Force and Motion:
An Evidence-Based Approach for Elementary Teachers

Pedagogical Principles and Content Overview for Professional Development providers

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Contents

1. Introduction

On August 1-5, 2011, as part of Horizon Research's AIM project, a professional development workshop on Force and Motion was held for 5th grade teachers. Most of the content-centered activities conducted at this workshop were also intended to be suitable for implementation in 5th grade classrooms. This guide is intended as an aid to professional development providers who wish to help teachers prepare to implement some or all of these activities in their own classrooms.

The first part of this guide starts with a brief introduction to guided-inquiry pedagogy and then elaborates on important factors in facilitating effective guided-inquiry style instruction using the materials developed for the workshop.

2. Guided Inquiry Pedagogy

2.1 Constructivism and how people learn

The constructivist view of learning holds that people generate knowledge and meaning when they try to make sense of their experiences in relation to the ideas they already hold (their prior knowledge). As such, an event that seems to affirm their prior knowledge also serves as evidence to reinforce it. However, when an event seems to contradict prior knowledge it may be dismissed as faulty, irrelevant, or (more preferably) lead to a state of "cognitive dissonance," in which prior knowledge is called into question. It is in the resolution of this conflict between experience and ideas that significant learning can take place. To facilitate such learning, it is essential to provide learners with experiences that challenge their current views of how the world works.

2.2 The Nature of Science and the role of evidence

Most people regard science as a body of knowledge, and unfortunately most science classes represent learning as the memorization of that knowledge. However, science is really the process by which this knowledge is determined. When scientists engage in "doing" science, they are really engaged in learning in much the same way as the constructivist view outlined above. As such, they use their prior knowledge to make predictions about the outcome of an event (sometimes, but not always, a controlled experiment). If the outcome agrees with their prediction, then their current understanding (prior knowledge) is reinforced. However, if the outcome is not in agreement with prediction, this can result in a modification, or outright rejection, of the current understanding.

It is important to note that, in the scientific process, it is the **evidence** gathered from observations that is used to ultimately judge whether ideas make sense or not. However, we must always admit that further evidence may emerge in the future that could change our thinking about those ideas. Thus, in science, ideas can never be proven right, but they can be judged as "good for now" (agree with existing evidence), or "poor" (not supported by evidence). (Of course, over the years, some ideas have come to be supported by such an overwhelming body of evidence that they are now generally regarded as being essentially "correct," but we should not forget the role that evidence has played in giving them this status.)

2.3 Guided-Inquiry

If the process of "doing" science is a good model for how people learn, then it should be more effective for people to learn science in as close to the same way that scientists do; by constructing ideas themselves using the scientific process itself! This is the principle behind inquiry-based instruction in science. However, it should be realized that, unlike basic scientific research where there are no specifically defined learning objectives, in a science class we have definite target ideas that we want our students to understand. Although it may seem that these target ideas are dictated by authority (via standards, benchmarks, and texts), in reality they are simply a subset of those science ideas that have been well established because they are supported by a large body of evidence.

If we can create a learning environment in which we arrange for learners to express their **prior knowledge**, make **meaningful observations**, focus their attention on **relevant evidence**, and promote **sense-making** based on that evidence, then we will have facilitated the learning of science ideas by actually "doing" science. It is just such a learning environment that a guided-inquiry pedagogical structure aims to promote. In such a structure, the guidance given is intended to move learners toward the target idea(s) by:

- Directing observations of relevant events;
- Focusing attention on what are the important aspects of these observations;
- Making direct connections between the evidence collected and the target idea(s);
- Breaking down the sense-making process into small steps; and
- Drawing attention to evidence that refutes common misconceptions.

2.4 Design Principles

The investigations for Force and Motion developed for the workshop were designed with a guided-inquiry structure based on a set of principles that tie in closely with the constructivist view of learning outlined above. In order to implement the investigations as intended, it is important to appreciate these principles and how they are applied in the investigations. The table below summarizes these principles and describes how they are applied in the investigations.

