5 E Model Science Lesson

Wave Behaviors in a Slinky ®

By

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5E Model Science Lesson WebQuest Discussion

In this section of the WebQuest, Group5 – AmLAK has taken a Guided Inquiry based science lesson plan originally organized to the MSMC Lesson Plan Guidelines and reformatted it to the guidelines of the Constructivist 5E approach identified in the assigned WebQuest, "Constructivism and the 5E Model Science Lesson." This "overlay" approach enabled us to see the 5E strategy in the context of the MSMC guidelines, and of even more value, to see where it would supplement or strengthen the lesson plan. While the MSMC outline lists 12 sections to a lesson plan, the 5E model focuses on the five stages: "Engage", "Explore", "Explain", "Elaborate", and "Evaluate".

We saw that the *engage* element corresponded closely with the MSMC "Introduction" or "Anticipatory Set" element. Focusing on the constructivist principles in the 5E strategy encouraged us to make stronger connections to prior knowledge, such as encouraging recollection of playing with a Slinky ® as a child.

The *explore* stage corresponded relatively well with the MSMC model's "Guided Inquiry Development" section; however, the 5E approach focused us more on drawing in students by exploring the Slinky model in small social groups, than as a whole class.

In the *explain* stage, students work in small groups articulating their observations and ideas. In many ways, this stage corresponded well with the MSMC stage of "Guided Practice with Feedback" using inquiry questions. In both models, students are interacting directly with the materials and each other to explain the observations and construct knowledge through authentic experience. The teacher acts as a facilitator and can offer guidance where misconceptions form.

Where the MSMC model offered lesson "Closure and Independent Practice", the 5E model offered *elaboration*. Here, students expand the concepts they have learned, and apply them to new situations. In the elaboration stage of this lesson, we included many of the same elements of independent practice as in the original lesson plan. Namely, finding applications in the real world and proceeding with additional inquiry in a slightly different context. In the case of this lesson, the additional inquiry is with a computer simulation of string behavior instead of classroom inquiry with the physical Slinky.

Finally, both formats emphasize *evaluation* as both an ongoing diagnostic process including teacher observations, and as summative project evaluations. Evaluation provides the opportunity for revisiting or clarifying misconceptions, providing feedback, and hopefully for the teacher to refine their own strategies. In the 5E constructivist model, evaluation can also lead to an open inquiry of what the next set of logical inquiries might be.

Overall, the 5E approach matched the MSMC Guided Inquiry Science lesson planning relatively well. It added extra emphasis on the constructivist principles of connecting to authentic prior knowledge (as in recollection of playing with a Slinky as a young child) and of the social nature of learning (as when explaining and discussing observations in small groups). Finally, the 5E approach also extends the value of evaluations beyond assessment to suggesting at least some subsequent questions that further inquiry would investigate. This touches on the very foundation of science as the endless unfolding of knowledge, and invites the student to participate in the exhilaration of scientific discovery and technological innovation characteristic of life in the 21st century.

5 E Model Science Lesson: Wave Behaviors in a Slinky®
Grade 11, 12 Regents Physics

Topic: Mechanical Waves - Motion and Behaviors

Teaching Strategy: Constructivism – Using the 5E Model

I. Goals, Standards, and Objectives

1. Goals

The student will discover several behaviors of mechanical waves by exploring the motions of a coiled spring (Slinky ®), developing and testing hypotheses, and interpreting observations.

2. Performance Objectives

Objective 1: Working in teams of three or four students, and given a Slinky, stopwatch, string, and a list of questions, students will devise experiments in which they will discover correctly at least 5 of 7 wave properties or behaviors.

Objective 2: After completing experiments that the student designs to answer questions about wave behaviors, the student will justify their conclusions in writing by citing evidence that supports their conclusion in at least 6 of 9 cases.

Objective 3: Given a classroom discussion, textbook, and list of terms describing waves, the student will correctly apply the terminology within their own writings about waves with at least 80% accuracy*.

