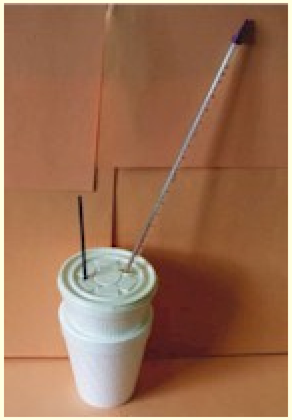
The LEP Model of Concept Development

The history of this model

This is the activity that inspired the LEP model approach to concept development in 1990:

- A grade nine class undertakes to measure the specific heat of a metal cylinder with a mass of 150g. The cylinder is placed in a beaker of boiling water for several minutes then transferred quickly to an insulated container containing 500 ml of water at 20^{o}C. Students worked in groups of three.
- The temperature of the water in the second container is recorded when it stabilizes at 24^{o}. From this information, the students were asked to calculate the specific heat of the cylinder.



Problems encountered:

1. Many students were unable to find the value of the correct specific heat of the metal (Aluminum).
2. On closer inspection, it was found that the students did not follow the steps correctly.
3. After a discussion it was clear that the students had a poor understanding of the concept of specific heat, or the ‘sub-concepts’ of mass, temperature, volume.
4. Students did not understand how the conservation of energy principle for this experiment should be applied.
5. Students were unable to set up the equation based on the conservation of heat principle.
6. Even when the equation was given to them they had problems manipulating the algebra required to solve for the value of the specific heat.

Our task then is to provide guidance so that:

1. Students have the appropriate theoretical and conceptual understanding to carry out the experiment.
2. Students know how to “look” in order to make observations appropriate to the task at hand and how to make interpretations (inferences).
3. Students find the general procedure that you would expect them to follow in the light of your discussion above.

Your task is to provide guidance so that:

4. Students become aware of good teaching and learning principles. Above all, they should be shown how to engage in *reflective learning* and *metacognitive* activities.

5. Students find diverse connections in science and practical applications for the concept discussed.

The experimentation continuum

Planning ---------> Designing -------------> Performing
Experiments Experiments Experiments

Concept-specific Laboratory Operations Concept-independent

Context-dependent Transferable

The experimentation continuum

There are essentially two types of experiments teachers are concerned with:

1. Experiments scientists do (scientific experiments).

2. Experiments teachers design for students (pedagogical experiments).

To become proficient along the experimentation continuum:

1. Scientists develop *scientific experiments* with an “experimental flair”. They design 'powerful' experiments that test the predictions and the consequences a theory, sometimes in an elegant way.

2. Teachers use and sometimes develop *pedagogical experiments* (and demonstrations) that attempt to illustrate the consequences of a theory. Teachers also try to illustrate and clarify concepts in science, relevant to the theory discussed.

To do an experiment in the classroom successfully, students must have:

- Possession of an appropriate conceptual background.

- Ability to perform certain laboratory operations successfully.

