying teaching and learning, and from teachers who have persevered to find ways to reach more children in order to maximize learning in their classroom. Many of these creative and highly effective teaching ideas arise from teachers who are embedded in the most challenging situations, and, as such, are motivated to explore, find, or develop new strategies or materials to use with their students so as to have a greater impact on their learning.

Teachers who embrace these challenges of teaching and learning accumulate a substantial set of teaching tools, combined with a clear framework and rationale for teaching (see section IV), are able to utilize *the appropriate tool for the moment at hand*. Dialogues are another teaching tool; a teaching strategy that will help teachers reach children in ways that other strategies might not. Dialogues involve students in speaking and listening, acting and reacting, tapping into emotional and kinesthetic parts of the brain. The Common Core State Standards for English Language Arts and Literacy in subject areas are very clear in that “students must learn to read, write, speak, listen, and use language effectively in a variety of content areas.” The Next Generation Science Standards are also very clear in that we must engage our students in learning using strategies that maximize engagement in all aspects of the process. In short, dialogues maximize student’s engagement in the learning process; all students are involved as active participants when dialogues are in play.

Dialogues have been tested from elementary to college levels and in urban, suburban and rural classrooms. You might decide to use them as is, or might modify them and add your own spin or local context to them. You might also craft some from scratch, or have students write dialogues; we have included some suggestions and tips for writing dialogues.

Credit for the germ of this idea and the initial spreading of the seed goes to Donald Cronkite of Hope College, who developed and used dialogues with his college biology students and shared this teaching strategy with high school teachers at a Woodrow Wilson Institute. Greg Bisbee was one of those in attendance, who then grabbed on with both hands and began writing dialogues for his own students in biology classes. Greg, a biology teacher extraordinaire, also began to spread the word and captured the attention and interest of myself and the coauthor of the *Dialogues for the Biology Classroom*, Kathleen Westrich. Westrich began writing dialogues for her students. Seeing the success of Bisbee and Westrich, being a science teacher educator, I quickly connected my future teachers with Bisbee and Westrich in order to learn about dialogues. Gradually we brought many others on board for writing and using dialogues in the classroom - in this case, outstanding physics teachers. Now the single seed planted by Professor Cronkite and his colleagues has turned into a blooming field of dialogues.

Dialogues engage learners at high levels, so try them! Your students will enjoy the activity, learn something about the content you are trying to teach them, and learn something about themselves.

Editor - Dr. Craig Berg

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Using This Book

There are four major units to this book:

Section I - Abstracts: This section provides the reader with a quick overview of each dialogue and the science concepts or terms embedded within. Scanning the abstracts helps the reader determine which dialogue might be suitable for the upcoming lesson.

Section II - Using Dialogues in the Classroom: This section details the key aspects of using dialogues in the classroom - the what, when, and how to, of using and writing dialogues. This section provides examples of how dialogues can target content goals, be used in conjunction with a lab activity, help teach about historical aspects of the subject, and help students grapple with current issues or science-based ethical dilemmas. In addition, there are numerous suggestions and tips for implementing dialogues in the classroom, and the benefits thereof, with guidelines on how to write your own dialogues, and how to have students create their own dialogues as a measure of what they learned.

Section III - The Physics Dialogues: This section contains the sixty-seven dialogues that cover twenty-one different units in physics. The dialogues are designed to help you teach many of the topics covered in a typical physics class.

Section IV - Science Dialogues and Teacher Decision-Making: This unit provides the reader with an overview of how dialogues fit into the big picture of classroom instruction, and how using dialogues connects to, and supports, the goals for students in science classrooms. While this unit is important, the typical reader will probably be more interested in the what and how to, and therefore read Section IV last. However, read Section IV to better understand how teacher decision-making is so critically important to success in the classroom, and how dialogues is one of the teaching tools that helps teachers accomplish the difficult task of helping students to develop a better understanding of physics. Use this section to help frame one's thoughts about teaching, in preparation for talking with administrators (or parents, or sometimes colleagues) who could benefit from a better understanding about what it takes to effectively teach science.

Section I - Dialogue Abstracts

Unit 1 - Measurement

1.1 Measure What?: Zig and Zag are attempting to connect phones with computers and discuss the advantages or disadvantages of Metric units versus English units.

Science concepts or terms include: accuracy, conversion factors, decimals, English System of Measurement, International System of Units, length, mass, measuring, Metric System, volume.

