[Physics Teacher Education Program Web Site]

Journal of Physics Teacher Education Online

Science teaching: Historical background

There have been many influential philosophers of education

Experiential Learning (J. Dewey)
Cognitive Load Theory (J. Sweller)
Conditions of Learning (R. Gagne)
Connectionism (E. Thorndike)
Constructivist Theory (J. Bruner)
Experiential Learning (C. Rogers)
Genetic Epistemology (J. Piaget)
Levels of Processing (Craik & Lockhart)
Multiple Intelligences (H. Gardner)
Situated Learning (J. Lave)
Social Development (L. Vygotsky)
Social Learning Theory (A. Bandura)
Subsumption Theory (D. Ausubel)
Information Processing Theory (G. Miller)

but none has dealt effectively with teaching science using inquiry-oriented approaches.

Definitions of inquiry

National Science Education Standards – NRC

"Scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world."

National Science Teachers Association - NSTA

"Scientific inquiry is a powerful way of understanding science content. Students learn how to ask questions and use evidence to answer them. In the process of learning the strategies of scientific inquiry, students learn to conduct an investigation and collect evidence from a variety of sources, develop an explanation from the data, and communicate and defend their conclusions."

What is inquiry-oriented teaching?

- Inquiry-oriented teaching is “centered”
  - student centered
  - knowledge centered
  - assessment centered
  - community centered
- Inquiry-oriented teaching needs a clearly defined approach that will systematically promote all the scientific and intellectual process skills expected of someone who is scientifically literate.

What are these process skills?

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Source: *Conceptual Framework for New Science Education Standards*, National Academy Press (2011).

Other guidance for inquiry teaching

Teaching Contrasts

Traditional approaches:

- teacher seen as an authority
- "received" knowledge
- emphasis on equations and answers

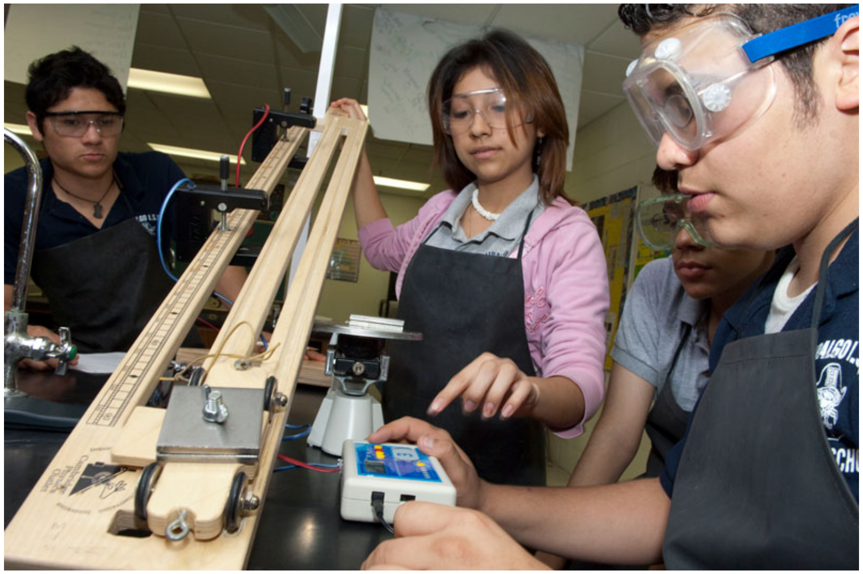
Inquiry approaches:

- teacher seen as facilitator
- construction of knowledge
- emphasis on questions and conceptual understanding

Learning Cycles

There is a need for detailed guidance.

A career-changing experience…



Levels of Inquiry Model of Science Teaching

Moulton Hall at I.S.U.

Talk Outline

- Fundamental questions about science teaching
- The inquiry spectrum
- Need for ongoing classroom dialogue
- Learning sequences
- Resources

Two fundamental questions:

What is the goal of science teaching?

Science Literacy

Knowledge: *science as both content and process including nature and history.*

Skills: *critical thinking and problem-solving skills.*

Dispositions: *informed thoughts, values, and actions.*

How do we best teach critical thinking and authentic inquiry-oriented problem-solving skills?

Levels of Inquiry Method of Science Teaching

The Inquiry Spectrum

Discovery Learning	Interactive Demonstration	Inquiry Lesson	Inquiry Lab	Real-world Application	Hypothetical Explanation
Rudimentary Skills	Basic Skills	Intermediate Skills	Integrated Skills	Culminating Skills	Advanced Skills

Teacher	**Locus of Control**	Student
Low	**Intellectual Sophistication**	High

Primary grades: Discovery learning – Interactive Demonstrations
Middle grades: Discovery learning – Inquiry Lessons
High school: Discovery learning – Real-world Applications
Best students: Discovery learning – Hypothetical Explanations

Discovery Learning

Discovery Learning	Interactive Demonstration	Inquiry Lesson	Inquiry Lab	Real-world Application	Hypothetical Explanation

Pedagogical Purpose

Students develop concepts (and learn name for new concepts) based on first-hand experiences.

Rudimentary Skills:

- Observing
- Formulating concepts
- Estimating
- Drawing conclusions
- Communicating results
- Classifying results

Interactive Demonstration

Discovery Learning	Interactive Demonstration	Inquiry Lesson	Inquiry Lab	Real-world Application	Hypothetical Explanation

Pedagogical Purpose

Students are engaged in explanation and prediction-making that allows teacher to elicit, identify, confront, and resolve alternative conceptions.

