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

## Overview for Professional Development Providers

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## 1. Introduction

As part of a study of the effects of professional development on teacher knowledge, classroom practice, and student learning, we tested a model for improving science education at the elementary grades that we believe could be implemented at scale. This model combines lessons learned about teacher professional development (PD), instructional materials, how people learn science in general, and the teaching and learning of force and motion. The work included developing a learning theory-based replacement unit focused on force and motion for upper elementary grades, and a PD program for preparing teachers to implement the unit. The activities within the PD are meant to be easily transferable to classrooms, provide reliable results, and make use of materials that have low associated costs and are accessible to teachers.

This document provides an overview of the AIM PD program and includes links to resources to help others prepare and implement the program. In addition to describing the overall structure and specific elements of the program, this document attempts to convey the thinking that went into the design of the program. We hope that this information will help others use and adapt the materials purposefully.

## 2. Rationale and Goals

There is a broad consensus that content knowledge, although essential for effective teaching, it is not sufficient. Effective science teaching requires what Shulman (1986) called pedagogical content knowledge (PCK). PCK includes such things as knowing common conceptions students bring with them to the classroom, what ideas students will struggle with, and topic-specific instructional strategies for fostering understanding.

However, by their own report, most elementary teachers do not have extensive preparation in science, and do not feel well prepared to teach the physical sciences (Banilower, Smith, Weiss, Malzahn, Campbell, & Weis, 2013). PD can have an impact on teaching (and ultimately student learning), especially if it includes a focus on helping teachers translate what they are learning to the classroom. One way to facilitate this transfer is to base the professional development on instructional materials, particularly if those materials are of high quality (i.e., content correct, based on learning theory, and provide educative supports) (Davis & Krajcik, 2005).

For these reasons, the AIM force and motion PD program was developed with three primary goals:

1. Deepen teachers' understanding of the content, both the content their students should be expected to learn and more advanced content that they need to teach the student content well;
2. Deepen teachers' understanding of how students learn science; and

3. Deepen teachers' understanding of and familiarity with high-quality, easy to use, and reliable instructional materials that they could use to facilitate instruction in their own classrooms.

## 3. AIM PD Principles and Design

Learning theory research has a number of implications for science teaching and professional development for teachers (for an overview, see Banilower, Cohen, Pasley, & Weiss, 2010). One is the importance of surface learners' initial ideas, both so they are aware of their own thinking and to provide direction for instruction. Another implication is the importance of engaging students intellectually with evidence about a phenomenon. This evidence could force learners to challenge their existing thinking and/or help them develop new ideas about how the world works. A third implication is that learners need structured opportunities to make sense of new ideas, for example, by drawing connections between the activity and the conclusions or between what they are learning and other ideas they already understand.

The AIM materials were designed with these principles in mind. The investigations follow a guided-inquiry pedagogical structure, and include four main features:

1. **Purpose and Key Question:** The purpose and key question provide focus and motivation for the investigation.
2. **What Do We Think?:** The "What Do We Think?" question posed at the beginning of the investigation helps to surface learners' prior knowledge on the content to be addressed.
3. **Activity:** Each activity is designed to allow students to gather evidence that supports the development of and, as appropriate, counter common misconceptions related to the targeted ideas.
4. **Making Sense:** The Making Sense questions help learners make meaning of the target ideas by encouraging them to reflect on how the evidence collected in the activity relates to their prior ideas and to connect the evidence to key question.

In this process, the data in the investigations serve as the authority on the topic rather than the facilitator, and requires participants to be intellectually active in their learning. This approach also models the nature of science—science is not a collection of "facts" but rather a dynamic body of knowledge that changes as new evidence is gathered.

In addition to engaging with the instructional materials using a guided-inquiry structure to learn about force and motion content, participants spend time during the PD learning about learning-theory based science pedagogy, also using a guided-inquiry structure. On day 2, participants are asked to reflect on how the workshop has facilitated their learning of the science content as a way of eliciting their initial ideas about effective science instruction. On subsequent days, participants engage with additional examples and terminology for talking about key elements of effective instruction. They are given an opportunity to apply these ideas to a written vignette of instruction, using specific examples from the vignette as evidence for their claims. A fishbowl discussion with the facilitator offers additional opportunities for participants to consider the instructional decisions made during the PD. Participants are also given time to raise concerns about implementing this pedagogy, and consider solutions with the group. Finally, the workshop provides another opportunity for sense making, having participants apply the ideas about effective instruction by analyzing a classroom video.

