Research Informing Instruction: 
How can Learning Progressions and Research-based 
Instructional Strategies Help Students Learn?

Francis Molina 
Adviser and Consultant 
National Science Digital Library (NSDL), U.S.A. 
DOST Balik Scientist at UP NISMED 
francis.molina@gmail.com 
PNU/PhilAAS, 18 March 2014
Propositions

• We have to believe in our students.

• Believing in them means we can help them achieve scientific and technological literacy. This requires us to be effective educators.

• We can be more effective K–12 educators by:
  1. Studying how student ideas might develop over time (=learning progressions) and
  2. Using research-based instructional strategies in our teaching.
But there’s some not-so-good news...

- Based on my limited classroom observations, there is little evidence that learning progressions are informing classroom practice in the Philippines.
- There is minimal use of effective teaching strategies, for example:
  - Explaining clearly the lesson purpose.
  - Asking guiding questions.
  - Using effective representations.
  - Using pre-assessments to ensure that precursor (earlier) ideas are in place.
Research-based teaching strategies are rarely used

<table>
<thead>
<tr>
<th>Location:</th>
<th>Elementary School</th>
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</thead>
<tbody>
<tr>
<td>Date:</td>
<td>October 9, 2013</td>
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<tr>
<td>Grade:</td>
<td></td>
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<tr>
<td>Learning Goal:</td>
<td>Learn the characteristics of the periodic table of elements.</td>
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<thead>
<tr>
<th>Time (Mins.)</th>
<th>5</th>
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<tbody>
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<td>1. Explaining and summarizing lesson purpose.</td>
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<td>2. Relating the lesson to students’ daily lives.</td>
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<td>Providing vivid experiences.</td>
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<td>3. Questioning to elicit reasons and explanations.</td>
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<td>Encouraging students to explain their ideas.</td>
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<td>4. Encouraging students to show improvement.</td>
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<td>5. Praising students for good effort.</td>
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<td>Supporting all students.</td>
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<td>6. Bringing interesting materials to class.</td>
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*Strategies 1-6 taken from TIMSS 2011. **Blue text** = Equivalent AAAS criteria. Total: 4
Research-based teaching strategies are rarely used

| Location: Calderon High School (Tondo, Manila) | Date: October 4, 2013 |
| Grade: | Learn the characteristics of the periodic table of elements. |

<table>
<thead>
<tr>
<th><strong>Teaching Strategy</strong></th>
<th><strong>Time (Mins.)</strong></th>
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<tbody>
<tr>
<td>5 10 15 20 25 30 35 40 45 50 55 60</td>
<td>Count</td>
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<tr>
<td>1. Explaining and summarizing lesson purpose.</td>
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<tr>
<td>2. Relating the lesson to students’ daily lives. Providing vivid experiences.</td>
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<tr>
<td>3. Questioning to elicit reasons and explanations. Encouraging students to explain their ideas.</td>
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<td>4. Encouraging students to show improvement.</td>
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<td>5. Praising students for good effort. Supporting all students.</td>
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<td>6. Bringing interesting materials to class.</td>
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*Strategies 1-6 taken from TIMSS 2011. Blue text = Equivalent AAAS criteria.

Total: 2

Notes: Teacher started out by reminding students what they studied last time. No explanation of lesson purpose. Questioning involved "filling in the blanks" at the end of the teacher's sentences, apparently involving recall of what the students read in the
What we’ll cover…

1. K–12 Learning Goals
3. An example of Learning Progressions Work: The NSDL Science Literacy Maps
4. Uses of the Maps and Their Inclusion in Teacher PD
5. Research-based instructional strategies
6. Q&A
K–12 Learning Goals
What are (K–12) learning goals?

- Expectations of what students should *know* and *be able to do* by the end of specific grade ranges/levels.
- “*Know*” = Knowledge learning goals.
- “*Be able to do*” = Skills learning goals.
- Synonyms: (content) standards, benchmarks (AAAS), performance expectations (NGSS), key stage standards (DepEd)
What makes a good learning goal?

- **Specific.** Must specify the precise knowledge and skills expected.

- **Coherent.** Sub-ideas should be related to each other.

- **Age-appropriate.** Sophistication should be at the right developmental level.

