Facilitating conceptual change through modeling in the middle school science classroom

This article examines a professional development program that helped teachers use models as a means to foster conceptual change in eighth grade science students and deepen their understanding about motion.

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Motion is a student-friendly science topic for middle school students because of the many kinesthetic opportunities for pushing, pulling, and accelerating objects. Yet we know these opportunities alone do not promote students' conceptual understanding. Fechhelm and Nelson (2007) note that students never fully understand the concept of an object's motion. Therefore, engaging students in both hands-on and minds-on experiences is needed for education that is relevant and complete.

Many middle school students enter science classrooms with pre-conceived ideas about their world. Some of these ideas are misconceptions that hinder students from developing accepted concepts in science, such as those related to motion. This article explores implications from an experience where middle school teachers used modeling strategies within the 5E pedagogy to actively engage their 50 eighth grade students in the conceptual change process during an all-day, week-long summer outreach camp.

The role of conceptual change in learning middle school science

Teaching for conceptual change based on multiple learning and teaching strategies means approaching science instruction from a knowledge-as-theory perspective (Özdemir & Clark, 2007). This focus was the underlying philosophy of a three-week professional development (PD) program involving five middle school teachers who participated in a camp that took place prior to direct work with the eighth graders. The knowledge-to-theory perspective sought evidence of students' assimilation and accommodation of new ideas (Kuhn, 1962; Posner, Strike, Hewson, & Gertzog, 1982). The PD sessions and instructional time during the outreach camp were videotaped to collect evidence of any conceptual changes in thinking that took place for both the teachers and the students. These tapes yielded evidence for determining the degree of change that might have occurred, and the teacher-student interactions offered a formative basis for guiding the professional reflection and planning of subsequent new science lessons during the camp. Through careful observation, teachers could see how their students assimilated scientifically-based thinking in place of preconceptions.

To start the conceptual change process, teachers in the summer outreach camp determined what students understood about the topic and linked these ideas with new ones embodied within the science lesson. To achieve this balance of valuing student ideas as well as presenting new concepts within science lessons, these middle school science teachers began by planning an array of hands-on modeling experiences following the 5E pedagogy (Engage, Explore, Explain, Elaborate, Evaluate).

According to Jonassen, Strobel, and Gottdenker (2005), modeling is a key strategy for supporting and assessing conceptual change in students' thinking, and it provides a rationale for engaging students in discourse and argumentation. Throughout these activities, students reflect on their thinking and their understanding of how science and mathematics work (National Research Council, 2012). Scientists use argumentation as they examine, review, and evaluate their knowledge and ideas from others (NGSS Lead States, 2013).

Although several theories of conceptual change are presented in science education literature, only a small segment addresses how to successfully engage middle school students in the conceptual change process and how to assess it within a broad range of learning contexts. Typically, young adolescents are curious and eager to learn about their worlds. From early childhood, students are active learners, and they prefer interactions with peers during learning experiences (Kellough & Kellough, 2008). Experience plays a central role in affording students the ability to construct meaning about what they learn. Within middle school classroom settings, students must have learning opportunities to use and develop their cognitive abilities to solve real-world problems. In developmentally responsive inquiry-based learning environments, students progress from concrete thinking and problem solving to creating and testing hypotheses, analyzing and synthesizing data, and thinking reflectively (Manning, 2002), thereby moving beyond simplistic recall that too often dominates schools paralyzed by over-emphasis on high-stakes testing. In vibrant middle level environments characterized by an emphasis on relevance and the kind of discovery so vital to higher order thinking that stimulates long-term learning, students also begin to develop the ability to construct arguments to persuade others, which simultaneously helps students to clarify their own thinking (Caskey & Anfara, 2007).

This case report of a summer middle school outreach science camp relies on a theoretical framework for modeling as a strategy to foster and assess conceptual change. Vosniadou (1999) defines conceptual change as the cognitive process of adapting and restructuring models, and this definition guided the implementation of the modeling-based strategy presented in the PD and the outreach camp. Testable ideas stemming from a person's individual and collective set of experiences tell stories about what happens in nature. These ideas are called models (Johnson-Laird, 1983; Morrison & Morgan, 1999).