Design Principle	**How Principle is Applied**
Learning is influenced by the learner's prior knowledge.	Learner's *initial ideas* are elicited in a "What We Think" section at the beginning of most investigations. Most investigations also build on ideas developed in previous lessons.
Learners' prior knowledge may be resistant to change and is often at odds with learning objectives.	Investigations are explicitly designed to elicit and then address *commonly held misconceptions*.
Learners construct their own knowledge gradually in a complex process requiring multiple exposures.	Investigations within and across Units and Cycles build on each other. *Misconceptions known to be particularly resistant to instruction* are addressed explicitly several times.
Learning is enhanced by social interactions.	Learners work through the investigations in pairs or small groups. The beginning and end of every investigation also includes class discussion of some initial ideas and of *summarizing questions*.
Interaction with external stimuli is critical to learning.	Whenever possible, learners perform hands-on experiments to gather evidence. Computer simulations, video and instructor demonstrations are used when it is not possible.

3. Units, Cycles, and Investigations

3.1 General Structure

The Force and Motion content area is broken down into Units, Cycles and Investigations. While it is tempting to see each investigation as a separate entity, they are designed to build on each other in a way that gradually builds up the "big" ideas for the whole content area. Each "big" idea is broken down into successively more focused sub-ideas that are the learning objectives for one or two individual investigations. A map of how the big ideas and sub-ideas are developed in these units is included on page 16 in this section. A table showing the lessons in which the ideas and sub-ideas are developed in these units is included on pages 17-19.

While a a group of learners is engaged in a particular investigation, it is important for the PD-provider to have a sense of where it fits in the "grand scheme" of idea building. In particular, for effective implementation, it is essential for the PD-provider to be aware of which ideas should have already been mastered, versus those yet to be addressed, toward which the investigation is building.

To give some structure, and allow for reasonable assessment opportunities, the whole sequence is broken down into Units and Cycles as follows:

- Unit 1: Motion
  - Cycle 1: Describing Position
  - Cycle 2: Describing Motion
  - Cycle 3: More advanced ways of describing motion
- Unit 2: Connecting Force and Motion
  - Cycle 1: The Effect of a Single Force
  - Cycle 2: The Effect of Combinations of Forces
  - Cycle 3: Changing Net Force and Mass

Units are composed of investigations designed for approximately 30 minutes of instructional time in PD. Some investigations contain multiple activities and may require additional time. PD-providers should use their judgment to determine stopping points.

3.2 Overall Investigation Structure

Most investigations (with very few exceptions) have the same structure. The sections are briefly described below, with more detailed tips and suggestions for implementation given in the next section of the guide.

Purpose and Key Question
This section gives a brief introduction to the investigation and describes what idea(s) will be addressed. The key question provides a focus for the investigation. The whole investigation is designed around addressing this question!

What We Think
This section is only included when it is felt that it is important to elicit learners' prior knowledge on the content to be addressed. When present, it usually consists of a scenario followed by one or more questions that ask learners to make predictions and provide their reasoning.

Activities
The main body of the lesson. In most cases, learners will perform experiments, watch a demonstration, or otherwise gather evidence. Guiding questions ask them to record this evidence and may also ask them to compare it with their prediction, or with what others have

recorded. For convenience, these activities are divided into STEPS that the teacher can use to control the pace of the class. (“Just do STEP 1,” “Work through to STEP 3, but not further.”)

Making Sense
With PD-provider guidance, it is in this section that learners try to make sense of the evidence they have seen. They will often be asked to make generalizations from their evidence and to propose an answer to the key question for the lesson. They may also be asked to apply their ideas to other, similar, situations.

This investigation structure promotes metacognition (learner awareness of how they are thinking about an idea and how that thinking is changing), by having them consider their initial ideas in the “What we think” sections, considering the meaning of data they collect, and generalizing from data to broader science ideas through the “Making Sense” questions. From time to time during the unit, PD-providers may want to help learners reflect on the learning process, asking questions such as, “How has your thinking about this idea changed, and why?”

3.3 Questions and responses

The investigations themselves are worksheets that learners navigate, with PD-provider guidance. It is important for the PD-provider to be aware of the way questions are situated in different sections of the investigations and when responses are, and are not, expected.

In the **Purpose** section, very often a scenario is described, together with a question about it embedded in the narrative. While PD-providers may pose the question as part of an oral introduction to the investigation, it is not expected that learners will answer this question at this point. It is merely meant as a means of focusing attention on the topic of the investigation. The **Key Question** plays a similar role. The PD-provider may choose to return to, and have students answer, these questions at the end of the investigation as a wrap up.

