Designing Professional Development for Science Teachers: The Implications of a Learning Theory Approach

Eric R. Banilower
Joan D. Pasley
Horizon Research, Inc.

NSELA PDI
March 28, 2012

horizon
RESEARCH, INC.

Icebreaker

- Read the two vignettes
- Which lesson is more likely to result in students understanding the science idea that is the focus of the lesson?

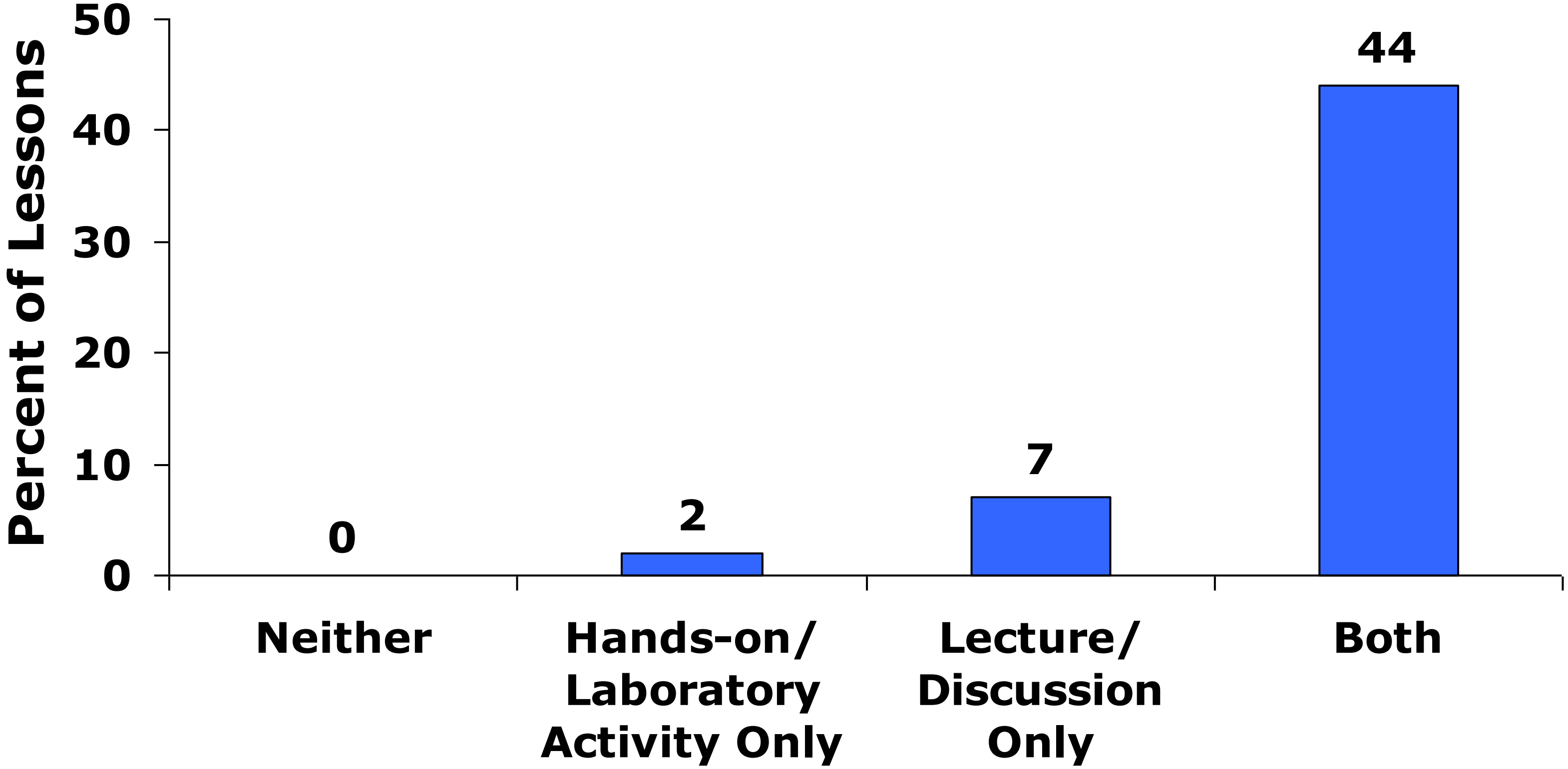
Effective Science Instruction: What Does Research Tell Us?