What does the learning research say?
| Grade 3                                                                 | Grade 4                                                                 | Grade 5                                                                 | Grade 6                                                                 |
|---|---|---|---|---|
| **PROPERTIES**                                                                 | **CHANGES MATERIALS UNDERGO**                                                                 | **PROPERTIES**                                                                 | **CHANGES MATERIALS UNDERGO**                                                                 |
| When students observe different objects & materials, they become aware of their different characteristics, such as shape, weight, definiteness of volume and ease of flow. Using these characteristics, these objects and materials can be grouped into solids, liquids and gases. | Aside from being grouped into solids, liquids, and gases, materials may also be grouped according to their ability to absorb water, ability to float or sink, and whether they decay or not. | After learning how to read and interpret product labels, students can decide whether these materials are harmful. They can also describe ways in which they can use their knowledge of solids and liquids in making useful materials and products. | In Grade 4, the students have observed the changes when mixing a solid in a liquid or a liquid in another liquid. From these investigations, students can now describe the appearance of mixtures as uniform or non-uniform and classify them as homogeneous or heterogeneous mixtures. |
| Using the characteristics observed among solids, liquids, and gases, students investigate ways in which solid turns into liquid, solid into gas, liquid into gas, and liquid into solid, as affected by temperature. | Changes in the characteristics of solid materials can be observed when these are bent, hammered, pressed, and cut. After investigating the changes in characteristics of materials due to temperature in Grade 3, students can now inquire about changes observed when a solid is mixed with a liquid or when a liquid is mixed with another liquid. Students learn that some changes in the characteristics of a product such as food or medicine may affect its quality. One way of finding out is by reading and interpreting product labels. This information helps them decide when these products become harmful. | In Grade 4, students investigated changes in materials that take place at certain conditions, such as changing the size, shape, volume, or temperature. In Grade 5, they investigate changes that take place under the following conditions: presence or lack of oxygen, and applying heat. They learn that some of these conditions can result in a new product. Knowing these conditions enable them to apply the 5R method (recycling, reducing, reusing, recovering and repairing) at home and in school. | Based on the characteristics of the components of a heterogeneous mixture, students investigate ways of separating these components from the mixture. They will infer that the characteristics of each of the components remain the same even when the component is part of the mixture. |
### Spiraling of Concepts about Matter Grade 7 - Grade 10

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<th>Grade 7</th>
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<th>Grade 10</th>
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<td><strong>PROPERTIES AND STRUCTURE</strong></td>
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<td>In Grade 6, students learned how to distinguish homogenous from heterogeneous mixtures. In Grade 7, students investigate properties of solutions which are homogeneous mixtures. They learn how to express concentrations of solutions qualitatively and quantitatively. They distinguish mixtures from substances based on a set of properties. Students begin to do guided and semi-guided investigations, making sure they are conducting a fair test.</td>
<td>Using models, students learn that matter is made up of particles, the smallest of which is the atom. These particles are too small to be seen through a microscope. The properties of materials that they have observed in earlier grades can now be explained by the type of particles involved and the attraction between these particles.</td>
<td>Using their understanding of atomic structure learned in Grade 8, students describe how atoms can form units called molecules. They also learn how ions are formed. Further, they explain how atoms form bonds (ionic and covalent) with other atoms by the transfer or sharing of electrons. They also learn that the forces that hold them together are caused by the attraction between flowing electrons and the positively charged metal ions. Students explain how covalent bonding in carbon forms a wide variety of carbon compounds. Recognizing that matter consists of an extremely large number of very small particles, counting these particles is not practical. So, students are introduced to the unit, mole.</td>
<td>Students investigate how gases behave in different conditions based on their knowledge of the motion of and distances between gas particles. Students, then, confirm whether their explanations are consistent with the Kinetic Molecular Theory. They also learn the relationships between volume, temperature, and pressure using established gas laws. In Grade 9, students learned that the bonding characteristics of carbon result in the formation of large variety of compounds. In Grade 10, they learn more about these compounds which includes biomolecules such as carbohydrates, lipids, proteins and nucleic acids. Further, they will recognize that the structure of these compounds are repeating units which are made up of a limited number of elements, such as carbon, hydrogen, oxygen and nitrogen.</td>
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**Changes Materials Undergo**

