THE LARGE CONTEXT PROBLEM (LCP) APPROACH:

An example of contextual teaching in physics

By Art Stinner

Research in science education shows that students leave school with:

A knowledge of isolated, disconnected facts.

A problem solving ability, mostly based memorizing algorithmic procedures.

A poor understanding of the nature of science and a spotty knowledge of the history of science.

The aims of the LCP approach :

1. **To liberate teachers from textbook-centered teaching.**

2. **To humanize the teaching of science by placing it in rich contexts, informed by the history and nature of science.**

The LCP Approach

The LCP approach was originally developed as a response to the discovery that:

…learning could be well motivated by a context with one unifying central idea capable of capturing the imagination of the students.

The Context-Content Problem

A general problem, however, emerges whenever teachers try to escape from textbook-and lecture-centered teaching to teaching science by way of contexts that students find attractive:

In order to answer the questions and solve the problems generated by a context (to get off the ground, to make a start), students already have to have mastered part of the content.

The Context-Content Problem

- The interaction between content and context, then, presents a central pedagogical problem. We could summarize the problem this way:

To motivate students to acquire content knowledge we set contexts that attract them. However, students often cannot deal with the questions and the problems that the context generates unless they already have some content knowledge.

- The traditional way out of this dilemma is to present the organized content knowledge of science to students at least by ‘middle years science’.
- Such concepts and conceptions as energy, photosynthesis, atomic structure, DNA, and kinetic molecular theory are often introduced in middle years, certainly by the first year of senior science.

- Confronting students with the finished products of formal science too early and too suddenly produces a discontinuity that may alienate students.

- This alienation then produces two distinct and incommensurate views of science in the minds of the students, namely 'school science' and 'common sense science'.

Our mandate as science teachers then is to try to ease the passage of children from early "common sense" apprehension of the world to a comprehension of organized scientific knowledge.

One plausible approach to achieve successfully the passage from early years common sense understanding of science to a scientist's understanding in the senior years might be early introduction to science by way of stories and contextual teaching that attracts students' interest.

- The senior years student should go further and be able to generalize and make connections between contexts and organized scientific knowledge.
- These connections should be made by engaging the student in discussion, asking for verbal arguments that involve personal knowledge as well as the language of decontextualized science

The Context-Content Problem

This act of generalization, however, often amounts to an epistemological break with common sense and the everyday world.

For example, physics teachers try to persuade students to escape from seeing the world of motion in Aristotelian terms into an understanding of motion in Newtonian terms. As physics teachers well know, such a break is difficult, and can be compared to a paradigm shift.

The insertion of LCPs into physics teaching

Insertion of appropriate LCPs for each major topic, namely:

Kinematics, dynamics, planetary motion, electricity and magnetism, wave motion and radiation, modern physics.

<u>Mechanics:</u>

Intuitive Physics

Motion and the Pendulum

Physics and the Bionic Man

The Flight of the Space Shuttle

Physics on the Moon

Physics and the Dambusters

The Physics of the Large and Small

The Story of Force

Gravity and planetary motion:

A Rotating Space Station

Physics on the Moon

Journey to Mars

Hitchhiking on an Asteroid

Asteroid/Earth Collisions

Electricity and magnetism:

Solar Energy

Wind Energy

Electricity in the Home

The Experiments of Faraday

Radiation and thermal physics:

Solar Energy

Solar Power in the Pyrenees

A Solar House for Northern Latitudes

Modern Physics

Calculating the Age of the Earth and the Sun

Thought Experiments and the Theory of Relativity

The Physics of Star Trek

Summing up…

The claim is that the LCP approach, for each major topic in the physics curriculum, will generate the questions, experiments, and problems that covers all the content that conventional textbook-centered would offer, but in a more interesting and meaningful way

These questions, experiments and problems then are to be integrated into a matrix of contextual science activities, informed by sound principles of pedagogy, and the nature and history of science.