1.2 Significant Figures are NASdy: Pip and Pep attempt to understand the rules of significant figures.

Science concepts or terms include: non-zero numbers, significant figures, where is the decimal?

1.3 Hockel and Ockel Discuss Density: Our two friends discuss the concept of density in terms of mass, volume and cookies.

Science concepts or terms include: density, mass property of a substance, volume.

Unit 2 - Graphing

2.1 Graph a Giraffe: Nix and Nox are hanging out at the zoo looking at the giraffes, and talking about the first few weeks of their physics course. They have a discussion about making good graphs.

Science concepts or terms include: dependent variable, independent variable, line of best fit, relationships, slope, uncertainty, y intercept.

2.2 Hip and Hop Practice Graphing: Hip and Hop have a data set and are trying to figure out how to graph the data.

Science concepts or terms include: graphing construction and interpretation.

Unit 3 - Linear Motion

3.1 Zip and Zap Talk Vectors: $3 + 4 = 5?$: Zip and Zap are having lunch when they start chewing on the topic of vectors.

Science concepts or terms include: displacement, magnitude, scalars, vectors.

3.2 Hockel and Ockel Discover the Difference in Graphing Distance vs. Displacement: Hockel and Ockel are working together in their physics classroom. The teacher has just explained differences between distance and displacement. Hockel and Ockel are reviewing and applying what they learned.

Science concepts or terms include: displacement, distance, graphing, reference point, scalar quantity, vector quantity.

3.3 Move It!: Rip and Rap are studying for a physics quiz and trying to sort out motion terms.

Science concepts or terms include: displacement, direction, distance, magnitude, measurements, motion, position, reference point, scalars, theory, vectors.

3.4 The Instantaneous Average Speed: Zip and Zap are taking a ride in a car and wrestle with how to compute average speed of an object.

Science concepts or terms include: average speed, distance, instantaneous speed, miles per hour, time.

3.5 Let's Get Going: In this dialogue, as they watch vehicles on the highway, Tex and Lex are wondering how force and mass affect the acceleration of trucks.

Science concepts or terms include: acceleration, direct relationship, factors affecting speed, forces, gravity, inverse relationship, Isaac Newton, mass vs weight, velocity, $F=M \times A$.

3.6 Speed Ain't Acceleration: Zip and Zap are in Zip's car cruising downtown on a Friday night, sitting side by side in the front seat, hitting the occasional bump and turning the occasional corner.

Science concepts or terms include: accelerate, constant speed, velocity.

3.7 Hip and Hop Learn How To Interpret Graphs: Hip and Hop are puzzling over speed and velocity graphs.

Science concepts or terms include: distance, graph interpretation, speed, time, velocity.

3.8 Hockel and Ockel Figure Out Newton's 3rd Law: Hockel and Ockel use springs and scales to help figure out Newton's 3rd Law.

Science concepts or terms include: action, net force, Newtons, Newton's 3rd Law, reaction, unbalanced force.

Unit 4 - Forces

4.1 May the Force Be With You!: Tick and Tock are sitting in their car in the ditch pondering the forces needed to get back on the road.

Science concepts or terms include: contact forces, field forces, force, friction, gravity, magnetism, static electricity.

4.2 Simple, Simple Machines: Zip and Zap discuss simple machines, mechanical advantage and efficiency.

Science concepts or terms include: efficiency, force, friction, mechanical advantage, resistance, simple machines.

4.3 Problem Under Glass: Washing dishes causes our two characters to ponder how air pressure can keep water in an upside down glass.

Science concepts or terms include: accelerate, air pressure, equilibrium, gravity, mass, pressure transmission, volume.

4.4 Let's Fly Away: Pip and Pep are talking about an upcoming flight and wonder about how planes stay in the air.

Science concepts or terms include: aerodynamics, airstream, Bernoulli's Principle, cohesive, drag, forces, lift, thrust, wing shape.

4.5 I Love Levers: Tick and Tock have stopped at the seesaw on their way home so they could put off studying for a physics test and relate the seesaw to the study of levers.

Science concepts or terms include: Archimedes, balance, first, second, and third class levers, forces, fulcrum, gravity, Law of the Lever, lever, simple machine, volume, weight.

4.6 Pressure Play: Pip and Pep are watching workmen connect pipes to a water main and wonder about the size of pipes and pressure of the water flowing within them.

Science concepts or terms include: Bernoulli's Principle, how size of pipe affects water pressure, pressure.