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<td>Students recognize that materials combine in various ways and through different processes, contributing to the wide variety of materials. Given this diversity of materials, they recognize the importance of a classification system. They become familiar with elements and compounds, metals and non-metals, acids and bases. Further, students demonstrate that homogeneous mixtures can be separated using various techniques.</td>
<td>Students learn that particles are always in motion. They can now explain that the changes from solid to liquid, solid to gas, liquid to solid, and liquid to gas, involve changes in the motion of and relative distances between the particles, as well as the attraction between them. They also recognize that the same particles are involved when these changes occur. In effect, no new substances are formed.</td>
<td>Students explain how new compounds are formed in terms of the rearrangement of particles. They also recognize that a wide variety of useful compounds may arise from such rearrangements.</td>
<td>In Grade 9, students described how particles rearrange to form new substances. In Grade 10, they learn that the rearrangement of particles happen when substances undergo chemical reaction. They further explain that when this rearrangement happens, the total number of atoms and total mass of newly formed substances remain the same. This is the Law of Conservation of Mass. Applying the Law of Conservation of Mass, students learn to balance chemical equations and solve simple mole-mole, mole-mass and mass-mass problems.</td>
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</table>
Mapping K–12 Learning Goals into Learning Progressions
What are learning progressions?

• Same as “spiraling of concepts.”

• “Descriptions of the successively more sophisticated ways of thinking about a topic that can follow one another as children learn about and investigate a topic” (Duschl et al., 2007).
Learning Goals can be Mapped into Learning Progressions

Later Idea

Targeted Idea

Precursor Ideas

The chemical elements that make up the molecules of living things pass through food webs and are combined and recombined in different ways. At each link in a food web, some energy is stored in newly made structures but much is dissipated.

Food provides molecules that serve as fuel and building material for all organisms.

Plants use the energy in light to make sugars out of carbon dioxide and water.

Plants use the food they make immediately for fuel or materials or store it for later use.

Food provides molecules that serve as fuel and building material for all organisms.

Organisms that eat plants break down the plant structures to produce the materials and energy they need to survive. Then they are...
• One idea “contributes to the understanding of the other.”

• Knowing one idea can be “helpful in learning” the other idea.

• The idea may be an essential prerequisite, but does not have to be.
For ease of mapping, learning goals are first unpacked into finer-grained or smaller key ideas

In solids, the atoms or molecules are closely locked in position and can only vibrate. In liquids, they have higher energy, are more loosely connected, and can slide past one another; some molecules may get enough energy to escape into a gas. In gases, the atoms or molecules have still more energy and are free of one another except during occasional collisions.

Analogy: Compound sentence.
How do we arrange and connect the following Weather and Climate benchmarks into a coherent learning progression?
The number of hours of daylight and the intensity of the sunlight both vary in a predictable pattern that depends on how far north or south of the equator the place is. This variation explains why temperatures vary over the course of the year and at different locations.

Because the earth turns daily on an axis that is tilted relative to the plane of the earth's yearly orbit around the sun, sunlight falls more intensely on different parts of the earth during the year. The difference in intensity of sunlight and the resulting warming of the earth's surface produces the seasonal variations in temperature.

The temperature of a place on the earth's surface tends to rise and fall in a somewhat predictable pattern every day and over the course of a year. The pattern of temperature changes observed in a place tends to vary depending on how far north or south of the equator the place is, how near to oceans it is, and how high above sea level it is.

Light and other electromagnetic waves can warm objects. How much an object's temperature increases depends on how intense the light striking its surface is, how long the light shines on the object, and how much of the light is absorbed.

A warmer object can warm a cooler one by contact or at a distance.
Mapping K-12 Learning Goals into Learning Progressions

- Simple to complex
- Specific to general
  (=concrete to abstract)
- Logic of the discipline
- Research on student learning

Result: *Weather and Climate Map*
An example of Learning Progressions Work: The NSDL Science Literacy Maps
An example of Learning Progressions Work: The NSDL Science Literacy Maps

http://strandmaps.nsdl.org
Maps for Mathematics

NSDL Science Literacy Maps are a tool for teachers and students to find resources that relate to specific science and math concepts. The maps illustrate connections between concepts as well as how concepts build upon one another across grade levels. Clicking on a concept within the maps will show NSDL resources relevant to the concept, as well as information about related AAAS Project 2061 Benchmarks and the Next Generation Science Standards.

Next Generation Science Standards corresponding to Benchmarks for Science Literacy are now available in selected SLM Benchmarks. Find out more about the crosswalk developed between AAAS benchmarks and the Next Generation Science Standards (NGSS).