The foundations and the matrix of activities in the LCP approach

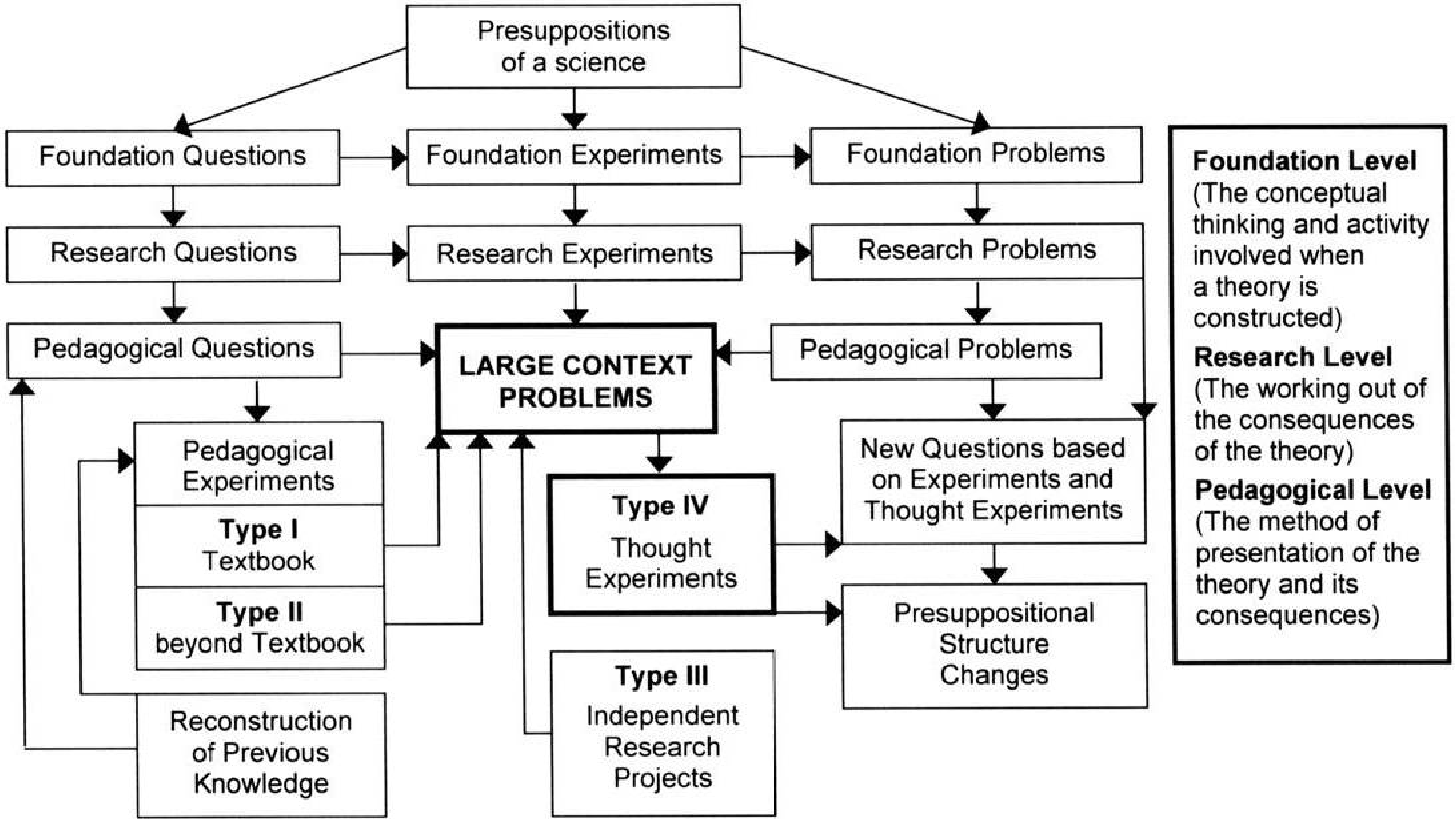

Figure 1: Levels of Investigation for Scientific Inquiry

For Newtonian physics (Mechanics)

Presuppositions

- Mathematics is the core of physical description and explanation
- Mass points interact via central forces
- Space is Euclidean
- Time is absolute
- Mass points interact instantaneously (Action-at-a-distance)

Mechanics…

Foundation Questions

- Is there an axiomatic system, expressed in the language of mathematics that can describe both celestial and terrestrial phenomena?
- What are the fundamental physical quantities and what are the laws that describe the dynamics of free fall, the motion of a conical pendulum, and collisions?
- How can we describe the force between the planets and the sun?
- Using these laws can we describe the complex motion of the planets around the sun?