In addition, to support teachers in transferring this knowledge to the classroom, the teacher versions of the instructional materials include educative "surrounds" that:

- specify target ideas and corresponding misconceptions for each investigation;
- describe how each investigation can lead learners to generate the evidence used to develop/support the target ideas and highlight aspects of the investigation where particular focus is needed; and
- identify specific challenges, solutions and implementation strategies relevant to particular events/steps within each investigation.

## 4. Suggestions for the PD Agenda

In keeping with the first goal described in Section 2, we suggest devoting much of the PD time to engaging participants in investigations designed to deepen their content knowledge. These investigations are highlighted in light blue on the sample agenda shown in Figure 1. Many of these investigations address ideas that are also student learning targets. Other content-centered activities (Unit 2 Cycle 3 and Unit 3) go beyond student learning targets to facilitate participants' mastery of more advanced concepts likely to be helpful in teaching the student ideas. Participants also spend time examining the Force and Motion Content Framework to see how the investigations build on each other to gradually construct the "big" ideas.

In addition to deepening participants' content knowledge, we consider it important to devote portions of the PD to help participants understand the learning theory-based pedagogy being used. These pedagogical activities are highlighted in dark blue on the sample agenda, and include smaller blocks of time to highlight findings about how people learn, engage in the fishbowl activity with the PD facilitator, complete daily individual reflections, and analyze the classroom vignette.

Finally, segments of time are set aside for development of the third goal of the PD program, to help deepen teachers' understanding and familiarity with high-quality instructional materials. In addition to the activities intended to help participants understand the learning theory-based pedagogy (which also underlies the instructional materials), time is provided for participants to discuss concerns and suggestions relative to implementing the Force and Motion unit in their own classrooms (seen in purple on the sample agenda). A more detailed sample agenda is also available.

Although the time spent working on unit activities is marked with light blue on the agenda, it should be noted that by completing the AIM Force and Motion activities during the PD, participants are provided with opportunities to learn about pedagogy and high-quality instructional materials in addition to content.

We initially planned the AIM Force and Motion PD to take place during a 5-day summer institute (represented by Days 1–5 on the sample agenda in Figure 1). However, we found that teachers confused Newton's Third Law (which is not addressed in the student materials) with the idea of "balanced forces" (which is addressed in the student materials). Teachers thought that when one object applies a force to a second object, and the second object applies a force of equal size and opposite magnitude to the first (the third law), the forces were "balanced." We addressed this issue during an academic year session (Day 6 on the sample agenda) using Unit 3. At that time, the majority of the teachers in attendance had taught at least some of the AIM Force and Motion unit to their students, so we also provided them time to share their successes and concerns with using the materials. The session also included time for the teachers to apply what they had learned about effective science instruction by analyzing two classroom vignettes and determining which lesson was more likely to result in students understanding the science idea and evidence for the idea.