**Note: By the end of the unit on waves, mastery of terminology of at least 85% accuracy would be expected. This lesson plan takes place near the beginning of the unit on waves so mastery of terminology (with ≥ 85% accuracy) is not yet expected.*

3. Standards

New York State Learning Standards:

NYS MST Standard 1: Analysis Inquiry, and Design: Scientific Inquiry

Key Idea 1: The central purpose of scientific inquiry is to develop explanations of natural phenomena in a continuing, creative process.

Key Idea 2: Beyond the use of reasoning and consensus, scientific inquiry involves the testing of proposed explanations involving the use of conventional techniques and procedures and usually requiring considerable ingenuity.

Key Idea 3: The observations made while testing proposed explanations, when analyzed using conventional and invented methods, provide new insights into phenomena.

NYS MST Standard 2: Information Systems

Key Idea 1 (specifically 1.5): Model solutions to a range of problems in mathematics, science, and technology, using computer simulation software.

NYS MST Standard 4: Science: The Physical Setting

Key Idea 4: Energy exists in many forms, and when these forms change energy is conserved;

4.1: Observe and describe transmission of various forms of energy;

4.3: Explain variations in wavelength and frequency in terms of the source of the vibrations that produce them.

Process Skills 4.1 i, ii, v, vii; 4.3 i, ii, iii, iv, vi, vii

Performance Indicators: 4.1 i, 4.3 a, b, c, d, e, f, h, m

NYS MST Standard 6: Interconnectedness: Common Themes

Key Idea 2: Models are simplified representations of objects, structures, or systems used in analysis, explanation, interpretation, or design.

Key Idea 4: Equilibrium is a state of stability due either to a lack of change or a balance between opposing forces.

NYS MST Standard 7: Interdisciplinary Problem Solving

Key Idea 2: Solving interdisciplinary problems involves a variety of skills and strategies including…generating and analyzing ideas; realizing ideas…and presenting results.

Cross-disciplinary

NYS ELA Standard 3: Language for Critical Analysis and Evaluation
NYS ELA Standard 4: Language for Social Interaction
NYS Career Dev and Occupational Studies Standard 2: Integrated Learning

National Science Education Standards*:*

CONTENT STANDARD A: "…do scientific inquiry. Understandings about scientific inquiry"
CONTENT STANDARD B: "… develop an understanding of… Motions and forces, Conservation of energy, Interactions of energy and matter."

II. Materials/Resources

4. Materials

Slinky ® or similar coiled spring
Strings
Stopwatch

5. Electronic Technology

Available for independent practice (in or out of class):
Computer with internet capability with Flash8 software, available free from:
http://www.adobe.com/shockwave/download/download.cgi?P1_Prod_Version=ShockwaveFlash
and access to the University of Colorado at Boulder's Physics Education Technology (PhET) website's Wave_On_A_String simulation accessible at,
http://phet.colorado.edu/simulations/sims.php?sim=Wave_on_a_String

III. Teaching and Learning Strategies

Background Note:
Prior to this lesson, the following terms have been defined in the context of waves, along with associated drawings. Definitions are listed in ***Appendix-D.***

Amplitude	***Compression region***	***Crest***	***Disturbance***
Elastic medium	***Equilibrium***	***Frequency***	***Longitudinal wave***
Period	***Periodic motion***		***Rarefaction region***
Transverse wave	***Trough***	***Wavelength***	***Wave velocity***

6. ENGAGE – identify, make connections, stimulate

- *Model introduction and linkage to prior knowledge:*

  "We've learned some terminology recently about waves and periodic motion. Today let's examine what these really look like and see what we can learn about wave properties and behaviors using a model. Models can help us to see and even discover things that pure talking might not make clear."