In the **What We Think** and **Activity** sections, many questions are posed, followed by some space, in which learners are expected to write their responses. In these sections, questions that require a written response are always “tagged” with a small icon (see below) and followed by space for the response. (Some activity titles may themselves take the form of a question, and some questions may be embedded in non-tagged sections of narrative. Written responses are not expected for these questions, though the PD-provider may choose to pose them as they focus student thinking.) Three different icons are used to tag questions for which written responses are expected. They are meant to convey what type of question is being asked:

Prediction question: Learners should use their current thinking to make a prediction or brainstorm about a scenario. This type of question is posed mostly in the What We Think section, but also appears often in Activity sections, when learners are expected to use the results of previous observations to infer what will happen next.

Observation question: Learners should record the results of an experiment. Posed exclusively in the Activity sections, this type of question may require recording a numerical value of a measurement, or a more general observation of an object's behavior. Often, in order to focus thinking on the relevant aspect of what they have seen, only certain choices are given for this latter type of observation question. (For example: Was the speed increasing, decreasing, or staying constant?)

Synthesis question: Learners should "put the pieces together" using the evidence they have recorded. This process could involve anything from simply using distance and time to calculate an object's speed, to beginning to make connections between the results of different activities, to making a generalization about the way the world works. Such questions usually occur toward the end of an Activity section.

The questions posed in the **Making Sense** section may serve two purposes. First, there will always be one or more questions aimed toward generating a consensus about how to answer the key question for the investigation. Second, learners may be asked questions that serve to check their understanding of certain key concepts, by explaining them or applying them in a different context.

4. Implementation strategies

4.1 Learning environment

In order for guided-inquiry instruction to be effective, there are certain behaviors, for both PD-providers and learners, which should be introduced and modeled by the PD-provider. In effect, all of these go to making the learning environment a "safe" place to express ideas and take intellectual risks without fear of "getting it wrong." These behaviors may be very different from those expected in traditional learning environments and so will require continuous reinforcement and support. Among the most important behaviors are the following:

Respect
All ideas expressed should be respected by everyone, PD-provider and learners alike, no matter how "crazy" they may seem. It is only when this behavior is established that learners will feel safe taking intellectual risks! It is important to realize that respecting an idea is not the same as assigning merit to it.

When a learner expresses an idea, a PD-provider can show respect by listening carefully and trying to understand what the learner is saying. It is often useful to repeat the idea, paraphrasing to make it clearer if necessary, and asking the learner if that is what was meant. If the PD-provider models this respect in dealing with learner ideas it will go a long way toward fostering this behavior from learners. One way to do this might be to occasionally ask one learner to explain another's ideas.

Evidence
In science, value is placed on an idea depending on how well it is supported by evidence. Thus, all ideas should be supported by evidence. When ideas are expressed, or claims made, without supporting evidence it is legitimate to ask, "Why do you think so?", or "What evidence supports your idea?" Learners should be encouraged to do so and the PD-provider should model it as well. In the end, it is the evidence that determines how much merit an idea has.
The nature of the evidence given to support a claim can be varied. At the end of a investigation it will usually take the form of observations made during the investigation itself. However, when eliciting initial ideas it may also come from everyday experience and prior instruction. In the investigations, opportunities to refer to evidence are typically prompted by questions.
When and how evidence should be used in answering questions is outlined below:

> *What Do We Think questions*
> At this point, learners have not yet gathered evidence from the investigation activity. However, learners may have ideas about what the activity outcome will be, and, when prompted, should give a reason for their thinking. For example, a learner might say, "I think the heavier object will fall faster because it has more gravity acting on it than the lighter object." Alternatively, a learner could share experiences that led to a prediction. For example, a learner might say, "I think the ball will roll faster and faster as it goes down the ramp because when my students run down a hill

they are going really fast when they get to the bottom." In some cases, learners may refer to experiences or evidence from previous investigation activities to support a prediction.

Activity questions

There are two types of questions that are typically posed in the activity portions of investigations. The first type asks learners about their observations or results from the activity. In answering these questions, learners are recording the data that will later serve as evidence for their claims. PD-providers can help learners record results clearly and with enough detail so another person could read and understand what the results were. PD-providers may need to remind learners to record units, such as meters/second, and may also need to prompt learners to provide additional detail in their descriptions and clearly label drawings.

The second type of activity questions are Synthesis questions. Here, the goals are for learners to look for patterns in their data and make a claim/reach a conclusion. PD-providers can help learners get into the habit of citing evidence to support their claims or conclusions by asking them questions such as, "How do you know?" or "What did you find in the activity that made you think that?".