Typically, students think more concretely when developing personal ideas to explain natural events, but they must think more abstractly when learning scientific concepts. Immersed within a modeling environment that helps to de-intensify the complexities of abstract thought, middle school students become better able to analyze and synthesize data, use hypothetical reasoning, and evaluate their ideas as well as the ideas of others (NGSS Lead States, 2013). These skills are critical for conceptual change learning, and this kind of transformation empowers young adolescents to take control of their lives and learning experiences in the ways that it broadens inquiry and encourages curiosity. Most importantly, conceptual change is more likely to occur as students begin to analyze their personal ideas of scientific occurrences (Swafford & Bryan, 2011).

During active learning experiences and reflection, students reorganize and add complexity to their conceptual models through assimilation and accommodation. Learners of all ages assimilate and accommodate new information to the degree that it is comprehensible, coherent, and plausible, in accordance with their existing conceptual models. Models are bridges that connect concrete learning by using physical objects to correspond to abstract ideas. Moving from concrete to abstract thinking means perceiving the likeness of parts in a situation that at first glance may appear to be unlike each other. Models provide a means for making this transition and support students in constructing relationships that form the basis for using graphs, tables, and formulas.

Students in this case report tested their ideas and theories when they conducted science experiments that involved models such as data tables and graphs. The next step was to have students make sense out of what was taking place; therefore, they were asked to tell a "story" about the models constructed during the investigation. Their stories included ideas about what occurred and why, affording insight into the students' line of thinking. The explanations included in their stories, according to Sparks (2013), leads to better educational outcomes because they encourage the whole adolescent in social, physical, and moral realms and place emphasis on cognitive growth.

Model building involved both mental and physical activities, and was used to facilitate and assess conceptual changes that took place in students' thinking (Jonassen et al., 2005). The eighth graders continued to manipulate their models, and, by doing so, they considered other ideas that were included in their stories. Thus, as their models changed, so did their thinking. Since conceptual change is task-dependent (Schnotz & Preuβ, 1999), the experience of building and revising models, along with writing stories about them, allowed teachers to compare the models that students built and the stories that supported them (Jonassen et al. 2005). This comparison of models and their descriptions revealed shifts in thinking over time.

As conceptual systems, models involve the interweaving of hands-on experiences and student ideas, which shed light on the relationships they share. Therefore, models offer a means for measuring student conceptual understanding through evaluation of the changes that take place in student models and the explanations embedded in student stories (Jonassen, et al., 2005; Lesh & Doerr, 2003). Modeling activities were planned throughout the 5Es to measure students' thinking over time. To determine whether conceptual change did or did not take place, a rubric proved helpful in identifying the tasks and the levels of change (see Appendix). In the rubric, column one identifies the phases of the 5Es along with the task for each phase. The remaining columns articulate the criteria for assessing student reasoning.

5E Pedagogy

A modified form of Bybee's 5Es (1997) was used to guide planning and teaching a series of lessons on motion. It was selected because of its connections to facilitating conceptual change. Figure 1 identifies the five phases of the 5Es and a description of student behavior and motion activities.

The phases of the 5Es presented opportunities for model building and for students to analyze their ideas and consider possible alternatives, leading to revisions of their models. The written stories explaining the constructed graphs provided a window into examining their thinking.

Student voices reflecting conceptual change

Engage

After viewing a cartoon, teachers elicited students' prior conceptions about speed and velocity. When students used the term "speed," they did not necessarily articulate its relationship with the concept of time. However, several students in the dialogue below relate speed to direction by using the phrase "from here to there."

Student 1: "Speed means running from here to there."

Student 3: "Velocity means how fast or far something moves."

Student 4: "Speed has to do with distance."

Student 3: "But also how fast."

Student 1: "Like how hard you can throw something from here to there."

Student 6: "Speed is about how hard you can throw or kick something."

These comments offer evidence that students were constructing mental models of motion. Teachers, after analyzing these comments, other remarks, and student stories, recognized the need to embed speed as a measure (ratio) in future lessons.

Explore

Students recorded their mental models of motion in their science notebooks. Specifically, their assignment was to construct a model of a ball rolling along the floor in a straight line and to write a detailed description in their notebooks so another group of students could reproduce the motion from the written description. Many students had trouble replicating each other's motions since many descriptions often focused solely on force. Students identified this weakness in their peers' written entries when they tried to construct the model as described. It became clear to them that they needed to consider measures of distance and time to get the ball rolling at the correct speed. When students included the relationship between these variables in their explanations to their peers , both groups, those writing the descriptions of their models and those following them, exhibited changes in their thinking regarding distance and time.