Basic Skills:

- Predicting
- Explaining
- Estimating
- Acquiring and processing data
- Formulating and revising scientific explanations
- Recognizing and analyzing alternative explanations

Inquiry Lesson

Discovery Learning	Interactive Demonstration	Inquiry Lesson	Inquiry Lab	Real-world Application	Hypothetical Explanation

Pedagogical Purpose

Students identify scientific principles and/or relationships by working with a teacher who demonstrates the inquiry process and uses a "think aloud" protocol throughout.

Intermediate Skills:

- Identifying/measuring variables
- Collecting and recording data
- Constructing a table of data
- Designing and conducting scientific investigations
- Using technology and math
- Describing relationships

Inquiry Lab

Discovery Learning	Interactive Demonstration	Inquiry Lesson	Inquiry Lab	Real-world Application	Hypothetical Explanation

Pedagogical Purpose

Students, working primarily on their own, establish empirical laws based on measurement of variables under controlled conditions.

Integrated Skills:

- Measuring metrically
- Designing and conducting controlled scientific investigations
- Using sensors and graphical analysis during investigations
- Establishing empirical laws on the basis of evidence and logic

Real-world Application

Discovery Learning	Interactive Demonstration	Inquiry Lesson	Inquiry Lab	Real-world Application	Hypothetical Explanation

Real-world Applications

Students solve problems related to authentic situations while working individually or in cooperative and collaborative groups using problem-based and project-based approaches.

Culminating Skills:

- Collecting, assessing, and interpreting data from a variety of sources
- Constructing logical arguments based on scientific evidence
- Making & defending evidence-based decisions and judgments
- Clarifying values in relation to natural and civil rights
- Practicing interpersonal skills

Hypothetical Explanation

Discovery Learning	Interactive Demonstration	Inquiry Lesson	Inquiry Lab	Real-world Application	Hypothetical Explanation

Pedagogical Purpose

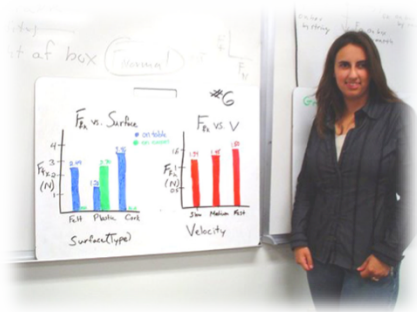
Students develop and test hypotheses that serve as tentative explanations for observed phenomena and guides for further experimentation.

Advanced Skills:

- Synthesizing and testing complex hypothetical explanations
- Analyzing and evaluating scientific arguments
- Generating new predictions
- Revising hypotheses in light of new data

Effective inquiry teaching will…

- include argumentation from facts with the use of discussion, whiteboarding, and Socratic dialogues.
- effectively address alternative conceptions:
  - elicit
  - identify
  - confront
  - resolve
  - reinforce



Effective inquiry teaching will…

- include classroom climate setting to prevent and overcome resistance to learning
  - students and parents
  - peers and administrators
- reduce classroom management problems
- engage the unengaged and interest the uninterested
- help students understand the nature of science

A Bridge to Inquiry

- Modeling Method of Instruction:
  - consistent with Levels of Inquiry approach to science teaching
  - but does not address entire inquiry spectrum
- An excellent free resource for teachers
- Curriculum available http://modeling.asu.edu
- A 3-week Modeling workshop available
- Area expert Dr. Jaafar Jantan (Malaysia)

Learning sequence example: Buoyancy

Buoyancy	Pedagogical Practice – Sinking Objects
Discovery Learning	Students reflect on mental models, experience floating and sinking, as well as buoyant force.
Interactive Demonstrations	Students develop a relationship between weight in air, in water, and the buoyant force.
Inquiry Lessons	Students identify factors that might influence buoyant force and conduct simple tests.
Inquiry Labs	Students establish empirical law for volume of immersed object and density of liquid, $F=\rho Vg$.
Real-world Applications	Students apply new knowledge to authentic situations individually or in small groups.
Hypothetical Explanations	Students generate explanations for pressure at depth, $P=\rho gh$, and *source* of buoyant force.

Levels of Inquiry Model Application

Discovery Learning	Interactive Demonstration	Inquiry Lesson	Inquiry Lab	Real-world Application	Hypothetical Explanation

Curriculum Planning

Teach the subject matter that you can best teach using inquiry-oriented approaches.

Instructional Development

Prepare learning sequences that incorporate all levels of inquiry to the greatest extent possible.

Research Opportunities

Resources

- Levels of inquiry: Hierarchies of pedagogical practices and inquiry processes. *Journal of Physics Teacher Education Online,* 2(3), February 2005, pp. 3-11.
- Levels of inquiry: Using inquiry spectrum learning sequences to teach science. *Journal of Physics Teacher Education Online,* 5(4), Summer 2010, pp. 11-19.
- The Levels of Inquiry Model of Science Teaching. *Journal of Physics Teacher Education Online, 6*(2), Summer 2011, pp. 9-16.
- Sample learning sequences based on the Levels of Inquiry Model of Science Teaching including Appendix. *Journal of Physics Teacher Education Online, 6* (2), Summer 2011, pp. 17-30.
- Dealing more effectively with alternative conceptions in science. *Journal of Physics Teacher Education Online,* 5(1), Summer, 2008, pp. 11-19.
- Whiteboarding and Socratic dialogues: Questions and answers. *Journal of Physics Teacher Education Online,* 3(1), September, 2005, pp. 3-10.
- Minimizing resistance to inquiry: The importance of climate setting. *Journal of Physics Teacher Education Online,* 3(2), December 2005, pp. 10-15.

http://www.phy.ilstu.edu/pte/publications/