Table of contents
- The Nature of Science
- The Nature of Mathematics
- The Nature of Technology
- The Physical Setting
- The Living Environment
- The Human Organism
- Human Society
- The Designed World
- The Mathematical World
- Historical Perspectives
- Common Themes
- Habits of Mind
- View All Topics

The Nature of Mathematics

- Mathematical Processes
- Mathematical Models
- Nature of Mathematics

For developers
- Technical training
- How to align resources to benchmarks
- Service API documentation

See Also
- Text-based Version
Maps for Mathematics

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Getting started
- How to use Science Literacy Maps
- Frequently asked questions (FAQ)
- How do I... (Tutorial Videos)

For developers

The Mathematical World
- Graphic Representation
- Symbolic Representation
- Ratios and Proportionality
- Describing Change
- Averages and Comparisons
- Correlation
- Statistical Reasoning
- Numbers
- Shapes
- Reasoning
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Getting started

The Physical Setting

- Changes in the Earth’s Surface
-Plate Tectonics
- Solar System
-Stars
-Galaxies and the Universe
-Gravity
-Atoms and Molecules
-Conservation of Matter
-States of Matter
-Chemical Reactions
-Laws of Motion
-Waves
-Weather and Climate
-Use of Earth’s Resources
-Energy Transformations
-Electricity and Magnetism
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Getting started
- How to use Science Literacy Maps
- Questions (FAQ)
- External Links
- About Us
- Accessibility
- Privacy Policy
- Contact Us

The Living Environment
- DNA and Inherited Characteristics
- Variation in Inherited Characteristics
- Biological Evolution
- Natural Selection
- Flow of Energy in Ecosystems
- Flow of Matter in Ecosystems
- Cell Functions
- Cells and Organs
- Diversity of Life
- Interdependence of Life
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- Text-based Version

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**Getting started**
- How to use Science Literacy Maps
- Frequently asked questions (FAQ)
- How do I... (Tutorial Videos)

The Designed World
- Materials Science
- Agricultural Technology
- Communication Technology
- Computers
- Manufacturing
- Health Technology
- Energy Resources
Get to know the Maps’ uses and benefits through the video tutorials.

How do I... (Tutorial Videos)*

- Find the right map?
- Move within a map?
- Examine big ideas and their connections?
- Call up resources related to a big idea?
- See the likely progression of student understanding?
- Identify student learning difficulties?
- Use the maps to find NSDL resources?
- Judge the quality of resources I find through the maps?

*Videos will open in a new window. Mouse over the bottom of the player to see the movie controls and to turn closed captioning on and off.

[x] Close
The NSDL Science Literacy Maps (based on AAAS Benchmarks) can be an important tool in teacher PD.

• Show the likely progression of student understanding of key ideas in science.

• Organized into “storylines” that can help determine curriculum and instructional sequencing.
Uses of the Maps and Their Inclusion in Teacher PD
Some Uses for the Maps

1. Improving content coherence when planning instruction.
2. Identifying students’ difficulties/misconceptions about the ideas.
3. Deciding on pre-assessments prior to teaching a concept.
4. Locating and assembling online resources for teaching.
Prior to teaching, spend 20-30 minutes to:

1. Locate the big idea you’re going to teach at http://strandmaps.nsdl.org.

2. Read the map-specific Research on Student Learning: What’s appropriate to teach given your students’ age/grade level?

3. Click on the big idea (standard) you’re going to teach to call up the info bubble and access:
   - **Related Benchmarks tab**: What pre-assessments can I use to prepare students for the lesson?
   - **Top Picks/Related Resources tab**: What phenomena and representations can I use in the classroom to help students learn the concept?
Research-based instructional strategies
The Science Educator’s Guide to Selecting High-Quality Instructional Materials

Overview

About the Guide
What makes a high-quality instructional material?
Evaluating Quality: Content Alignment and Instructional Support
Tutorial
Forms

About the Guide. This Science Educator’s Guide to Selecting High-Quality Instructional Materials presents a method for judging the quality of K-12 teaching materials, both in print and online. It is based on AAAS Project 2061’s curriculum-materials analysis procedure, which was developed over several years with funding from the National Science Foundation and in consultation with K-12 teachers, materials developers, scientists, teacher educators, and cognitive researchers nationwide. The procedure's criteria for making judgments about materials are based on the relevant research into effective science teaching and learning.