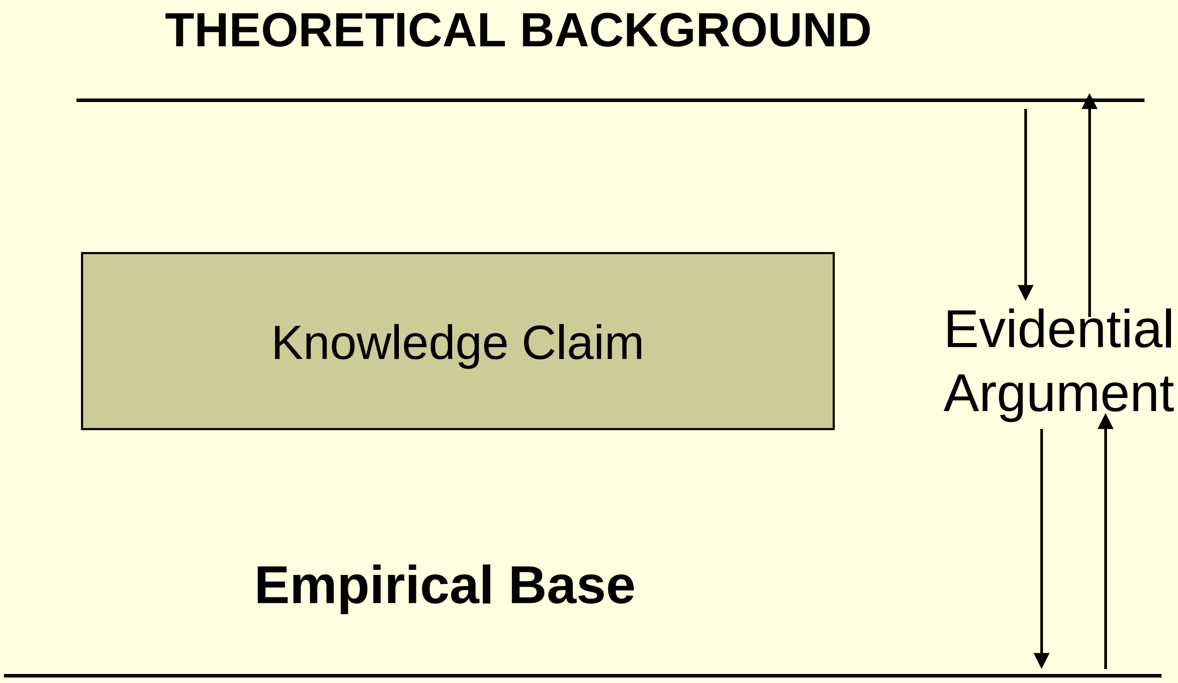
- Ability to do the experiments. That is, to handle the apparatus and carry out the laboratory operations in an organized and skilful way in order to achieve certain goals.

Pedagogical experiments

Teachers should also ensure that students develop their own experiments along the experimental continuum, that go beyond the standard textbook “cook book”.

First step toward the LEP model

The relationship between theoretical background, evidence, empirical (experimental) base, and a knowledge claim:



Examples of Knowledge Claims

1. The earth revolves around the sun
2. The sun is 150,000 km from Earth
3, There is helium in the sun
4. Second-hand smoke causes lung cancer
5. Bacteria are about 1 micron long.
6. Blood undergoes a circular motion in the body
7. The density of air at sea level is 1.29 kg/m^3.
8. A hydrocarbon burning produces carbon dioxide and water
9. Plants ‘inhale’ carbon dioxide and ‘exhale’ oxygen.
10. The escape velocity from earth is 11.2 km/s.

For each of the statements:

1. A claim is made of the form: "I know that...". We will call such claims knowledge claims.
2. Support is found for that knowledge claim. We will call this support evidence.
3. Background experience and knowledge is available. We will call this theoretical background or knowledge background.
4. An appropriate argument is given that connects the knowledge claim with the evidence by way of the theoretical background. Let us call this way of arguing an evidential argument.

The Theory-Evidence connection

- These examples then suggest that evidence is only meaningful if it is supported by a sound background knowledge.
- Moreover, this support must be based on an appropriate argument given and understood by the person who makes the knowledge claim.
- In summary then, the selection of evidence (and the decision of the adequacy of this evidence) depends on the background knowledge of the knowledge claimer as well as his/her experience in presenting an appropriate argument.

The transition from ‘finding evidence to a knowledge claim’ to ‘ teaching scientific concepts’.

To understand concepts in science students must be presented with a similar ‘evidential argument’ as the one made for a knowledge claim.

Clearly, students need to be comfortable with the basic concepts involved in an evidential argument to back up a knowledge claim.