Explain

During this phase, students were formally introduced to the academic language of motion while constructing multiple models, specifically, data tables and graphs, to describe and predict motion. In the explore stage, when students laid meter sticks end-to-end to measure the distance a ball moved along the floor at a constant speed, they used their stopwatches to measure the distance traveled at certain intervals of time and recorded these measures in their notebooks. After several attempts at creating a constant motion with the ball, students obtained consistency in their measures to the point that they could learn about interpolating data using smaller time intervals (e.g., half-second intervals) (see Figure 4).

Figure 1 Middle School 5E Motion Lesson

Phases	Student Behaviors/Activities
Engage	1. **Lesson Focus:** Motion with emphasis on distance, time, speed, and direction—the concept of velocity. 2. **Setup:** Wile E. Coyote and Road Runner cartoon. 3. Show the cartoon. 4. Ask questions to prompt prior knowledge of motion: Is there anything moving in the cartoon? What do you see move in the cartoon? Do these motions happen in real life? When someone is driving, does the car move at constant speed? Do you see characters in the cartoon speeding up? Slowing down? Not moving at all? What are the important ideas when describing or predicting speed? Why do you think so?
Explore	1. **Group Task:** Create a motion in a straight line with a tennis ball, measuring tape, and stopwatch. 2. **Directions:** a. Students use the measuring tape and stopwatch to create a motion. b. They explore ways to create this motion. c. Group members decide how to describe the motion they created and each member writes it in their science notebook. d. Another group reads the description and follows the written description to replicate the motion as recorded in the science notebook. 3. When all groups had an opportunity to replicate at least one motion written by another group, ask: Were you able to recreate or replicate the motion as described? Why or why not? What ideas are missing? What was strong about your peers' description? What was weak about your peer's description?
Explain	1. On the following day, select one group to read their description of their motion created and another group to follow their description to replicate the motion. 2. To connect ideas from the Engage (viewing the cartoon) and the Explore (creating a motion), ask the following questions: Did you consider distance when creating your motion? Why? Why not? Did you consider time when creating your motion? Why? Why not? Did you consider the ratio of distance and time as a viable measure? Why? Why not? 3. After students respond, present information on the role that variables of distance and time played in the investigation. Have students create a constant motion with a ball rolling along the floor using meter sticks to measure distance and stopwatches to measure time. Have students tabulate their measures. Ask questions to ensure they understand the relationship between these variables and that the ratio of distance/time represents a viable measure. 4. Use the academic language of distance and time and review the idea of ratio. On chart paper, plot this relationship on a graph from one of student examples presented earlier. 5. Next, demonstrate the connection between the slope of the graph to the ratio of distance/time. 6. All students respond to the questions in their notebooks: What variables are important in describing and predicting motion (distance and time)? Why? Have students share their written responses with their peers. 7. On a Post-It Note, students respond to "What is the key to writing reasonable motion stories?" and place it on the doorframe as they leave.
Elaborate	1. **Group Materials:** A sheet of distance-time graphs, one TI graphing calculator with a motion sensor and graphing application per group. 2. **Group Task:** "Match the Graph" (Van de Walle & Lovin, 2006). Students match each graph on their sheet (see Figure 2) using the calculator and motion sensor. 3. **Introduction to the lesson:** Briefly review what took place in the engage and explore along with the vocabulary and concepts presented in the Explain to set up the modeling activities they will experience in the elaborate. 4. **Group Directions:** a. Each graph on your sheet represents a graph of distance versus time. b. Using technology, reproduce each graph. c. Group roles: one runs the technology, one creates the graph, one provides directions (see Figure 3). d. A description for each graph is written in their notebooks. 5. Teacher monitors each group by listening to student exchanges and checking notebook entries to determine use of academic language and reasoning skills when writing the graph stories in their science notebooks.