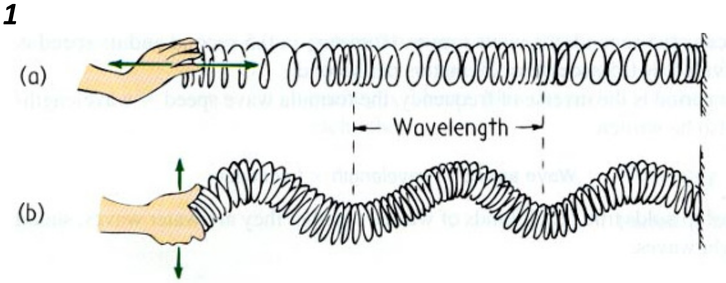
Walk toward a Slinky resting on the end of the teacher's desk or lab bench.

"Remember playing with a slinky as a child. Think of the motions you could make with just a few simple movements. A Slinky can be a useful model for learning more about both transverse and longitudinal waves in an elastic medium."

- *Demonstration*

  Recruit a volunteer to hold one end of the Slinky at the end of the tabletop.
  Extend the Slinky 2 to 3 meters across the tabletop.
  Encourage students to pay close attention to what they see.
  Demonstrate and describe each of the following using the Slinky as shown in Figure 1:
  - a) Transverse pulse propagating from the teacher to the opposite end
  - b) Period transverse waves.
  - c) Longitudinal pulse propagation
  - d) Periodic longitudinal waves

Figure 1



Slinky waves can be made by vibrating the first coil back and forth in either a horizontal or a vertical direction. Source: Joseph F. Alward, PhD, Department of Physics, University of the Pacific
http://sol.sci.uop.edu/~jfalward/physics17/chapter10/chapter10.html

7. EXPLORE – direct involvement in groups

- *Small Groups:*
  Break students into small groups of three or four. Instruct them to experiment with the slinky and reproduce the various wave patterns.

- *Link terminology to the model*

  - Create a transverse wave train, and ask students to find the *amplitude, crest, trough, wavelength,* and *period* of the waves produced.
  - Create a longitudinal wave train, and ask students to find the *amplitude, condensation region, rarefaction region, wavelength,* and *period* of the waves produced.

- During this process, allow students to talk to each other about what they think they recognize. Confirm to students when they are correct.
- Here is an opportunity for the teacher to perform some informal assessments of the students' understanding of the lesson.

Topics to Explore…

- *Discussion Questions:*
  Now let's look at some questions, and in each case, when we answer, we will cite the evidence that supports our answer.

  Q: How would you determine the frequency of the waves we produce?
  Possible Ans: We count the number of periods in 10 seconds, and then divide by 10.
  We see my hand moving, and can count the number of times it moves during 10 seconds.

  Q: Which way is the velocity of the waves?
  Ans: Along the length of the slinky. We can see the wave moving along the length.

  Q: Which way is the motion of the slinky in the transverse wave?
  Ans: Perpendicular to the direction of wave propagation. We can see the spring moving back and forth perpendicular to the spring length.

  Q: Which way is the motion of the slinky in the longitudinal wave:
  Ans: Parallel to the direction of the wave propagation. We can see the spring compressing and expanding parallel to the length of the spring.

  Q: How might you determine the velocity of the wave?
  Possible Ans 1: Use a timer to measure the time for one pulse.
  Possible Ans 2: Measure the wavelength and multiply by the frequency. ($v = f\lambda$)

- *Reminder to list evidence*

In each case, we cited the evidence from our observations or measurement. It may accompany reasoning that supports the conclusions we state. This is important. Scientists reach conclusions about their hypotheses based on evidence and reasoning.

Remember when you try to answer questions, whether it is one from me, or testing your own hypothesis, you should record you conclusion (if you've reached one) along with what evidence you observed or collected, that lead you to each conclusion.