Unit 5 - Gravity

5.1 What Goes Up Must Come Down: Aristotle and Galileo Discuss Falling Objects: In this dialogue, Aristotle travels in time to meet with Galileo and discuss their contrasting ideas about the physics of falling objects.

Science concepts or terms include: air resistance, forces on falling objects, Four Element Theory, hypothesis, repetition of tests, scientific evidence, scientific methods.

5.2 Gravity of the Situation: Newton and Hooke, competitors for scientific fame in the late 1600's, argue for the merits of their contrasting ideas related to the composition of light and the equation describing gravitational force.

Science concepts or terms include: composition of light, evidence, gravity, inverse relationship, inverse squared relationship, Universal Gravitation Equation.

5.3 Weighty and Massive Ideas About Gravity: Zip and Zap are lifting weights, discussing weight versus mass and gravitational force.

Science concepts or terms include: direction, energy, force, magnitude, mass, Newtons, scalar, vector, weight.

Unit 6 - Rotational Motion & Projectile Motion

6.1 Compare and Contrast Translational and Rotational Motion: Hip and Hop are in the middle of a physics class, attempting to compare translational motion with rotational motion.

Science concepts or terms include: acceleration, angular velocity, angular displacement, constant velocity, displacement, rotational motion, translational motion.

6.2 Come Fly With Me: After playing softball in Physical Education class, Kit and Kat enter the physics classroom and discuss the forces affecting the motion of a projectile.

Science concepts or terms include: arc, components, horizontal force, hypothesis, independent force, initial velocity, parabola, projectile, trajectory, vectors, vertical force.

Unit 7 - Momentum and Impulse

7.1 Hip and Hop Get Impulsive: Hip and Hop are spectators at a football game and the conversation turns to momentum and impulse.

Science concepts or terms include: car air bags, gymnastics and forces, impulse, mass, momentum, motion, speed.

7.2 Hockel and Ockel Become Impulsive: In the backyard, jumping on a trampoline, Hockel and Ockel discuss momentum and impulse.

Science concepts or terms include: impulse, inverse relationship, mass, momentum, velocity, $F \times t = I$.

7.3 12 x 1 not equal to 6 x 2: Pip and Pep are playing with Newton's Cradle and thinking about the factors affecting the colliding spheres.

Science concepts or terms include: collision, conservation of momentum, kinetic energy, Law of Conservation of Energy, mass, momentum.

7.4 Bowling with Newton: Pip and Pep are still playing with a Newton's Cradle made of bowling balls, and compare their understanding of the Law of Conservation of Momentum with what is happening to the swinging spheres.

Science concepts or terms include: Law of Conservation of Momentum, momentum.

Unit 8 - Energy, Work and Power

8.1 Gasoline Versus Diesel Engines: Pip and Pep discuss the differences between using gas or diesel fuel, and the difference in the engines that use each.

Science concepts or terms include: compressions, engine, power, temperature, torque, weight.

8.2 Roller Coasters: Zig and Zag are two physics students talking about roller coasters. They're trying to use their physics knowledge to figure out how fast a new ride will go.

Science concepts or terms include: air resistance, closed system, friction, gravity, kinetic energy, Law of Conservation of Energy, potential energy.

8.3 Hockel and Ockel Get Energized: Hockel and Ockel are riding their bikes when their thoughts turn to potential and kinetic energy.

Science concepts or terms include: energy conversion, gravity, kinetic energy, mass, potential energy.

Unit 9 - Thermal Energy: Heat and Temperature

9.1 To Heat or Not to Heat?: Zip and Zap are discussing thermodynamics as applied to heating a home.

Science concepts or terms include: heat, insulator, Newton's Law of Cooling, temperature, thermostat.

9.2 Hip and Hop Talk Temperature: Hip and Hop walking through snow, slush and ice from the bus stop to school and ponder temperature and various units for measuring temperature.

Science concepts or terms include: absolute zero, Celsius, Fahrenheit, freezing point, ice, Kelvin, kinetic energy, molecular motion, Rankin, slush, snow, temperature.

Unit 10 - Gas and States of Matter

10.1 Snow on the Mountain: Pip and Pep watch a hawk soaring on an air current and begin to wonder how air pressure, temperature and other factors come into play in their lives.

Science concepts or terms include: air pressure, boiling point, condensation, expansion.

10.2 Combined Gas Law: After conducting some experiments, Boyle, Charles and Gay-Lussac discuss the results they had concerning the relationships they found between pressure, volume and temperature.