The transition is made in analogy with the evidential argument model

1. In order to teach concepts (that goes beyond simple memorization) we exchange ‘knowledge claim’ with “concept”,
2. The Theoretical Background is changed to:

   Logical Plane of Activity:

   Symbolic-Algorithmic-Factual- Descriptive,

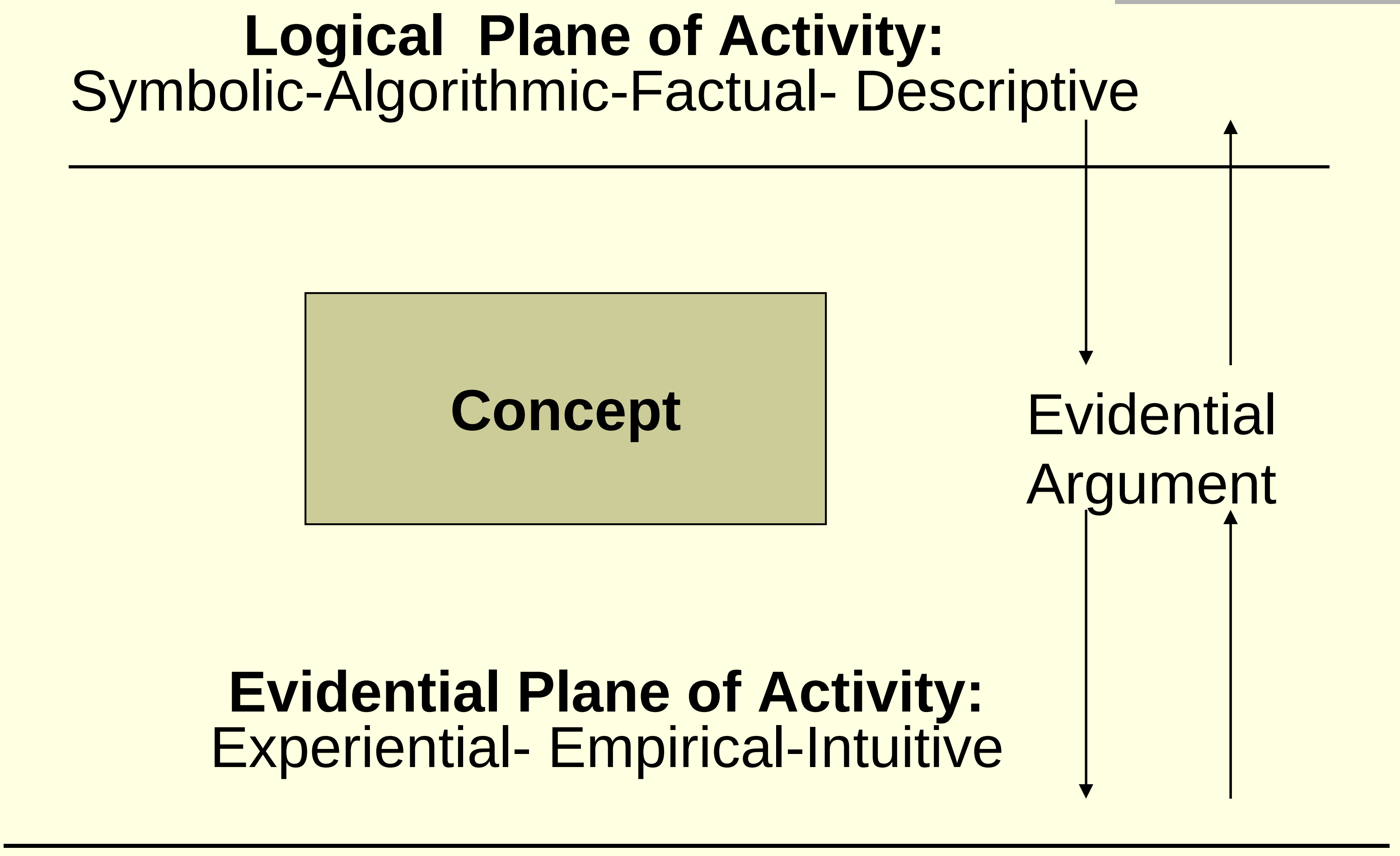
   and

3. The Empirical Base becomes the:

   Evidential Plane of Activity:

   Experiential- Empirical-Intuitive

Second step toward the LEP model:



Third step toward the LEP model:

Now we add the basic questions asked on these two planes of activity:

For the Logical Plane of Activity:

"*What operation(s) will link the concept to the evidential plane?*"

For the Evidential Plane of Activity:

"*What are good reasons for believing that…"?*

"*What are the diverse connections of the concept?*"

Third step toward the LEP model…:

However, based on modern constructivist theory (MCT), students go through a process of equilibration in internalizing a concept (see previous ppt on constructivism).

Using the findings of MCT, we added a third plane of activity, the “Psychological Plane of Activity”. This plane of activity is essential if we want to ensure good concept learning for the student..

Fourth step toward the LEP model:

When students give an evidential argument for a knowledge claim, they often have problems because they do not really understand the underlying concepts they use.

Therefore, teachers must find a way to ensure that students have a solid understanding of basic concepts that goes beyond simple memorization.

The Psychological Plane of Activity

Psychological Plane of Activity:

Recognizing, respecting, and building on students' preconceptions.

The basic questions asked on this plane of activity are:

Is the concept *under discussion:*

Intelligible?

Plausible?

Fruitful?

The main function of this plane is to "filter" the dialogue between the Logical and Evidential Planes.

The three planes of activity: The Logical Plane

- On this plane of activity we encounter the finished products of a science, such as laws, principles, models, theories, and “scientific facts".
- The basic question on this plane is:

  "What is (are) the operational definition(s) relevant to the concept(s)?“

  The answer to this question is important, because it determines to what extent the activity on the *logical plane* relates to the *evidential plane.*

The three planes of activity: The Evidential Plane

- On this plane of activity we encounter the experimental, intuitive, experiential connections that support what we accumulated on the *logical plane*.

- The first question we should ask on this plane is: "*What are good reasons for believing that*...?"

- The second question we should ask is:

  "*What are the diverse connections of this concept?*"

The three planes of activity: The Evidential Plane

For the first question:

Here we are looking for evidence that "makes sense" to the student.

For the second question:

Here we wish to show that the concept is valid when used in seemingly disparate areas in scientific inquiry.

The three planes of activity: The Psychological Plane

- In this plane we pay attention to the students' pre-scientific knowledge, and to their previous school science.
- Here we study the responses they have to some key questions we pose in testing their readiness to accommodate a concept.

The questions are:

Is the concept under discussion:

Intelligible?

Plausible?

Fruitful?

The Psychological Plane: Is the concept intelligible?

- The first question sets the necessary precondition for a concept to be considered at all as a candidate for assimilation or accommodation:
- The student must find a concept *intelligible* before any meaningful teaching can take place.

The Psychological Plane: Is the concept plausible?