Figure 1 *(continued)* Middle School 5E Motion Lesson

Elaborate *(continued)*	6. **Review:** A graph is placed on the screen for the class to view. Ask: What ideas are important when describing motion? Why? What is the story behind this graph? What do the horizontal and vertical axes tell us about the motion? What are the relevant variables in this graph? Why do you say that? Are there clues in the model (the graph) about the relationship between distance and time? How? In what ways? (Students identify the independent and dependent variables [distance and time] and connect direction to the ratio of distance/time, leading to an understanding of velocity). Define velocity by getting students to connect direction to the ratio of distance/time. 7. **Close Lesson:** What is the relationship between distance walked and the time it takes? Have students examine a motion using a data table and construct a graph as presented in Figure 4. Have each student write the story behind this graph in his/her notebook.
Evaluate	1. **Begin with a review:** Project a graph on the wall and ask: How did you move to create this graph? What's the story behind this graph? How does the shape of the graph represented how you moved? 2. Provide the *Create A Journey Story* activity. 3. Students create a motion story for each of six distance-time graphs. 4. Do one together, then have the students in groups do the next four. Have graph six done individually to assess their reasoning. 5. Look for the following in their stories: An understanding that the starting position of the motion is relevant; uses terms of distance, time, velocity, and axes correctly. 6. Use the rubric (see Appendix) to assess student thinking over time.

Toward the end of the explain stage, students described, using key vocabulary, the relationship between distance and time and how speed can be represented as a ratio (in other words, the slope of the graph) using the coordinate axes to measure each variable.

Elaborate

Building on their experiences from the explain stage, students used technology to further develop their understanding of motion using a distance-time graph model. They matched a given set of distance-time graphs by walking back and forth in front of a motion sensor, measuring their walking distance from the sensor, and measuring the time it took them to walk. The purpose of the activity was to build the relationship between speed and the slope of the graph through the independent variable, time, and the dependent variable, distance. By using their bodies to create the motion, students understood slope in the context of the direction in which their bodies were moving. Thus, a positive slope indicated walking away from the sensor while a negative slope indicated walking toward the sensor.

Students comprehended the distance-time graph by including the relationship between speed, slope, and

Figure 2 Sample distance-time graphs from "Match the Graph" sheet

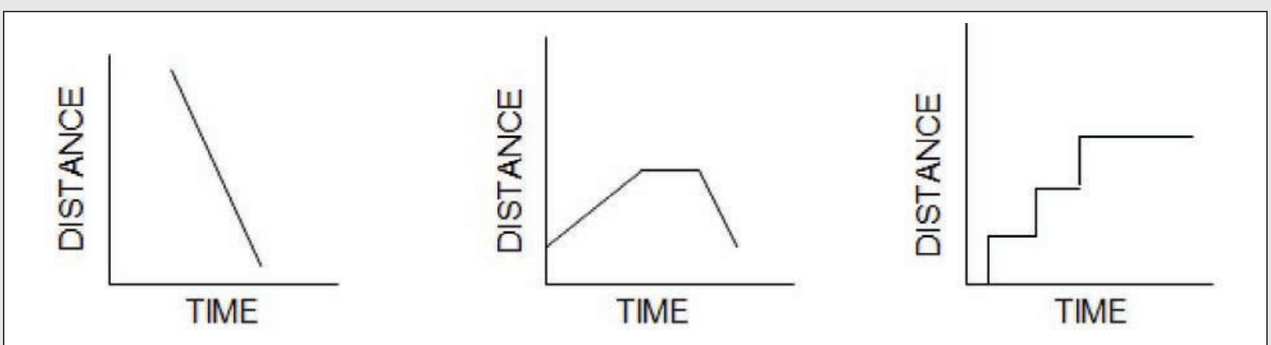


Figure 3 Students graphing motion with technology to create the third graph in Figure 2

direction in their stories. Through constructing and telling the story behind the distance-time graph, students had a better understanding of the definition of velocity. Analyzing student interactions as they were revising their graphs (models) revealed how their thinking and reasoning evolved.

Student 6: "You gotta walk faster. The line [on the calculator] isn't steep enough."

Student 7: "Yeah. See? This line [on the paper] tilting this way says you came back faster."

Student 5: "Oh. So walk faster? Backwards? How fast?"

Student 6: "Yeah. Cover your steps faster."

Such student exchanges show that they centered on relating speed (distance/time) to direction (moving away and toward the sensor). Student stories included well-developed explanations of how someone moved back and forth in front of the sensor to create a particular distance-time graph. The majority of students matched the graphs successfully and wrote coherent stories for their models (graphs), demonstrating that their pre-conceived ideas about motion were changing.