Making Sense questions

Making Sense questions are intended to help learners generalize from the specific examples in the activity to the science concept more generally. In these questions, evidence from the activities is used to help learners recognize patterns that hold true in other contexts. For example, learners should make the conceptual leap from understanding that the motion of *these* toy cars rolling down *these* wooden ramps in *this* professional development session is similar to the motion of other objects rolling down inclined planes in other settings. PD-providers should prompt learners to provide evidence in their answers to the Making Sense questions.

Responsibility

The responsibility for generating knowledge (ideas) lies with the learners, supported and guided by the PD-provider. The aim is to have learners come to consensus on an idea that is supported by the evidence and reject ideas that are not. The PD-provider should not validate ideas, but should ask questions about corroborating/refuting evidence when other learners do not. Another important role for the PD-provider is to promote consensus building and to move on when it seems consensus on a "good" idea has been reached. (Note: This should not take the form of confirming that the consensus idea is "correct," but rather that it is an idea that seems to explain all the evidence, and so is a "good" idea.)

4.2 Working in groups

One of the design principles stated in Section 2.4 (above) is that learning is enhanced by social interaction. Research shows that discussing ideas with each other is a valuable way for learners to examine their thinking and so having learners work in pairs or small groups, whenever possible, is a way to promote this interaction. However, having learners work in groups can also pose logistical challenges, such as groups working at different speeds, incompatible personalities, dominating group members, "passenger" group members (one member letting the others do all the intellectual work), etc. To minimize such problems it may be best for the PD-provider to form (or re-form) the groups, rather than have them always self-select. In doing so, some issues to bear in mind are:

- Mix abilities: Do not have groups composed entirely of advanced or more novice learners.
- Mix genders: If possible do not have single sex groups. However, make sure there are no groups with only a single woman in them.
- Group sizes: Groups of three or four are probably the best. When a dispute about ideas occurs within a group an odd number allows there to be a majority opinion for group reporting purposes.
- Personalities: Do not put one dominating personality in a group in which the other members are extremely quiet, or are "passengers."
- Passengers: Assign roles such as "Equipment Manager," "Recorder," "Motivator" to group members. Rotate these roles regularly. If you have enough "passengers," form a group composed entirely of them. Hopefully this will force them to make substantial contributions.

Reorganizing groups has both advantages and disadvantages. On the plus side it allows the PD-provider to split dysfunctional groups and allows learners to see that they can work productively with a variety of other learners. On the other hand, groups often seem to work better the longer they stay together.

4.3 Whiteboards

At many points in the investigations learners are expected to share their thinking with the whole class. A good way to do this is to use whiteboards on which they draw or write using dry erase markers. Having groups of learners do this gives some pedagogical advantages.

- Negotiation: When a group of learners has to agree on a single board that represents their thinking, it promotes much more discussion than when they simply write/draw on their own worksheets.
- Formative assessment: When the PD-provider circulates around the room while the boards are being prepared s/he can get a good sense of what ideas are being expressed, and in what proportion. Doing so allows the PD-provider to better prepare mentally for the discussion to follow.
- Visual representation: When learners present their ideas, everyone can see their visual representation of them, rather than relying only on a verbal description.
- Summarizing: During the discussion, the PD-provider can group boards with similar characteristics and so present a visual summary of how the learners are thinking.
- Archiving of ideas: If the boards are not erased they can be kept as a visual reminder of how the learners were thinking and then revisited at the end of (and perhaps during) the investigation to see whether learners' ideas have changed.

For ease of use and viewing, whiteboards should be at least 2′ by 2′ and can be easily made from 8′x4′ white wall panels sold in home improvement stores. They will usually even cut them for you! However, be careful to ensure that the dry erase markers can really be erased on the surface – some surfaces are better than others. (Alternatively, large blank posters or butcher paper could be used.)

4.4 Sharing strategies

When it comes time in the investigation to share ideas among the whole group there are several strategies the PD-provider can use. The choice of which to use can often be informed by circulating while learners are working and getting a senses for whether most are already in agreement, or whether there are competing ideas being expressed. Among the sharing strategies commonly used are:

All groups present

If it seems there are varying ideas within the class it is valuable to make them all public by having every group present. This approach is also useful to help establish/maintain the behavior that all ideas are valuable and respected and so should almost certainly be done at the first opportunity and repeated at least once per Cycle. However it takes more time, so do not use it unnecessarily.

Pick one or two groups only

When it seems that everyone is thinking the same way, it can save time to have only one or two groups present their ideas and then simply ask whether everyone else agrees. Of course, if there is any fundamental disagreement, then time should be taken to cover it.