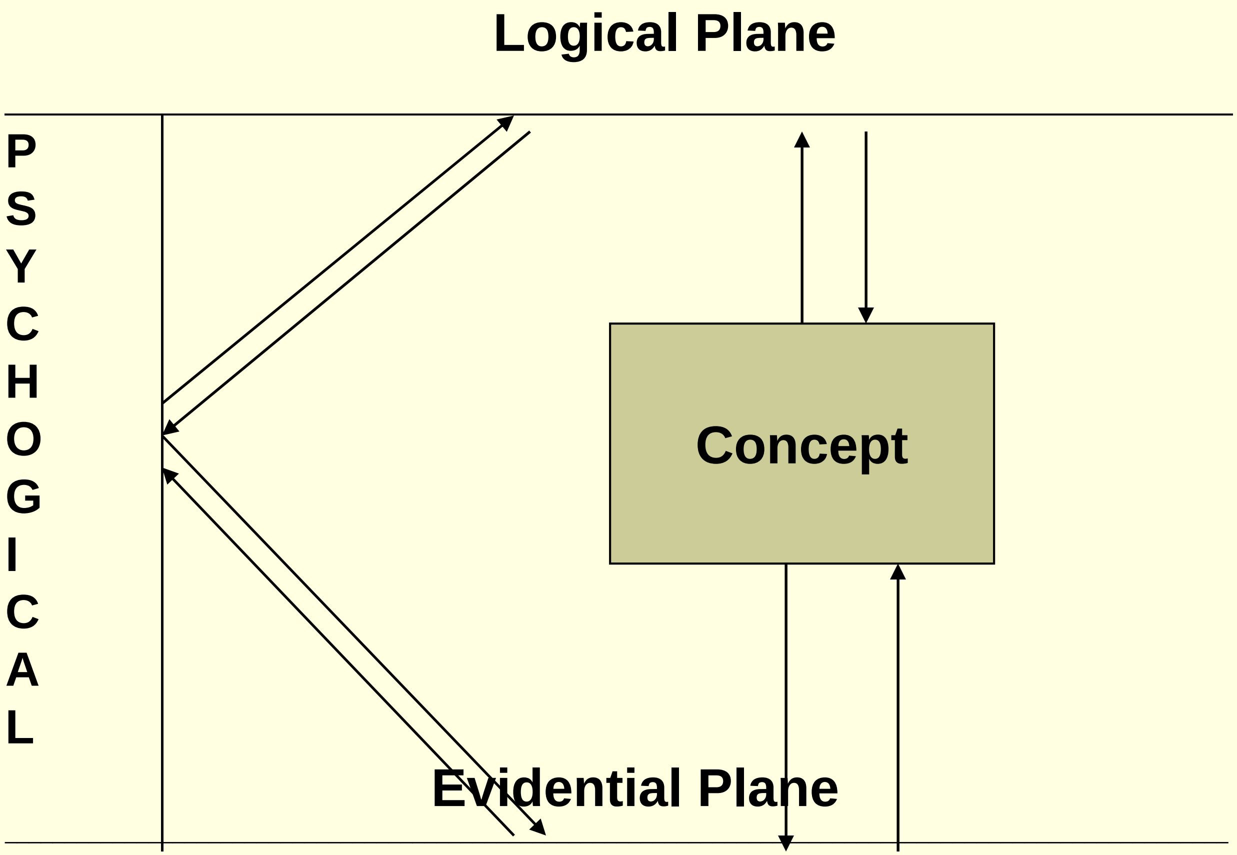
- If the first question (intelligibility) cannot be answered with certainty we cannot proceed to the second question which sets the stage for establishing *plausibility.*

- The student then cannot go beyond meaningless algorithm-recitation on the *logical plane,* since a connection with the *evidential plane* is not possible.

The Psychological Plane: Is the concept fruitful?

- Ideally, of course, one wishes to see every concept carried through to satisfying the requirements of the third question, that of *fruitfulness.*
- In physics, for example, that would mean being able to answer questions about how Newton connected his mathematical formulation of laws with the available experimental evidence.
- In the chemistry, for example, that might involve the student consciously trying to understand such phenomena as *electrolysis, electroplating,* and how experimental evidence suggests the concepts of *electrovalence* and *covalence*.
- In biology, for example, the student might want to know how diseases spread throughout the body, what the underlying causes of heart attacks and strokes are, etc.

The LEP Model of conceptual change



Examples of concepts

Pressure, Force, Power, Circulation, Concentration, Mitosis, Miosis, Homeostasis,Valence, Equilibrium, Density, Osmosis,Temperature, Energy, Potential Energy, Gravitational Energy, Speed, Acceleration, Kinetic Energy, Centripetal Acceleration, Heat Energy, Evolution, Displacement, Electric Resistance, Electric Voltage, Electric Current, Potential Gradient,