- *Limitations of a Model*

"Remember that the Slinky *models* wave behaviors, but it is only one model. The natural world has many types of waves. They include spherical waves, planar waves, radial waves, and as we will discuss in a few weeks, electromagnetic waves. Furthermore, while the Slinky shows energy transfer without propagating mass of the spring, this is only one medium. Others media might be air, wood, steel, water, and so on. We always want to consider the limits of a model when we use one."

8. EXPLAIN – communicate observations

- *Introduce the problems:*
  - Now let's see if you can discover some behaviors of waves using the Slinky.
  - I'll give you some questions to get you going.
  - When you have a hypothesis, discuss among your group how you can test your hypothesis.
  - When you reach a conclusion, write an explanation of how you reached that conclusion and site the evidence you obtained to support it.
  - Use the terminology you have learned to help express yourself clearly.

- *Guided Inquiry Questions: (Available on associated worksheet* ***Appendix-A*** *with acceptable solutions in* ***Appendix-B****)*

  1. Describe the relationship between the *frequency and the power* of the propagated waves. (Recall: Power = Energy/time).
  2. Describe the relationship between *wave amplitude and power*.
  3. What is the relationship between *frequency and wave velocity*?
  4. What is the relationship between *amplitude and wave velocity*?
  5. How can the propagation *velocity* of a wave be *increased*?
  6. What happens when waves pass each other in opposite directions and they are *in-phase* with each other?
  7. What happens when waves pass each other and they are *out of phase* with each other?

9. Accommodations and Modifications for Learners with Special Needs

Early Mastery: Students who have shown early mastery will be asked use a second, denser spring to describe what happens to the incident and transmitted wave when the Slinky and the denser spring are attached. They will also be asked to determine the phase of the reflected wave from a fixed end and a free end or a Slinky.

Students with social, emotional, behavioral, or physical limitations: Students with these limitations will be asked to answer the Guided Inquiry Questions using the PhET Waves_On_A_String computer simulation available at http://phet.colorado.edu/simulations/sims.php?sim=Wave_on_a_String .

Difficulty paying attention: Let students pull on the demonstration string; ask student to help with the demonstration.

IEP & 504 Plan: Any student with an IEP or 504Plan will be given the modifications or environmental assistance required.

10. ELABORATE – expand, make connections, apply understanding

Authentic Observation: Due in 1 day.

Come back tomorrow with at least one example of periodic, cyclical, vibratory, or other wave motion that you find in the world. I recommend more than one, because as we go around the room to see what you came up with, I will not accept any repeats.

Inquiry Completion: Due in 2 days.

Finish writing up your discoveries. Be sure to support your claims with an explanation.

Simulation Model: Due in 3 days. (***Appendix C*** *shows acceptable solutions*.)

Go to the PhET Waves on a String website at
http://phet.colorado.edu/simulations/sims.php?sim=Wave_on_a_String

1. Play with it for 5 or 10 minutes just to get used to it
2. If you did not discover how to increase wave velocity using the Slinky in class, then see if you can discover how to increase the velocity by using the simulation. If you did discover how to increase the wave velocity in class, then using the simulation model, try to confirm you conclusion.
3. Describe the reflected pulse from a string with a free-end, and with a fixed end. Bring in a screen capture, or drawing of the respective reflected pulses.

11. EVALUATE – evaluation & assessment

Evaluation Instrument
Teacher observation: Student participation in guided inquiry including discussion with peers, careful observation, hypothesis identification and testing.
Inquiry question worksheet: Conclusions (2 pt each x 7), observations (2 pt each x 7), explanations (3pts each x 7), terminology 6 pts total.
Homework – wave example
Homework – Simulation
Homework problem sheet

Waves Behavior Inquiry Questions:

Name: ______________________ Date:________________

Names of others in your group: ____

On a separate sheet of paper, state your conclusions for each of the questions listed, along with an explanation supporting each conclusion.

1. Describe the relationship between the *frequency and the power* of the propagated waves. (Recall: Power = Energy/time).