- There has been, and continues to be, much debate over what constitutes effective science instruction.
- “Reform”
  - Students working in small groups
  - Hands-on activities
  - Focusing on topics selected by the students

Effective Science Instruction: What Does Research Tell Us?

- "Traditional"
  - Delivering information through lectures or readings
  - Students working on practice problems and worksheets
  - Students doing "confirmatory" lab activities

What percent of lessons using a specific pedagogy were highly rated?



(Weiss et al., 2003)

Effective Instruction

- Current learning theory focuses on students' conceptual change, and does not imply that one pedagogy is necessarily better than another.

Effective Instruction

- The learning theory described in the National Research Council's volumes *How People Learn* (2003) and *How Students Learn: History, Mathematics, and Science in the Classroom* (2005) offers guidance on how to improve teaching.

- In addition, the Framework for the Next Generation Science Standards emphasizes students experiencing the practices of science as part of learning science concepts.

- There is considerable evidence from research that people learn best when:
  - they are motivated to learn;
  - their initial ideas are activated/elicited;
  - they have opportunities to confront ideas that are inaccurate;
  - they formulate new ideas based on evidence; and
  - they are encouraged to reflect upon how their ideas have evolved.

Key Components

- Motivation
- Activating/eliciting prior knowledge
- Intellectual engagement with relevant phenomena
- Use of evidence to critique claims
- Sense-making

Motivation

- However well-designed the instruction, students are unlikely to learn if they do not have a desire to do so.

- Instruction should "hook" students by addressing something they have wondered about, or can be induced to wonder about, possibly, but not necessarily, in a real-world context.

Motivation

- Extrinsic motivators
  - Rewards
  - Assessments
- Intrinsic motivators
  - Desire to improve
  - Interest in the content

Motivation

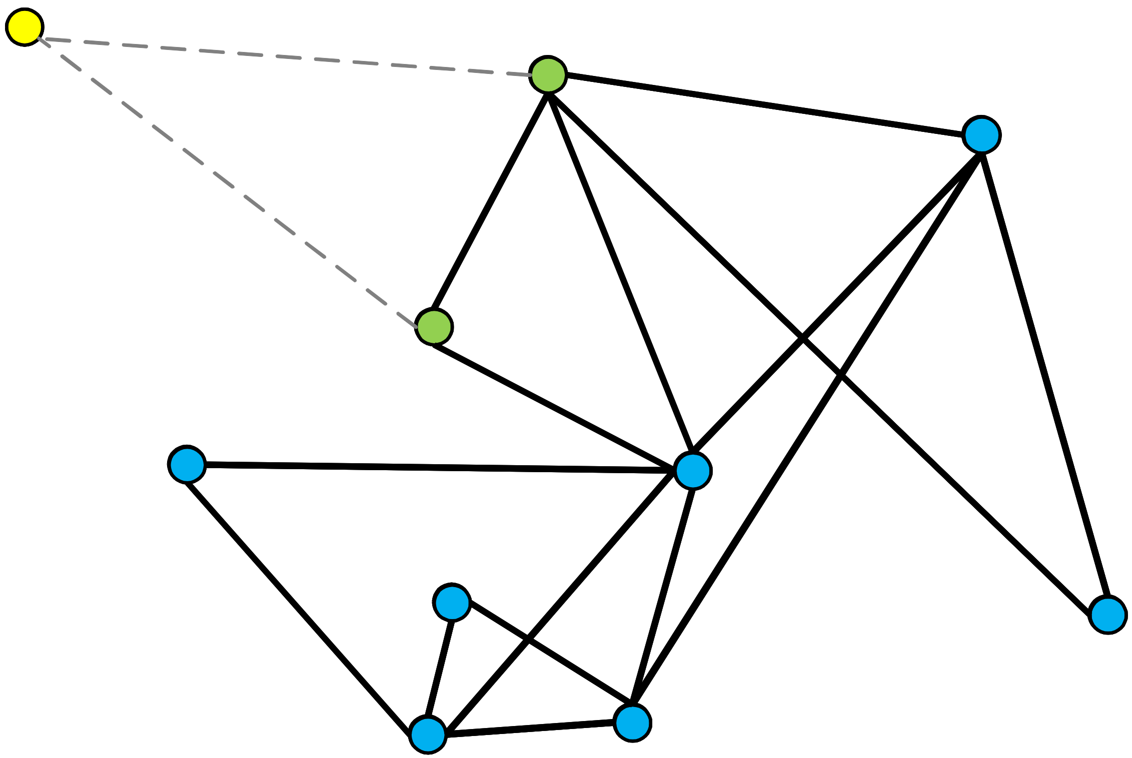
- Doesn't happen only at the beginning of instruction