Simultaneous display
When whiteboards are being used to present ideas it is often helpful to simply have all groups display their boards in a way that everyone can see them, and then just have everyone look at them. After a few seconds the PD-provider can simply ask the learners what they see, or prompt further for similarities and differences. This strategy works best when the information is presented in a simple way (perhaps in a single diagram). If there are not seriously conflicting ideas,it is a quick way to establish that. If the groups fall into one of only two "camps," this strategy can also be a quick way for everyone to see that, but in this case the PD-provider should also get various groups to present their thinking in more detail and allow others to comment.

Gallery walk
Again, this strategy works best when whiteboards are being used. One group member stays with each board, ready to explain to other learners. The rest of the group circulates around the room to examine the boards of other groups. When they return to their "home" group, allow time to discuss what they have seen, then ask the learners for comments. This strategy is useful when the displays are a little more complex and so learners need to focus on more details when examining them.

Assigned questions
In the Making Sense section of an activity it is often useful to assign specific groups to be responsible for supplying an answer to specific questions. It is best to assign two groups to each question and distribute responsibilities to as much of the class as possible. However, particular assignments should not be made too early, which would enable groups to avoid thinking about some of the questions. (Note that assigning fast-working groups to questions that require whiteboard responses is a way to keep them engaged while slower groups are still working.)

When reporting, the first group presents their answer, and the second group then responds to it. If the PD-provider has previously ascertained that there seems to be general agreement about a particular question, then these two groups can be assigned at random. After they have given their responses the PD-provider should always ask the rest of the class whether they agree as well. However, if there are competing ideas within the class, the PD-provider should make sure two groups are chosen that represent those competing ideas. After these competing ideas have been presented the PD-provider should open things up for a full class discussion.

4.5 Independent versus PD-provider-led pacing

It is up to the individual PD-provider to decide at what grain size they will guide learners during the investigation. At one extreme, the PD-provider could simply introduce the investigation and then let groups work through independently, only stopping for general discussions when appropriate. At the other extreme, the PD-provider could lead the learners thought the whole investigation one question at a time, discussing each briefly as they go. Where on this spectrum one chooses to operate will depend on several factors that only s/he is equipped to judge, such as the existing content knowledge, group dynamics, equipment and space availability, etc.

4.6 Tips for particular lesson sections

Much of what is discussed above are general strategies that could be used at any appropriate point in an investigation. In this final section, tips for conducting particular sections of investigations are discussed.

Purpose/Key Question

Although learners could simply read this section themselves, it is probably better for the PD-provider to give an oral introduction to the investigation, based on the content of this section. In this way the PD-provider can emphasize what the topic of the investigation is, and focus students attention on the key question to be answered. In this introduction, the PD-provider may also wish to make appropriate connections with ideas developed in previous investigations, and so start to help learners put together the "big picture."

What We Think

The PD-provider should introduce the scenario to be discussed, pose the prediction questions to be answered, and then allow learners time to discuss with each other and record their responses. While they are doing this, the PD-provider should circulate around the room to get some sense of what ideas are being expressed and so decide what form the ensuing class discussion should take. This sequence could be repeated for each prediction question in turn, or the whole set of questions could be dealt with at one time. (If whiteboard displays are expected, the PD-provider should remind learners of that also.)

While the PD-provider is circulating, and also when learners present their ideas during the discussion, the PD-provider should **not** pass judgment on them. However, it is legitimate to probe for the reasoning or evidence behind learners' responses. As ideas are presented, the PD-provider should also ask for any learner comments on them. Also, if learners seem to stray too far from the topic of the investigation, then it is legitimate to redirect them back again.

At the end of the class discussion the PD-provider should summarize the ideas that seem to be present among learners in a non-evaluative way, and then move on to introducing the activity to follow.

Activities
In an oral introduction to the activity, the PD-provider should explain briefly what learners are going to do, and point out how it is going to help learners test their ideas. Learners should then be directed to work through the activity at whatever level of guidance the PD-provider has chosen, question by question, STEP by STEP, or independently. Depending on equipment availability, the PD-provider may choose for learners to work on hands-on activities in pairs, small groups, as a whole class, or to follow a demonstration.

As learners work on experiments, the PD-provider should circulate, making sure learners are performing the tasks as indicated, looking out for misunderstandings or malfunctioning equipment. (Remember to try all the experiments in advance!) In addition, the PD-provider should be prepared to intervene if learners are not focusing on the observations and evidence that are relevant for a particular activity. If there is a lot of confusion it is usually best to simply stop the whole class and redirect them.