Evaluate

The task, "Create A Journey Story," (Van de Walle & Lovin, 2006) requires students to create a story for a specific distance-time graph. Teachers assess students' thinking and their level of conceptual change by (1) evaluating the stories, focusing specifically on how students connected the topics of distance, time, speed, and direction, and (2) scaffolding their thinking to understand the concept of velocity. The dialogue below demonstrates how students make the connection between slope in a distance-time graph and velocity.

Student 9: "So as you walk away faster, the line gets steeper."

Student 8: "This is walking back" [Points to a line with negative slope].

Student 7: "We can write the time here [Points to x-axis]. Minutes or seconds?"

Student 9: "Doesn't matter. We just need to show time to show how fast."

Student 11: "Make sure it's walking back."

The following student dialogue relates to the journey story for the second graph in Figure 2. A deeper understanding of constant speed and its relationship to velocity is confirmed when Student 4 says, "It's a straight line …."

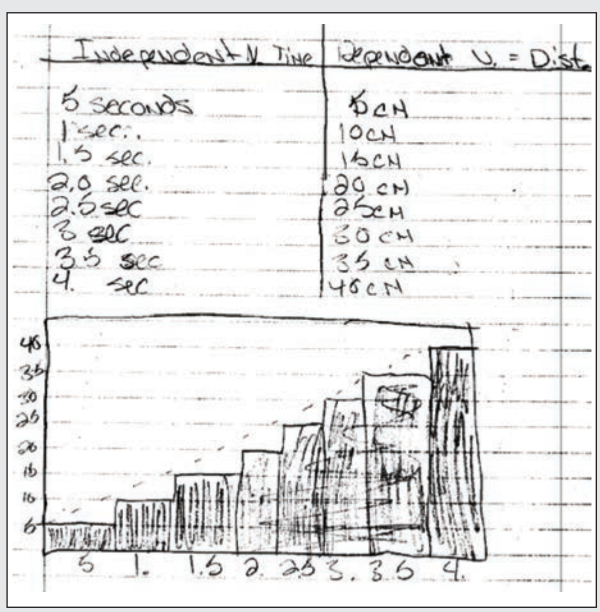
Student 2: "He started running at a steady speed."

Student 3: "Or velocity. He's running away."

Student 4: "It's a straight line. Like, it looks the same speed every time."

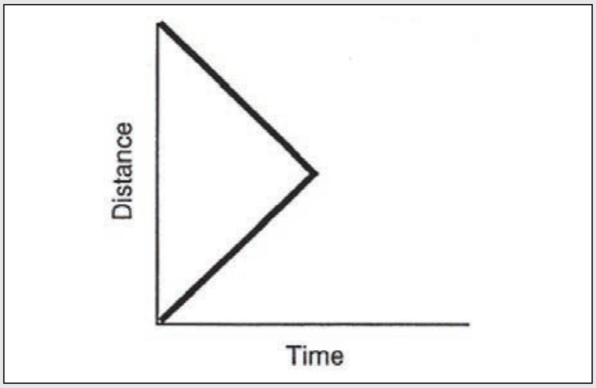
Student 2: "Except later where he's faster but moving in the opposite direction."

Figure 4 Students use multiple models to represent the relationship between distance and time



For those students who wrote stories for the "impossible" graph (see Figure 5), there was evidence that they exchanged their previously held ideas for those that were more plausible.

Figure 5 An "impossible graph" challenge



The exchanges between the following students provide a strong indication that they modified their thinking about direction, thereby making a connection between speed and velocity.

Student 9: "That's really fast in that direction!"

Student 2: "If you're a superhero. You can go backward in time."

Student 11: "You don't have to. I have a story: *'One day a friend of mine decided to meet up. He lives in east side, I live northeast. We met up at the same place, same time, same speed."*

Student 7: "Yeah, they start at different places from different directions."

Also, in the evaluate phase, a game called the "vocabulary loop" was used to review science learning. This review took the form of a game in which each student received a card that bears one phrase, "I have [science term]" and another phrase "Who has [definition of a different science term]." The student who has the word or phrase on her or his card that matches the "who has" definition stands up next and reads her or his "I have [matching word]" followed by their "Who has" definition. The process is then repeated until all science vocabulary terms have been matched with their respective definition. The loop ends when the last definition matches the first term that is read. Students responded well to this culminating activity, with a success rate of more than 80% when matching terms to definitions.