- Should consider how students are motivated throughout instruction.

Activating/Eliciting Students' Prior Knowledge

- Research has shown convincingly that students do not come to school as empty vessels; rather, they come with ideas they have gleaned from books, TV, movies, and real-life experiences.

- Activation of related ideas "readies" a person for the learning to take place.



- Students' prior ideas may either facilitate or impede their learning of important ideas.

- When prior ideas are not consistent with how we think about a concept in science, the learning involves "undoing" misconceptions. (e.g., the distance of the earth from the sun determines the seasons)

- In cases such as these, it's important to elicit learners' prior ideas specific to that concept, as well as their reasons for those ideas.

What do plants need to live?

vs.

Where do plants get their food?
How do you know?

Intellectual Engagement with Relevant Phenomena

- Learners should have opportunities to engage with appropriate phenomena/ examples/data that provide evidence for the targeted idea.

- "Engaging" means learners doing the thinking, but it doesn't necessarily mean them doing a hands-on activity.

horizon RESEARCH, INC.

- Learners should be guided to attend to the relevant aspects of the phenomena/ examples/data with which they've engaged.
  - Could be the result of instructor questions/ prompts
  - Could be the result of directions for an activity

Targeted idea: Mass alone does not determine whether an object sinks or floats in a fluid.

- Students are shown three objects. The teacher points out that they have different masses and volumes.

- Students examine whether three objects sink or float. The smallest and lightest one sinks, while the two bigger and more massive objects float.

- They then see if three objects, with the same mass, but different volumes, sink or float. The smallest one sinks and the other two float.

Use of evidence to critique claims

- Learners should have opportunities to reflect on the meaning of the phenomena/examples/data and make claims about the targeted ideas.
- Learners should have the opportunity to consider how well their and others' claims/conclusions are supported by evidence.
- Considering a variety of evidence facilitates the development of robust conceptual frames.

Targeted idea: Mass alone does not determine whether an object sinks or floats in a fluid.

After the demonstrations the teacher asks students what the implications of the demonstrations are. She also pushes students to use evidence (specifics of what they observed) to support their arguments.

Teacher: So what does this experiment tell us about mass and sinking and floating?

Student 5: Mass doesn't seem to matter.

Teacher: Does everyone agree? [Many students nod their heads in agreement.]

Teacher: Who can tell me why?

Student 6: The really heavy object in the first demonstration floated, but when you tested the other two objects that also were 400 grams, one floated and one sank.

Teacher: So what does that tell us?

Student 7: If mass was the reason why things float or sink, all of the 400 gram objects would have either sank or floated, but two floated and one sank.

Sense-making

- Learners should have support in using data to draw appropriate conclusions about what they've experienced.

- Learners should have opportunity to reflect on how their new understanding of the targeted ideas relates to their initial thinking and/or to apply their new understandings to other contexts.

Targeted idea: Mass alone does not determine whether an object sinks or floats in a fluid.

The teacher summarizes what the students are concluding and asks them for examples from outside the classroom that supports this conclusion.

Teacher: It sounds like we agree that mass alone does not determine whether an object floats or sinks. Can we think of some examples from real life that support this conclusion?

Student 8: At the swimming pool, we throw in coins and dive after them. They sink to the bottom of the pool, but they aren't very heavy.