In some activities there may be points at which a mid-way class discussion takes place. In such cases, these are intended to be brief and just make sure everyone is on the same page as far as relevant observations and inferences are concerned.

Making Sense
It is important that learners record reasonably constructed responses to the Making Sense questions. For this reason it is highly recommended that the PD-provider lead the class in discussing them one question at a time, and then prompt learners to record a response that is the consensus. Reaching such a consensus will likely be easy in most cases, but may be quite difficult when deeply held misconceptions are involved. Although it is preferable that all learners agree on an idea, in rare cases it may be necessary to move forward with a "majority" opinion. In such a case the PD-provider should not confirm one idea as being "correct," but simply say that because most learners seem to think one way we will carry the idea forward, but continue to check it. It may even be desirable to create a "parking lot" for such ideas, to remind learners to continue checking on them.

PD-providers are often worried that learners will come to consensus on a "poor" idea and so will not come to understand the desired learning objective. However, it should be emphasized that the investigations have been designed so that this should not happen. If they are implemented as intended, in an inquiry-based manner, with the PD-provider guiding the learners to base their thinking on evidence, then the desired target ideas will emerge.

4.7 A note on complete answers and explanations

At almost every point in an investigation, learners are asked to explain their thinking or reasoning, or cite the evidence on which it is based. Very often, learners will give one word answers to such prompts, such as "car," or "graph," or "motion." The PD-provider should not accept these answers and point out that these are not truly explanations or reasoning. Instead, a better, and more complete, description should be given, such as "The speed of the car increased when we pushed it.", or "The graph went down when the car got slower.", or "The position of the student changed, so he must have moved."

Similarly, when explaining the behavior of an object, some connection should be made to the "big" ideas used, such as: *"As the block was sliding across the table the only force acting on it was a frictional force acting on it in the opposite direction to its motion. When a single force acts on an object in the opposite direction to its motion, an object's speed will decrease, so the block got slower and slower."*

4.8 Target Ideas and Common Misconceptions

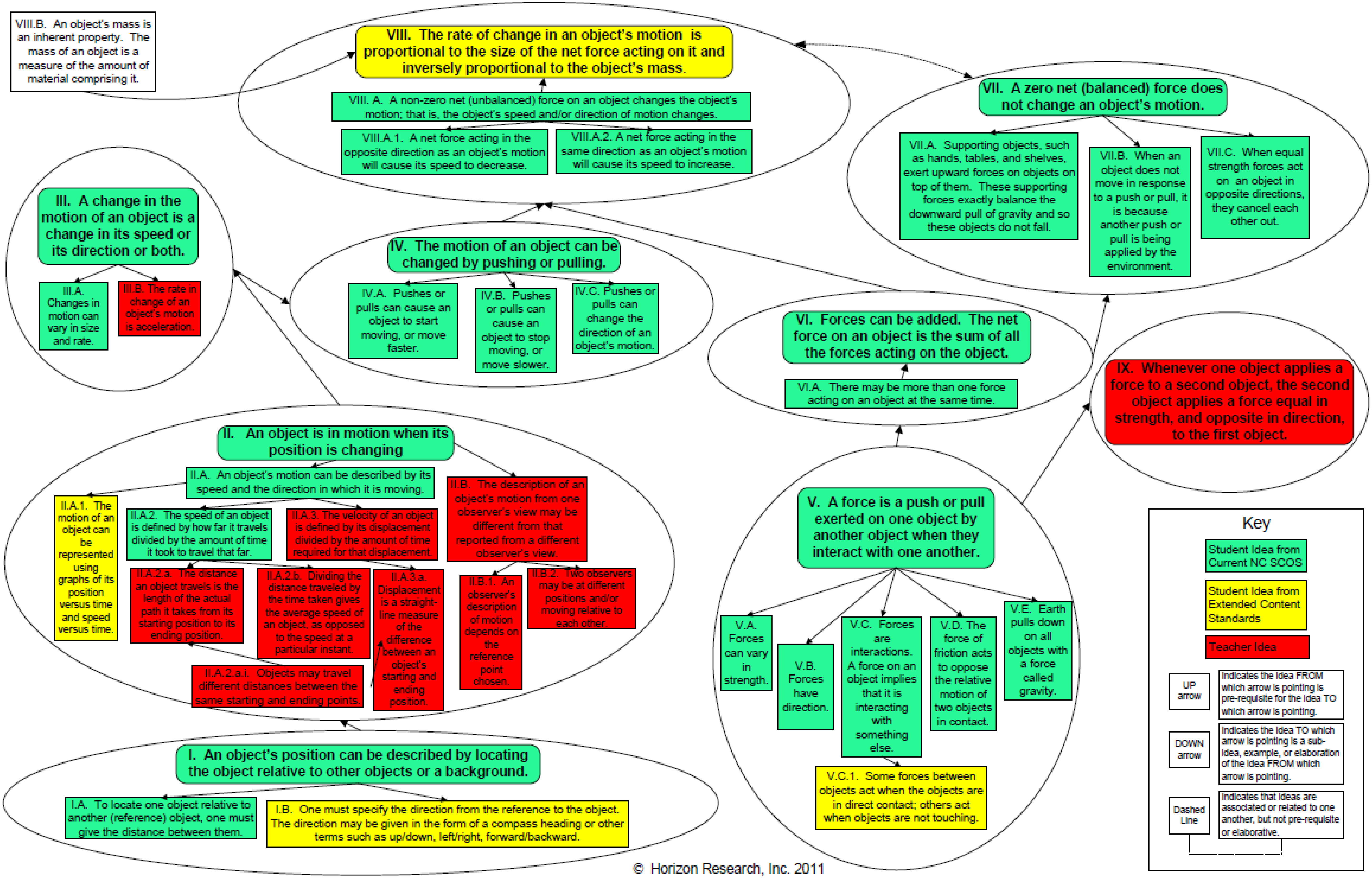
At the beginning of each annotated investigation is a section giving the Target Ideas and some Common Misconceptions. The Target Ideas are those the learners should **develop** by the **end of the lesson**. If they are given to learners at the beginning of the lesson, the inquiry-based nature of the class is seriously diluted! The Common Misconceptions are not meant to be exhaustive, but should include the main ideas learners are likely to express.