Science concepts or terms include: Combined Gas Law, gas, pressure, temperature, volume, PV/T

10.3 Using Gas Law Formula to Determine Relationships Between Variables: Zim and Zoom discuss how they think they did on their chemistry quiz and how to use the gas law formula.

Science concepts or terms include: direct relationship, inverse relationship, pressure, volume, $PV=nRT$.

10.4 Full of Hot Air: On a snowy winter day, Jib and Jab are eating in the school cafeteria, and chewing on the events of the past weekend.

Science concepts or terms include: Charles' Law, Graham's Law, particle motion, speed, temperature.

10.5 Gas has Mass: Sis and Sas are doing an experiment to show that gas has mass.

Science concepts or terms include: gas, mass.

10.6 Changing State of Matter: Tiff and Tuff are getting ready for a barbecue when Tuff realizes he is out of propane gas for the grill. They discuss how gas changes when pressure is applied.

Science concepts or terms include: changes in pressure, gas.

10.7 Go to the Recycling Center: Tiff and Tuff discuss how the pressure of gas changes when temperature is changed- Gay Lussac's law.

Science concepts or terms include: Gay Lussac's Law, pressure, temperature.

Unit 11 - Waves

11.1 Hockel and Ockel Learn to Wave: Our two friends are in their physics class working with a slinky and studying wave action.

Science concepts or terms include: compression, electromagnetic wave, longitudinal, moving particles, sound, transverse, waves.

11.2 Hip and Hop Talk About Waves: Hip and Hop are at the beach where a discussion of waves takes place.

Science concepts or terms include: energy, medium, molecules, waves.

11.3 A Dip in the Pool : Zip and Zap Discuss Light Waves: Zip and Zap are lounging in the pool and pondering the spreading of water waves and light waves.

Science concepts or terms include: disturbances, electromagnetic field, light, wavelength, waves.

Unit 12 - Sound

12.1 Wha'd You Say?: Nip and Tuck are talking about a rock concert they attended last weekend and now Nip's ears are still ringing.

Science concepts or terms include: decibels, ear buds, hair cells, hearing aids, hearing loss, high frequency, log relationship, loudness, perception, sound energy.

12.2 If a Tree Falls in the Forest: Zip and Zap Discuss Sound: Zip and Zap are on a fishing trip when they ponder sources and transmission of sound.

Science concepts or terms include: eardrum, mechanical radiant energy, infrasound, pitch, pressure waves, medium, pressure variation, sound, tone, transmission, ultrasound.

Unit 13 - Light and Color

13.1 Hip and Hop Learn Why the Sunset Appears Red: After learning about why the sky is blue, Hip and Hop tackle the challenge of finding out why the sunset appears red.

Science concepts or terms include: atmosphere, colors, frequencies, light, wavelengths.

13.2 Color Harmony: Pip and Pep are riding the after-school bus, see a rainbow, and discuss light and color and the possibility of "light harmonies."

Science concepts or terms include: eyes, color, frequency, light, waves.

13.3 Wave Particle Duality of Light: It is the 1600's and Isaac Newton and Christian Huygens have conflicting views on the composition of light.

Science concepts or terms include: diffraction, energy, evidence, interference, Law of Reflection, light, medium, particle model, properties, refraction, wave model.

13.4 The Frosting Baster: Pip and Pep are chatting about Pip's frosting baster and realize how changing the height relates to the Inverse Square Law.

Science concepts or terms include: Inverse Square Law, light intensity.

13.5 Color Mixing: Zig and Zag Ponder Primary Colors in Light and Pigments: Zig is captivated by colors and engages Zag in a discussion about how primary colors differ in light and pigments.

Science concepts or terms include: additive method of color mixing, light reflection and absorption, primary colors of light, pixels, primary colors of pigments, secondary colors, subtractive method of color mixing, wavelengths.

Unit 14 - Optics

14.1 I've Got My Eye On You: Hip and Hop are two physics students talking about eye problems and how lenses and laser surgery fix the problem.

Science concepts or terms include: Ben Franklin, bifocal lenses, concave lenses, convex lenses, farsightedness, laser surgery, nearsightedness, retina.

Unit 15 - Static Electricity

15.1 I Get a Charge Out of You: Nip and Tuck talk about static electricity, what causes shocks, and why it's more common in winter.

Science concepts or terms include: charges attract, electronegativity, electrons, grounding, humidity, opposite unbalanced charges.