Conceptual change is a gradual process, and the 5Es offered many avenues for students to alter their thinking as they participated in model building. In this case report, the interaction between students' prior knowledge and new information fostered a cognitive conflict between what students thought they "knew" about motion and what became clearer and more plausible. Throughout the phases of the 5Es, teachers assessed changes that took place as students revised their thinking during the model construction process. By using a variety of evaluation venues, all eighth grade students had opportunities to demonstrate what they had learned in different ways (National Middle School Association [NMSA], 2010).

Discussion

Using models is an important strategy in teaching and learning that middle school teachers can use to scaffold learning and foster conceptual change, as demonstrated in this case report. The eighth graders became good at building their models (assimilation), and the students continued to adjust the models as new ideas occurred to them (accommodation). By analyzing student models, written explanations, and oral comments, teachers involved students in the conceptual change process. When challenged with creating a motion using a tennis ball, students attacked this problem using what they knew about motion, but they went a step further by writing stories about what they constructed. Creating a motion proved to be a good learning task as well as a good assessment task for all students involved in the camp. Modeling was an ideal context to assess these students' thinking because it engaged and challenged them to perform at a higher level (Hogan & Fisherkeller, 2000; NMSA, 2010).

According to Bruner (1990), both constructing and telling stories are essential in negotiating meaning about the world. Such a strategy seemed to be ideally suited to the camp attendees. By writing a story for their models, students used academic vocabulary in a way that demonstrated their level of understanding of the concept of motion. Their model stories that described and predicted the motion of an object relied on the measures of distance and time. As students wrote and read their stories, they recognized their mistakes more easily. For example, they realized that the motion of an object is independent of how much force they used to move it. Furthermore, vague notions of the roles that direction and initial position played in describing and predicting motion became clearer as students became immersed in constructing their models.

As the eighth graders manipulated objects and built models for motion, they acquired new ideas, modified old ones, and they began to think in a different way. As new ideas developed, they were empowered to seek answers to broader questions, and they became problem solvers and critical thinkers while building and writing stories about their models. This case report chronicles the creation of stories for models that forced eighth grade students to restructure their learning. It is from these student-generated stories that teachers designed a platform for investigating what their students were thinking, addressing student science misconceptions in a developmentally responsive way, and, most importantly, supporting their students' progress toward assimilating and accommodating new ideas about motion.

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Appendix

Rubric for Achieving Conceptual Change

Topic: Learning about the Principles of Motion

Student tasks and assessing reasoning throughout the 5Es		**4 -- Exceeds Expectations** (Student demonstrates a clear understanding of the lesson content, goes beyond what is presented, explores other options when conducting investigations, and responds accurately in writing and when speaking.)
Explore Phase *Task:* Construct a model for an object in motion	*Assessing reasoning:* To what degree can a student build a relationship between distance and time that helps describe and replicate an object's motion?	Describes an object's motion after recognizing a relationship between distance and time. Replicates an object's motion after recognizing a relationship between distance and time.
	Assessing reasoning: To what degree can a student point out strengths and weaknesses of their own and their peers' models based on the variables of distance and time?	Points out the majority of the strengths of his/her constructed model and those constructed by peers based on variables of distance and time. Points out the majority of the weaknesses of his/her constructed model and those constructed by peers based on variables of distance and time.
	Assessing reasoning: To what degree can a student create a table of measures relating distance traveled to time elapsed?	Creates a table of measures that relates distance traveled to time elapsed without errors.
Explain Phase *Task:* Graphing a motion using multiple models (representations)	*Assessing reasoning:* To what degree can a student plot measures of distance and time on a graph to demonstrate understanding of the coordinate axes?	Plots measures of distance and time on a graph correctly. Explains coordinate axes correctly.
	Assessing reasoning: To what degree can a student build the relationship between the slope of the distance-time graph to the ratio of distance over time?	Grasps the relationship between the slope on the distance-time graph to the ratio of distance over time as supported by an explanation provided in his/her own words of this relationship.
Elaborate Phase *Task:* Match the graph using representations	*Assessing reasoning:* To what degree can a student demonstrate an understanding of the importance of direction and starting position when replicating a motion?	Understands the importance of direction and starting position when replicating a motion as reflected in the extensive written statements in his/her science notebook.
	Assessing reasoning: To what degree does a student understand the importance of direction, slope, and starting position when describing and predicting a motion?	Has a clear understanding of the importance of direction, slope, and starting position when describing and predicting a motion orally and in writing.
Evaluate Phase *Task:* Create a Journey Story	*Assessing reasoning:* To what degree can a student explain the relationship between slope, direction, and starting position when developing a reasonable motion story (scenario) for a specific distance-time graph?	*Develops* a reasonable motion story (scenario) for a specific distance-time graph by explaining the relationship between slope, direction, and starting position.
Evaluate Phase *Task:* Motion vocabulary loop	*Assessing reasoning:* To what degree can a student associate a scientific term to its correct definition during the vocabulary loop?	*Matches* scientific terms to the correct definitions *80%* of the time during the vocabulary loop.