4.9 Introducing Vocabulary

Research shows that people learn, understand, and retain scientific knowledge best when they develop a conceptual understanding *first* and then assign vocabulary to the concept. For example, in Unit 2, Cycle 1 Exploration #4, learners experience a "rubbing" force between two surfaces that acts to oppose the direction of an object's motion. The term "friction" is introduced after learners experience and understand that such a force exists. In science education, the introduction of terminology following the development of the concept is often referred to as a "just in time" approach—learners acquire the scientific vocabulary when they have the ability and need to use it correctly.

This is not to say that developing science vocabulary isn't important; it is. To support learner understanding of science concepts, and the vocabulary that go with those concepts, we suggest using a class “word wall.” (A word wall is typically a list of vocabulary terms covered during instruction that is prominently displayed somewhere in classroom common space, usually on a poster or bulletin board.) Based on what is known about learning, we recommend adding terms to the word wall *after* the concept and corresponding vocabulary have been addressed through instruction and learners have demonstrated understanding of the terms. At the end of the investigations in the Implementation Guide are suggestions for which key terms should be ready for placement on a word wall.

5. **Force and Motion Content Framework**



6. **Force and Motion Activities-Idea Matrix**

	U1C1 Beginnings	U1C1 Exploration 1	U1C1 Exploration 2	U1C1 Application	U1C2-Beginnings	U1C2-Exploration 1	U1C2- Exploration 2	U1C2-Exploration 3	U1C2-Application	U1C3T-Extension 1*	U1C3T-Extension 2*	U1C3-Extension 1	U1C3-Extension 2	U1C3-Extension 3	U2C1-Beginnings	U2C1- Exploration 1	U2C1- Exploration 2	U2C1- Exploration 3	U2C1- Exploration 4	U2C1-Application	U2C2-Beginnings	U2C2-Exploration 1	U2C2-Exploration 2	U2C2-Application 1	U2C2-Application 2	U2C3T-Extension 1*	U2C3T-Extension 2*	U2C3T-Extension 3*	U3C1T Beginnings*	U3C1T Exploration* 1	U3C1T Exploration* 2	U3C1T Exploration* 3
I. An object's position can be described by locating the object relative to other objects or a background	x	x	x	x																												
I.A. To locate one object relative to another (reference) object, one must give the distance between them.	x	x	x	x																												
I.B. One must specify the direction from the reference to the object. The direction may be given in the form of a compass heading or other terms such as up/down, left/right, forward/backward.	x	x	x	x																												
II. An object is in motion when its position is changing					x		x			x		x	x	x																		
II.A. An object's motion can be described by its speed and the direction in which it is moving.					x							x	x	x																		
II.A.1. The motion of an object can be represented using graphs of its position versus time and speed versus time.										x			x	x																		
II.A.2. The speed of an object is defined by how far it travels divided by the amount of time it took to travel that far.							x																									
II.A.2.a. The distance an object travels is the length of the actual path it takes from its starting position to its ending position.											x																					
II.A.2.a.i. Objects may travel different distances between the same starting and ending points.											x																					
II.A.2.b. Dividing the distance traveled by the time taken gives the average speed of an object, as opposed to the speed at a particular instant.											x																					
II.A.3. The velocity of an object is defined by its displacement divided by the amount of time required for that displacement.											x																					
II.A.3.a. Displacement is a straight-line measure of the difference between an object's starting and ending positions.											x																					