15.2 Hockel and Ockel Learn the Shocking Truth: Ockel accidentally bumps Hockel and receives a shock, which prompts a discussion about static electricity.

Science concepts or terms include: conductors, cumulating charges, electrical charges, electron, friction, grounding, negative, nucleus, positive, proton, static electricity.

Unit 16 - Current Electricity

16.1 Parallel and Series Circuits: Hockel and Ockel Go With the Flow: In this episode our two characters attempt to make sense out of electric currents and how a series circuit differs from a parallel circuit.

Science concepts or terms include: circuits, electricity, parallel, resistance, series.

16.2 Battle of Currents: Nip and Tuck, two physics students, are wondering about a rumor they've heard that the U.S. uses alternating current and Europe uses direct current electricity.

Science concepts or terms include: adapters, alternating current, direct current, Edison, electrons, frequency, Hertz, Tesla, transformers, transmission, voltage, Westinghouse.

16.3 Current, Voltage and Resistance, Oh My!: While Zip and Zap are hard at work trying to fix a leak in the plumbing, they discuss the similarities between plumbing and electricity.

Science concepts or terms include: conductors, current, electrons, insulators, Ohm's Law, resistance, voltage.

16.4 The Discovery of the Battery: Galvani, a biologist, and Volta, a physicist, discuss their recent findings related to electricity and the discovery of the battery.

Science concepts or terms include: evidence, experiment, Galvani's experiment, Leyden Jar, static electricity, Voltaic Pile Battery.

Unit 17 - Magnetism

17.1 Hip and Hop Talk About Magnets: Hip and Hop are on a hiking trip where the use of their compass leads to a discussion about magnets.

Science concepts or terms include: compass, magnetic field, magnetic north, magnetic poles, magnets.

17.2 Hockel and Ockel Repel and Attract: Hockel and Ockel use paper clips and magnets to help them better understand magnetism.

Science concepts or terms include: atomic level, current, directional spin, electrons, magnetic field, magnetism, magnets, nucleus.

Unit 18 - The Atom

18.1 History of the Atom: A Conversation Between Democritus and Schrödinger: Democritus, a Greek philosopher, has transported through time to meet Austrian physicist Erwin Schrödinger, the father of quantum mechanics. Together they discuss the changing model of the atom, through time, as new discoveries are made.

Science concepts or terms include: atomic theory, Chadwick's neutron discovery, changing model of the atom, Dalton and The Atomic Theory, history of science, J.J. Thomson and "The Plumb Pudding Model," Neils Bohr, Rutherford, Schrödinger-Heisenberg Electron Cloud Model, The Gold Foil Experiment.

18.2 Learn About the Atom: Hop tutors Hip about the atom.

Science concepts or terms include: atom, electrons, energy levels, forces, neutrons, nucleus, protons.

18.3 Atom Smashers: Tick and Tock are discussing the new Large Hadron Collider particle accelerator and the unanticipated benefits of pure research.

Science concepts or terms include: Big Bang, dark energy, dark matter, hadrons, Large Hadron Collider, leptons, muon, neutrino, particle physics, protons, pure scientific research, quarks.

Unit 19 - Nuclear Physics

19.1 Discovery of Radioactivity: Henri Becquerel: It is the late 1890's and electricity is just being developed. Henri Becquerel is about to make another important discovery and is talking to his wife about his work that sets up the discovery of radioactivity.

Science concepts or terms include: energy, experiment, hypothesis, phosphorescence, scientific methods, spectrum, uranium, variables, X-ray.

19.2 Learn About Radioactivity: Hip and Hop ponder Tsunamis, nuclear power plants, microwave ovens and radiation.

Science concepts or terms include: electromagnetic spectrum, nuclear power plants, radiation.

Unit 20 - Quantum Theory and Relativity

20.1 Time Travel - Part 1: Pip and Pep are chatting about a movie they have just watched that was based on time travel.

Science concepts or terms include: Theory of Relativity, time travel.

20.2 Time Travel - Part 2: Pip and Pep continue their discussion about time travel and Einstein's ideas about the speed of light and how your reference point can affect time.

Science concepts or terms include: Einstein, speed of light, time travel.

Unit 21 - Creative Controversy

21.1 Pip and Pep - Conversations Concerning Creative Controversy: This is a dialogue we used to introduce a teaching strategy called Creative Controversy, also call Structured Controversy, in which students wrestle with the pros and cons of a science-based issue or ethical dilemma.

Science Concepts or terms include: a teaching strategy.