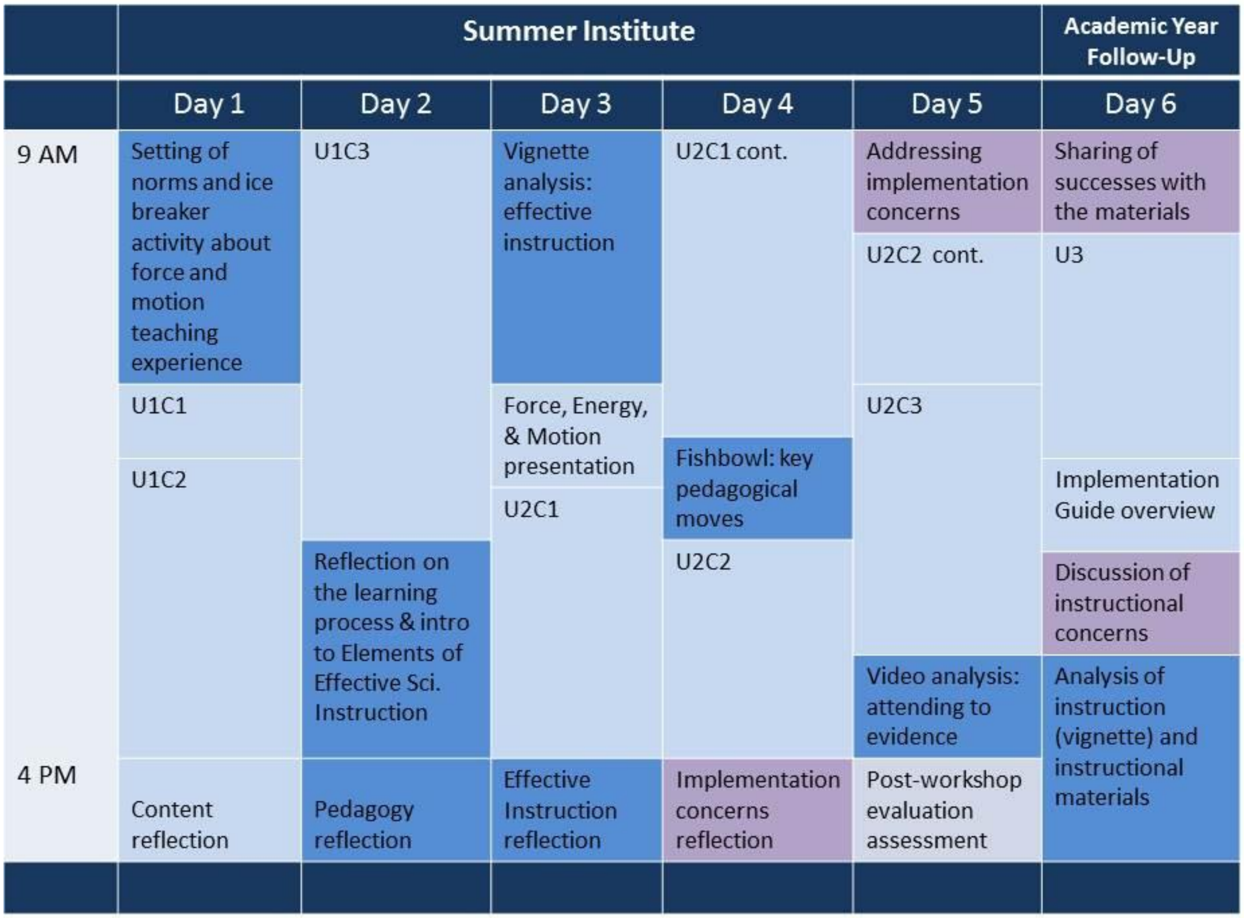


Figure 1

## 5. Tips for Implementing the PD

As described in Section 3, the guided-inquiry pedagogical structure of the PD depends on participants taking responsibility for constructing ideas in collaboration with their peers. Encouraging learner contributions is facilitated by establishing a "safe" place where participants can express ideas and take intellectual risks with the confidence that their contributions are valued as a part of the idea-building process. There are certain behaviors for both leaders and learners that should be introduced and modeled by the facilitator. These behaviors and further discussion of the PD environment are found in section 4 of the Pedagogical Principles and Content Overview (PP&CO). An introductory presentation can be used to establish expectations for professionalism at the outset of the program.

More detailed information intended to enhance preparation for leading teachers in PD is also provided in section 4 of the PP&CO. Specific topics addressed include:

- Effective strategies for developing and sharing ideas in the PD setting;
- Considerations for learners working in pairs or small groups;

- How to use whiteboards effectively;
- Implementation supports included in the teacher version of the instructional materials; and
- When and how to introduce scientific vocabulary in the classroom.

## 6. Assessing the Impact of the PD

In order to assess the impact of the AIM PD on teachers' content knowledge, HRI used a 25-item assessment previously developed by the AIM project. The assessment includes three kinds of items, each set in instructional contexts: (a) knowledge of science content; (b) assessing teacher content knowledge through the analysis of student thinking; and (c) assessing teacher content knowledge through instructional decision-making. The assessment is meant to be administered prior to, and at the conclusion of, the PD. More detailed information about the assessment, including its validity and reliability as well as administration instructions, is available in the Force and Motion Teacher Assessment User Manual.

## 7. Additional Resources

In preparing for and reflecting on the Force and Motion PD, the AIM project has assembled additional resources that other PD providers will likely find useful. These resources are listed below with corresponding links:

- Videos and simulations are incorporated into investigations to reliably provide evidence used for developing the target ideas.
- Activities-Idea Matrix lists the ideas addressed in each of the investigations.
- Supplies list indicates the supplies needed for each investigation in the AIM instructional materials.
- Helpful Facilities Features documents some tips about what to look for in a facility to host the AIM PD.
- Classroom Observation Protocol and User Guide assists those interested in observing teachers implementing the AIM materials with their students.

## References

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