III. A change in the motion of an object is a change in its speed or its direction or both.						x																										
III.A. Changes in motion can vary in size and rate.								x					x	x																		
III.B. The rate in change of an object's motion is acceleration.											x																					
IV. The motion of an object can be changed by pushing or pulling.						x		x	x						x	x																
IV.A. Pushes or pulls can cause an object to start moving, or move faster.						x		x	x									x														
IV.B. Pushes or pulls can cause an object to stop moving, or move slower.						x												x														
IV.C. Pushes or pulls can change the direction of an object's motion.						x		x																								

	U1C1 Beginnings	U1C1 Exploration 1	U1C1 Exploration 2	U1C1 Application	U1C2-Beginnings	U1C2-Exploration 1	U1C2-Exploration 2	U1C2-Exploration 3	U1C2-Application	U1C3T-Extension 1*	U1C3T-Extension 2*	U1C3-Extension 1	U1C3-Extension 2	U1C3-Extension 3	U2C1-Beginnings	U2C1- Exploration 1	U2C1- Exploration 2	U2C1- Exploration 3	U2C1- Exploration 4	U2C1-Application	U2C2-Beginnings	U2C2-Exploration 1	U2C2-Exploration 2	U2C2-Application 1	U2C2-Application 2	U2C3T-Extension 1*	U2C3T-Extension 2*	U2C3T-Extension 3*	U3C1T Beginnings*	U3C1T Exploration 1*	U3C1T Exploration 2*	U3C1T Exploration 3*
V. A force is a push or pull exerted on one object by another object when they interact with one another.									x						x	x	x		x													
V.A. Forces can vary in strength.																			x													
V.B. Forces have direction.															x																	
V.C. Forces are interactions. A force on an object implies that it is interacting with something else.															x	x																
V.D. The force of friction acts to oppose the relative motion of two objects in contact.																			x													
V.E. Earth pulls down on all objects with a force called gravity.									x								x															
V.C.1. Some forces between objects act when the objects are in direct contact; others act when objects are not touching																	x															
VI. Forces can be added. The net force on an object is the sum of all the forces acting on the object.																						x										
VI.A. There may be more than one force acting on an object at the same time.																					x	x										
VII. A zero net (balanced) force does not change an object's motion.																				x	x		x	x	x							
VII.A. Supporting objects, such as hands, tables, and shelves, exert upward forces on objects on top of them. These supporting forces exactly balance the downward pull of gravity and so these objects do not fall.																				x					x							
VII.B. When an object does not move in response to a push or pull, it is because another push or pull is being applied by the environment.																					x			x								
VII.C. When equal strength forces act on an object in opposite directions, they cancel each other out.																					x			x								
VIII. The rate of change in an object's motion is proportional to the size of the net force acting on it and inversely proportional to the object's mass.								x														x				x	x	x				
VIII. A. A non-zero net (unbalanced) force on an object changes the object's motion; that is, the object's speed and/or direction of motion changes.																					x	x		x	x							
VIII.A.1. A net force acting in the opposite direction as an object's motion will cause its speed to decrease.																							x	x	x							
VIII.A.2. A net force acting in the same direction as an object's motion will cause its speed to increase.																							x	x	x							
IX. Whenever one object applies a force to a second object, the second object applies a force, equal in strength, and opposite in direction, to the first object.																													x	x	x	x

Key:
Green: Student idea
Red: idea intended for teacher professional development

* These activities are intended for use in teacher professional development settings.