Rubric to Assess Levels of Students' Reasoning About the Principles of Motion

3 -- Meets Expectations (Student demonstrates an understanding of lesson content and applies some of it when conducting investigations and includes some of it when writing and when speaking.)	**2 -- Approaching Expectations** (Student understands, to some degree, the lesson content and is inconsistent when applying it during investigations and when writing or speaking.)	**1 -- Does Not Meet Expectations** (Student has a rudimentary understanding of the lesson content. Needs additional opportunities to apply the content during investigations and when writing and speaking.)
Describes an object's motion in general terms and begins to see the relationship between distance and time. Replicates an object's motion in general terms; begins to see a relationship between distance and time.	Describes an object's motion in very limited terms and has limited awareness of the relationship between distance and time. Replicates an object's motion, but fails to recognize the relationship between distance and time.	Does not describe an object's motion and is not aware of the relationship between distance and time. Does not replicate an object's motion and does not recognize the relationship between distance and time.
Points out at least two/three of the strengths of his/her constructed model and those constructed by peers based on variables of distance and time. Points out a few of the weakness of the model he/she constructed and those constructed by peers based on variables of distance and time.	Points out at least one strength of his/her constructed model and those constructed by peers based on variables of distance and time. Points out at least one weakness of his/her constructed model and those constructed by peers based on variables of distance and time.	Points out no strengths of models constructed by peers. Does not construct a model based on variables of distance and time. Points out no weaknesses of a model constructed by peers.
Creates table of measures that relates distance traveled to time elapsed with no more than two errors.	Has difficulty creating a table of measures that relates distance traveled to time elapsed demonstrating levels of misunderstandings.	Does not create table of measures that relates distance traveled to time elapsed.
Plots measures of distance and time on a graph with no more than two errors. Explains coordinate axes with no more than two inaccuracies.	Has difficulty plotting measures of distance and time on a graph; demonstrates levels of misunderstandings. Provides a very limited explanation of coordinate axes.	Does not plot measures of distance and time on a graph. Does not explain coordinate axes.
Has a limited grasp of the relationship between the slope on the distance-time graph to the ratio of distance over time as supported by an explanation provided in his/her own words of this relationship.	Has minimal understanding of the relationship between the slope of the distance-time graph to the ratio of distance over time when attempting to explain this relationship in his/her own words.	Does not grasp the relationship between the slope of the distance-time graph to the ratio of distance over time.
Has a limited understanding of the importance of direction and starting position when replicating a motion as reflected in the written statements in his/her science notebook.	Has minimal understanding of the importance of direction and starting position when replicating a motion as reflected in the written brief statements in his/her science notebook.	Does not understand the importance of direction and starting position when replicating a motion as reflected in the written minimal statements in his/her science notebook.
Has a limited understanding of the importance of direction, slope, and starting position when describing and predicting a motion both orally and in writing.	Has minimal understanding of the importance of direction, slope, and starting position when describing and predicting a motion both orally and in writing.	Does not understand the importance of direction, slope, and starting position when describing and predicting a motion both orally and in writing.
Develops a reasonable motion story (scenario) *that includes a few inaccuracies* when describing a specific distance-time graph and the relationship between slope, direction, and starting position.	*Develops* a reasonable motion story (scenario) *that is only 50% correct* when describing specific distance-time graph and the relationship between slope, direction, and starting position.	*Does not develop* a motion story.
Matches scientific terms to the correct definitions *70%* of the time during the vocabulary loop.	*Matches* scientific terms to the correct definitions *60%* of the time during the vocabulary loop.explain this relationship in his/her own words.	*Matches* scientific terms to the correct definitions less than *50%* of the time during the vocabulary loop.