The Guide is designed to help science educators determine how well an instructional material supports students in learning important science ideas such as those described in national benchmarks and standards. With its step-by-step procedure for taking a critical look at instructional materials, the Guide can help science educators take a more informed approach to a number of essential tasks. For example, textbook selection committees can use the Guide to compare the strengths and weaknesses of different curriculum materials. Classroom teachers can use it to decide how best to adapt or supplement the materials they are currently using. And curriculum developers can use the Guide to help them focus their new instructional designs more precisely on the ideas they want students to learn. The online version of the Guide includes examples from textbooks that have received high and low ratings when previously evaluated using the Project 2061 procedure, interactive tutorials, files that can be used as templates for recording evaluation judgments, and links to useful online resources.
Instructional Quality Criteria

The curriculum-analysis procedure uses the following criteria, grouped into seven categories, to determine the extent to which a material’s instructional strategy is likely to help students learn the content. Many of these criteria are equally applicable to classroom teaching.

I. Providing a Sense of Purpose for Students
   I.A Conveying Unit Purpose
   I.B Conveying Lesson or Activity Purpose
   I.C Sequencing Activities

II. Building on Student Ideas
   II.A Attending to Prerequisite Knowledge and Skills
   II.B Alerting Teachers to Commonly Held Student Ideas
   II.C Assisting Teachers in Identifying Their Students’ Ideas
   II.D Addressing Students’ Ideas

III. Engaging Students with Real World Examples/Phenomena
   III.A Providing a Variety of Relevant Real World Examples/Phenomena
   III.B Providing Firsthand and Vicarious Experiences
IV. Developing and Using Mathematical or Scientific Ideas
   IV.A Providing Evidence for Learning Goals
   IV.B Introducing Terms and Procedures Meaningfully
   ▶ IV.C Representing Ideas Effectively
   ▶ IV.D Connecting and Synthesizing Ideas
   IV.E Demonstrating Skills and Use of Knowledge
   IV.F Providing Practice

V. Promoting Student Thinking about Experiences and Knowledge
   V.A Encouraging Students to Explain Their Ideas
   ▶ V.B Guiding Interpretation and Reasoning
   V.C Encouraging Students to Think about What They Have Learned

VI. Assessing Student Progress
   VI.A Aligning Assessment to Goals
   VI.B Probing Student Understanding
   VI.C Assessing Effectively
   VI.D Informing instruction

VII. Enhancing the Learning Environment for Students
   VII.A Providing Teacher Content Support
   VII.B Encouraging Curiosity and Questioning
   VII.C Welcoming All Students
Content Alignment and Instructional Quality Criteria were Used in Textbook Evaluations

- *Middle Grades (Grades 6–8) Mathematics*
- *Middle Grades Science*
- *High School Biology*

The criteria can also be used to evaluate the quality of teaching.
## Middle Grades Science Textbooks: Ratings on Instructional Criteria

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<td>II. TAKING ACCOUNT OF STUDENT IDEAS</td>
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<td>Assisting teacher in identifying own students’ ideas</td>
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<td>IV. DEVELOPING AND USING SCIENTIFIC IDEAS</td>
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<td>V. PROMOTING STUDENT THINKING ABOUT PHENOMENA, EXPERIENCES, AND KNOWLEDGE</td>
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<td>Encouraging students to explain their ideas</td>
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Some Instructional Quality Criteria Appear to be More Important than Others

AAAS mathematics study looked at five criteria:

1. Representing Ideas Effectively
2. Encouraging Student Explanations
3. Asking Guiding Questions
4. Finding Out Students’ Ideas, and
5. End of Lesson Assessment
A professional development program supporting grade 4, 5, and 6 teachers in teaching concepts in biology, physical science, and Earth science.

Teachers use two lenses to analyze videocases of science teaching and learning: the Student Thinking Lens and the Science Content Storyline Lens.
Science Teachers Learning from Lesson Analysis [STeLLA] (Roth et al., 2009)

Student learning was significantly predicted by teachers’ use of *three content storyline teaching strategies*:

1. Linking science content ideas and activities.
   → III. Providing a Variety of Relevant Real World Examples/Phenomena

2. Linking content ideas to other science ideas.
   → IV.D Connecting and Synthesizing Ideas

3. Using and selecting content representations matched to the main learning goal.
   → IV.C Representing Ideas Effectively
Recap: Propositions

- We have to believe in our students.
- Believing in them means we can help them achieve scientific and technological literacy. This requires us to be effective educators.
- We can be more effective K–12 educators by:
  1. Studying how student ideas might develop over time (=learning progressions) and
  2. Using research-based instructional strategies in our teaching.
Access a PDF version of this presentation at http://www.learningprogressions.com.

My contact info: francis.molina@gmail.com.
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My contact info: francis.molina@gmail.com.

Questions or Discussion Points?
Thanks!