Student 9: Boats. They are really heavy, much heavier than coins, and they float.

Magnets Lesson

- Kindergarten
- Beginning of a unit on magnetism.

Magnets Lesson

- Prior to this lesson students came up with the following definition for magnetic:

When something sticks to or is attracted to a magnet it is magnetic.

Magnets Lesson

Targeted idea: Some materials are magnetic and some are not; everything that is magnetic is metal, but not all metals are magnetic.

Magnets Lesson

- As you watch the lesson, consider the elements of effective science instruction and jot down notes on the extent to which students had an opportunity to learn the targeted idea. What aspects of the lesson:
  - facilitated their learning?
  - were likely to get in their way?

Task

- Individually, think about the Magnets lesson.
  - What would a teacher need to know and be able to do to implement it effectively?

- Discuss with group.

AIM's Perspective: Teachers need

- A vision for effective science instruction
- Deep content knowledge
- Knowledge of how students think about the target idea/possible misconceptions
- Knowledge of experiences that engage students and provide evidence for the target idea

AIM's Perspective: Teachers need to be able to

- Challenge/build on student thinking
- Help students attend to the important aspects of their science experiences.
- Facilitate students making claims based on evidence
- Facilitate students' connecting what they do in instruction to the target idea

The AIM Study

- We decided to conduct a test-of-concept study of a particular model for PD.

- Chose to work in Force and Motion:
  - A difficult topic for many elementary teachers; and
  - There is a relatively large body of knowledge about the teaching and learning of this topic (e.g., common misconceptions, phenomena that provide evidence for an idea).

AIM PD Principles

1. Develop a Vision of Effective Science Instruction Based on learning theory
   - Elicitation of initial ideas
   - Engagement with phenomena that provide evidence for target ideas
   - Use of evidence to support/critique claims
   - Sense making

AIM PD Principles

2. Deepen teachers' disciplinary content knowledge
   - Using a learning theory-based approach
   - Going beyond what students are expected to learn when necessary

AIM PD Principles

3. Develop teachers’ pedagogical content knowledge
   – Knowledge of how to sequence ideas for students
   – Areas of student difficulty (including preconceptions/naïve ideas)
   – Knowledge of evidentiary phenomena that can build students’ conceptual understanding

AIM PD Principles

4. Increase the likelihood of transfer to the classroom
   – Provide teachers with high-quality learning-theory based instructional materials
   – Reliably provide evidence for the target ideas
   – Use cheap, easy-to-find supplies
   – Include educative teacher supports

So, What Did We Do?

- A large part of the institute had teachers experiencing the student activities:
  - Model effective science instruction
  - Help them understand the content
  - Prepare them to implement the activities in the classroom

Typical Activity

- “What do we think” – surfaces prior knowledge.
- Activities engage learners with phenomena that provide evidence for the target idea.
- “How do you know” questions encourage the use of evidence from the activity to support a claim.
- “Making sense” questions helps learners relate the target idea to their initial thinking, what they did in the activity, and apply the idea to other contexts/examples.

- Also incorporated time to discuss and reflect on the experiences from the teacher perspective.
  - Reflective writing
  - Fishbowl with facilitator
  - Analysis of instruction (vignettes, video)

Summer Institute Agenda

	Monday	Tuesday	Wednesday	Thursday	Friday
9 AM	Icebreaker: experiences teaching F&M	Content Activities	Fishbowl: key pedagogical moves	Content Activities	Addressing Imp. Concerns
	Content Activities				Content Activities
			Content Activities		
		Reflection on the Learning Process & Intro to Elements of Effective Sci. Instruction		Implementation Concerns	Video Analysis: attending to evidence
4 PM	Content Reflection		Pedagogy Reflection	Practice with the Elements	Post-Assessment

horizon
RESEARCH, INC.

- It’s not reasonable to expect teachers, particularly at the elementary level, to have deep pedagogical content knowledge for every content area they teach.

Educative Supports

- Important background information at the beginning of the activity:
  - Ideas targeted by the activity;
  - Common misconceptions related to the targeted ideas; and
  - A description of how the activity is intended to help students get to the targeted ideas (i.e., what the relevant aspects of the activity are).