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Mechanics…

Foundation Problems

- To show that Galileo’s law of free fall is just a special case of the second law of motion.
- To find the mathematical description of centripetal acceleration.
- To combine the laws of motion with centripetal acceleration to find the period of the moon’s rotation around the earth.
- To show that a spherical homogenously distributed mass has the same gravitational effect as a point equivalent mass.
- To find the nature of the path of a planet obeying an inverse-square force law.
- To show that Kepler’s laws are just a consequence of the laws of motion and the universal gravitational law.

Mechanics…

Foundation Experiments

- Collision experiments with pendula.
- The conical pendulum
- Atwood’s Machine (~1780)

Foundation Thought Experiments

- First law of motion
- Rotating bucket
- Rotating spheres (in the void) connected by a cord.

Mechanics…

Pedagogical Questions

- Given a velocity-time graph, how can you find the average velocity? (Simple)
- Can you show that centripetal acceleration is given by v^2/r? (Moderately difficult).

  Can you show that a conical pendulum has the same period as a simple pendulum? (Difficult)

Mechanics…

***Pedagogical Problems*:**

1. What is the unbalanced force acting on a 1000 kg car that is accelerating at $2m/s^2$? (Simple)
2. How far will a car moving at $20m/s^2$ slide when the brakes are applied, if the coefficient of friction is 0.2? (Moderately difficult).
3. Compare the periods of two pendula of the same lengths, on the Earth and on the Moon. (Difficult)

Mechanics…

Pedagogical experiments

(Type I, found in textbooks)

1. Using a ticker-timer, study the motion of a dynamic cart when a constant unbalanced force is acting on it.
2. Using video camera describe the motion of a freely falling heavy object

Mechanics…

Experiments

(Type II, generally not found in textbooks)

1. Design an experiment to find the relationship between the time it takes to empty a large can, with a small hole in the bottom, and the initial height of the water level.
2. How does the force between two parallel and cylindrical bar magnets vary with the distance between them?
3. Investigate the forces on the knee joints of the bionic man when jumping to a height of 10m

Mechanics…

Research Projects **(Type III)**

1. Build an accelerometer and test it in a car.
2. Study the trajectory of a baseball using a video-camera.
3. Examine the motion of a bouncing tennis ball (vertical and horizontally moving).

Mechanics…

Thought Experiments (Type III)

1. Newton’s bucket
2. Newton’s rotating sphere in a void
3. How do you “turn around” in deep space?

Mechanics…

New Questions:

- Why are inertial and gravitational masses equivalent?
- Is inertia a local effect or is it dependent on the mass of the universe?
- Can force and mass be expressed in a non-circular way?
- How can we quantitatively demonstrate how particles of matter in motion endowed with forces produce the observed phenomena in nature, for both large and small-scale phenomena?

LCPs for Mechanics

LCP 1: Intuitive Physics and Motion

LCP 2: Motion and the Pendulum

LCP 3: One that is designed by the teacher, with the students. For example:

1. The physics of driving.
2. Physics and sport.

Guidelines for Writing LCPs

1. Map out a context with <u>one unifying central idea</u> that is deemed important in science *and* is likely to capture the imagination of the student.

2. Provide the student with experiences that can be related to his/her everyday world as well as being simply and effectively explained by scientists' science but at a level that "makes sense" to the student.

3. Invent a "story line" (may be historical) that will dramatize and highlight the main idea. Identify an important event associated with a person or persons and find binary opposites, or conflicting characters or events (Egan, 1986) that may be appropriate to include in the story.

Guidelines for Writing LCPs

4. Ensure that the major ideas, concepts and problems of the topic are generated by the context naturally; that it will include those the student would learn piece-meal in a conventional textbook approach.

5. Secure the path from romance to precision to generalization (Whitehead, 1929). This is best accomplished by showing the student that:

   a. problem situations come out of the context and are intrinsically more interesting;

   b. that concepts are diversely connected, within the setting of the story as well as with present-day science and technology;

   c. there is room for individual extension and generalization of ideas, problems and conclusions.

Guidelines for Writing LCPs

6. Map out and design the context, ideally in cooperation with students, where you as the teacher assumes the role of the research-leader and the student becomes part of an on-going research program.

7. Resolve the conflict that was generated by the context and find connections between the ideas and concepts discussed with the corresponding ones of today.