2. Describe the relationship between *wave amplitude and power*.

3. What is the relationship between *frequency and wave velocity*?

4. What is the relationship between *amplitude and wave velocity*?

5. How can the propagation *velocity* of a wave be *increased*?

6. What happens when waves pass each other in opposite directions and they are *in-phase* with each other?

7. What happens when waves pass each other and they are *out of phase* with each other?

Answer Key: Waves Behavior Inquiry Questions

Each response should list an observation, some explanation of how that observation leads the student to a conclusion, and a conclusion. Following are ***examples*** of acceptable responses to the Wave Behavior Inquiry Questions.

1. Describe the relationship between the *frequency and the power* of the propagated waves. (Recall: Power = Energy/time).

   Conclusion: *The power increases with the frequency.*

   Explanation: *I saw that John was working a lot harder when he was moving the slinky back and forth quickly, than when he moved it slowly. There was a lot more kinetic energy in Johns arm. Since "Power" is energy per unit time, he expended much more power generating the waves at the higher frequency.*

2. Describe the relationship between *wave amplitude and power*.

   Conclusion: *The power increases with the wave amplitude.*

   Explanation: *I saw that John was working a lot harder when he was moving the slinky back and forth through a large amplitude, than when he moved it just a little. He had to move the spring through a larger distance to create the larger amplitude waves. Since energy is force x distance, John put more energy into the large amplitude wave than the small amplitude wave of the same frequency. Since "Power" is energy per unit time, he expended much more power generating the waves at the higher frequency.*

3. What is the relationship between *frequency and wave velocity*?

   Conclusion: *The wave velocity was independent of the frequency.*

   Explanation: *When we moved the slinky back and forth quickly, we measured about the same amount of time for the wave to travel as when we moved it back and forth slowly. (Students may indicate observed time in seconds, and frequency or period tried.) Since changing the frequency did not really change the propagation velocity, the two are independent.*

4. What is the relationship between *amplitude and wave velocity*?

   Conclusion: *The wave velocity was independent of the amplitude.*

   Explanation: *When we moved the slinky back and forth through a large amplitude, we measured about the same about of time for the wave to travel as when we moved it up and down just a little. (Students may indicate observed time in seconds, or amplitudes tried in centimeters.) Since changing the amplitude did not really change the propagation velocity, the two are independent.*

5. How can the propagation *velocity* of a wave be *increased*?

   Conclusion: *The wave velocity increases with the tension in the slinky (or how tight we pulled the slinky).*
   Explanation: *When we pulled the slinky coils tight, the wave traveled much faster across the same distance than when the slinky was looser. (Students may list measured propagation velocities obtained.)*

   Alternate Response:
   Conclusion: *The wave velocity increases by changing from a transverse wave to a longitudinal wave.*
   Explanation: *When we changed from generating a transverse wave, to a longitudinal wave, it took less time for the wave to travel. Since velocity is distance per unit time, the velocity was faster with the longitudinal wave than the transverse wave. (Students may list measured propagation times or velocities observed.)*

6. What happens when waves pass each other in opposite directions and they are *in-phase* with each other?

   Conclusion: *When in-phase waves travel toward each other, the amplitude of the combined wave increases when they pass each other*
   Explanation: *We created two transverse wave pulses with 50 cm amplitudes on the left side of the spring (in-phase). When they traveled toward each other, the combined wave had a larger amplitude at the moment they passed each other. (Students may list measured amplitude of the wave produced during the constructive interference.)*

7. What happens when waves pass each other and they are *out of phase* with each other?

   Conclusion: *When out-of-phase waves travel toward each other, the amplitude of the combined wave diminishes when they pass each other*
   Explanation: *We created two transverse wave pulses with 50 cm amplitudes each on opposite sides of the spring (out-of-phase). When they traveled toward each other, the combined wave virtually disappeared at the moment they passed each other. (Students may list measured amplitude of the wave produced during the destructive interference.)*

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