- Additional guidance embedded throughout the activity:
  - Logistical suggestions for the activity;
  - Implementation suggestions to help ensure students do the activity as intended (and ways they may go wrong); and
  - Expected student responses to questions and what those answers indicate about student thinking.

Did it Work?

Data Collection

- Content assessments
  - Teacher
  - Student

- Teacher questionnaires – instructional practices, beliefs about science instruction, contextual factors

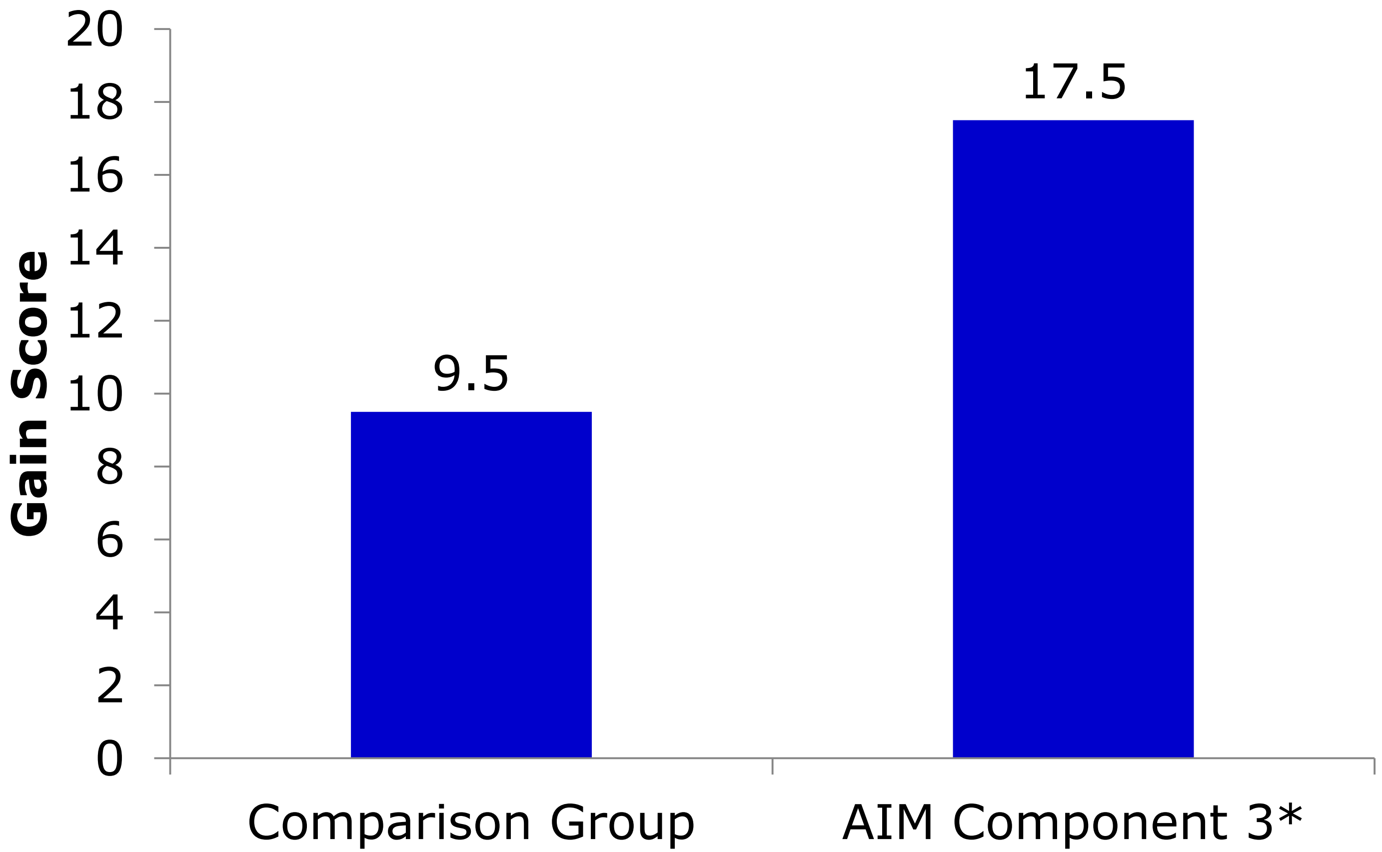
horizon RESEARCH, INC.

Data Collection

- Classroom observations – focusing on student opportunity to learn and fidelity to the materials

- Teacher interviews – instructional decision making process

Teacher Assessment Data



* $p < 0.05$

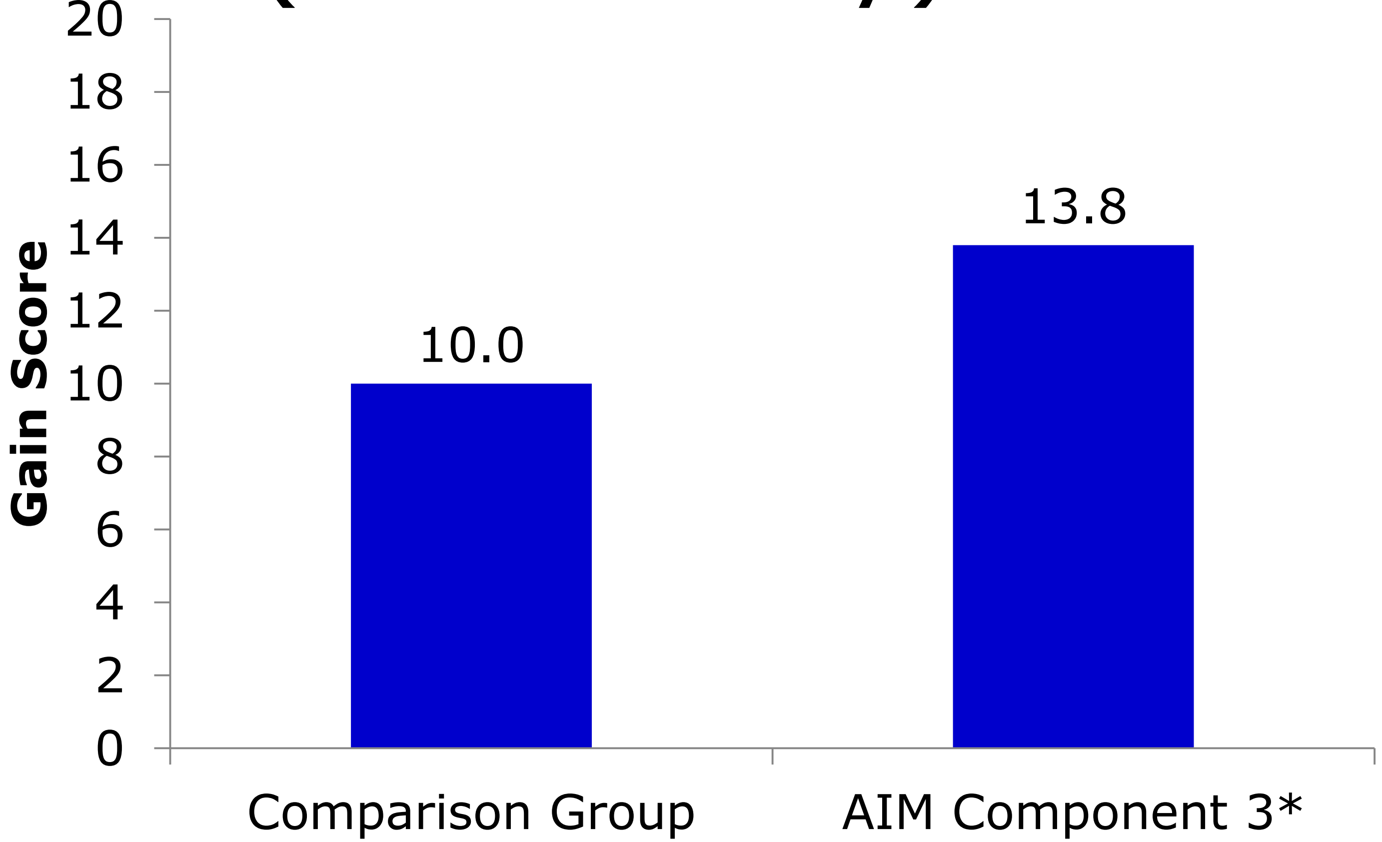
horizon RESEARCH, INC.

Classroom Observations

- There has been a wide range of fidelity to the activities and pedagogical approach:
  - Extent to which the activities are used; and
  - Varied degrees of success at adopting the pedagogical approach.

- When teachers used the implementation guide, instruction was more closely aligned with PD principles.

Student Assessment Data (Preliminary)



* $p < 0.05$

Horizon Research, Inc.

Implications

- PD around learning-theory based instructional materials can have significant impacts on teacher and student learning.

- This approach is scalable.

- This work was done as part of a research study about effective professional development.

- There are other important features of professional development systems that might increase the types of gains we found:
  - On-going: Similar approach in other content areas would reinforce vision of effective instruction
  - Site-based: Opportunities to discuss and continuously improve instruction

What Does This Mean for You?

Questions To Ask about PD

- To what extent does it focus on helping teachers understand important science ideas, and the evidence for those ideas?
  - What they are expected to teach
  - What they need to know and be able to do to teach it well

Questions To Ask about PD

- To what extent does it model *and* make explicit learning-theory based instructional practices?
  - Common vision of effective instruction
  - Opportunities to understand nuances and not get caught up on “features”

Questions To Ask about PD

- To what extent does it facilitate transfer to the classroom?
  - Opportunities to consider differences between PD and classroom
  - Addresses potential barriers
  - Opportunities for practice and feedback

Questions To Ask about Instructional Materials

- To what extent do they reflect what is known from research on learning?
  - Elicitation of prior knowledge
  - Engagement with evidentiary phenomena
  - Opportunities to make/critique claims with evidence
  - Opportunities for sense making

Questions To Ask about Instructional Materials

- To what extent do they provide educative support to teachers?
  - Ideas students are likely to bring to class
  - Areas in which students are likely to struggle
  - Connections between activities and targeted ideas

Resources AIM Can Provide

- We are interested in collaborations with additional partners to continue studying the materials we developed.

- In addition, we've developed several instruments for evaluating professional development and its impacts.

Horizon Research, Inc.

Instrument Topics

1. Force and Motion;
2. Populations and Ecosystems (i.e., Interdependence);
3. Evolution and Diversity; and
4. Properties of and Changes in Matter.

horizon RESEARCH, INC.

Instruments

PD-Provider Log

- Captures what teachers experience in PD.
- PD providers complete a log at the end of each day of PD on the targeted topic.
- 15 minutes or fewer to complete each day.

Log Components

- Log asks about features of the PD
  - Ideas addressed
  - Time spent on different goals
  - How teachers were engaged
  - Alignment of PD with learning theory

Teacher and Student Assessments

- Each assessment takes about 30 minutes to administer.
- All teacher assessment items are set in the context of work that teachers do, e.g., using content knowledge to analyze student thinking.

Classroom Practice

- Teacher questionnaire
  - Beliefs about effective instruction
  - Teacher efficacy
  - Contextual factors that affect science instruction
  - Instructional practices (alignment with learning theory)

Three Ways to Use Instruments

1. Looking at PD and its impact on teacher knowledge:
   - Complete PD-provider logs
   - Administer content assessment to teachers pre- and post-PD

2. Looking at how teacher content knowledge relates to classroom practices and student learning:
   - Administer content assessment to teachers prior to their teaching of the unit on targeted topic
   - Administer student content assessment at the beginning and end of unit on targeted topic
   - Administer teacher questionnaires

3. Looking at complete chain of events from PD, to teacher content knowledge, to classroom practices, to student learning

Contact Information

aim@horizon-research.com

www.horizon-research.com/aim/

This presentation was prepared with support from the National Science Foundation through a grant to Horizon Research, Inc. (NSF Award No. EHR-0928177). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the presenters and do not necessarily reflect the views of the National Science Foundation.

Horizon RESEARCH, INC.