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Why Model?

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Why model?

“The first question that arises frequently—sometimes innocently and sometimes not—is simply, "Why model?" Imagining a rhetorical (non-innocent) inquisitor, my favorite retort is, "You *are* a modeler." Anyone who ventures a projection, or imagines how a social dynamic— an epidemic, war, or migration—would unfold is running *some* model.”

Joshua M. Epstein (2008): Why Model? *Journal of Artificial Societies and Social Simulation* vol. 11, no. 4 12

Epstein identifies 16 reasons for modelling, inc.:

- Explain: Explanation is not the same as prediction
- Suggest dynamical analogies

  "It is a startling and wonderful fact that a huge variety of seemingly unrelated processes have formally identical models"

- Promote a scientific habit of mind

  militant ignorance—an iron commitment to "I don't know."

- Reveal the apparently simple to be complex and the complex to be simple

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"That humans (and animals) create internal representations of their environment (as well as of themselves) is probably the central notion in the cognitive sciences….Depending on the particular field within the cognitive sciences, one finds talk of such things as "schemata", "cognitive maps", "mental models" or "frames" " .

Giere, R, (1988) Explaining Science, Chicago, The University of Chicago Press

Giere again

"'internal maps' of the external world"

"… I will argue that scientific theories should be regarded as similar to the more ordinary sorts of representations studied by the cognitive sciences. There are differences to be sure….But fundamentally the two are the same sort of thing"

Nersessian (2008) has integrated these ideas into a theory of

MODEL BASED REASONING

in which the construction and manipulation of iconic, analogical mental models is considered as a form of reasoning in its own right.

Internal & external representations form a coupled system which facilitates model-based reasoning!

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Three different perspectives:

Social Science (Epstein)
Philosophy (Giere)
Cognitive science (Nersessian)

All point to modelling as a natural aspect of thinking

Modelling in practice: Bell & Trumble (2008)

Pre-service teachers, using computer simulations to gather data on moon phases.

Prior determination of ideas with reflection

Simulations replace difficult observations

Augmented by physical modelling

Plenty of support and chance for discussion

Effective.

Barbara Y White & John R Frederiksen, 1998

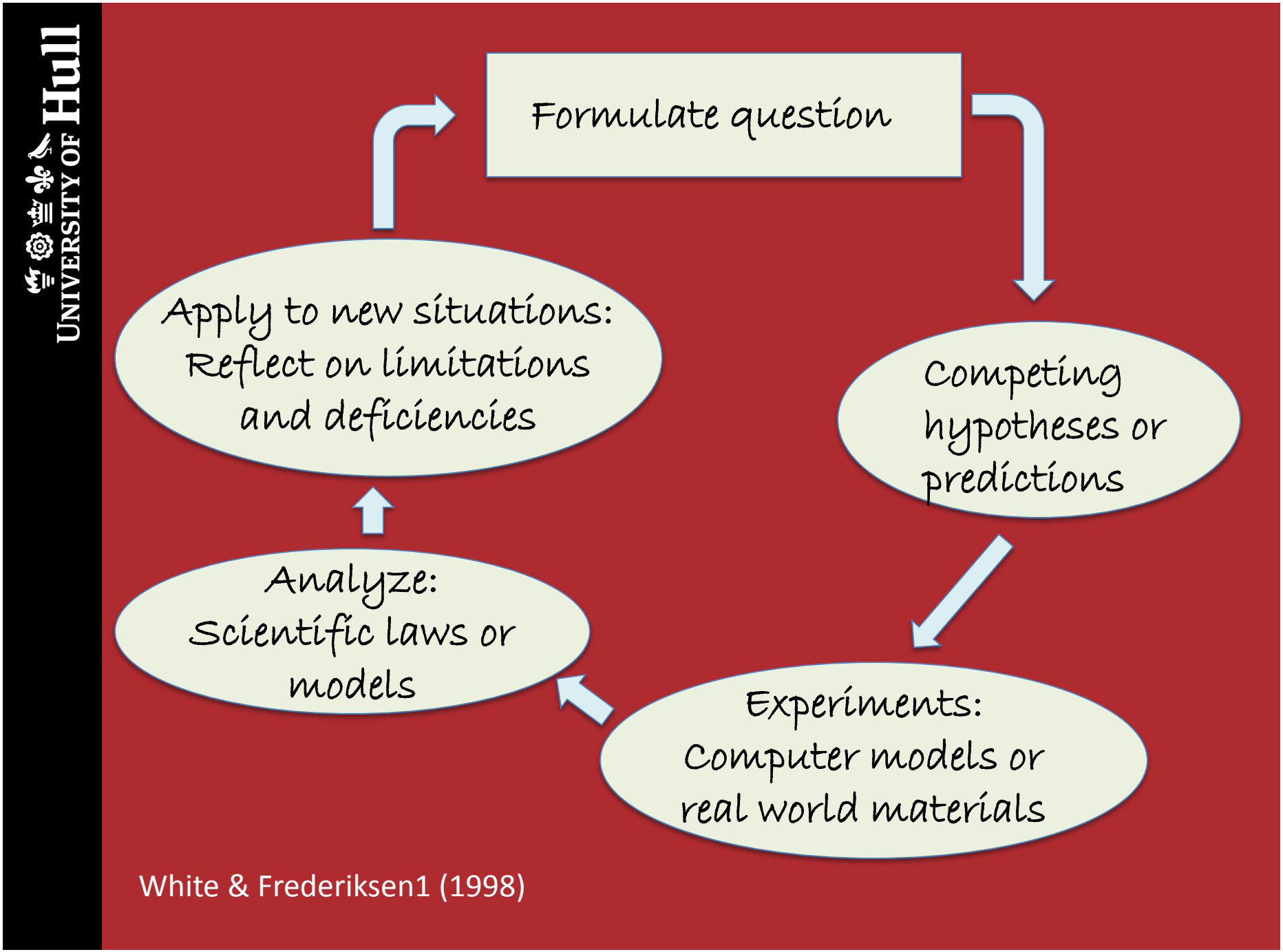
Large project to introduce modelling into the urban school curriculum. Report great success, esp. with low achievers.

Among a number of conclusions, two stand out:

Inquiry learning:

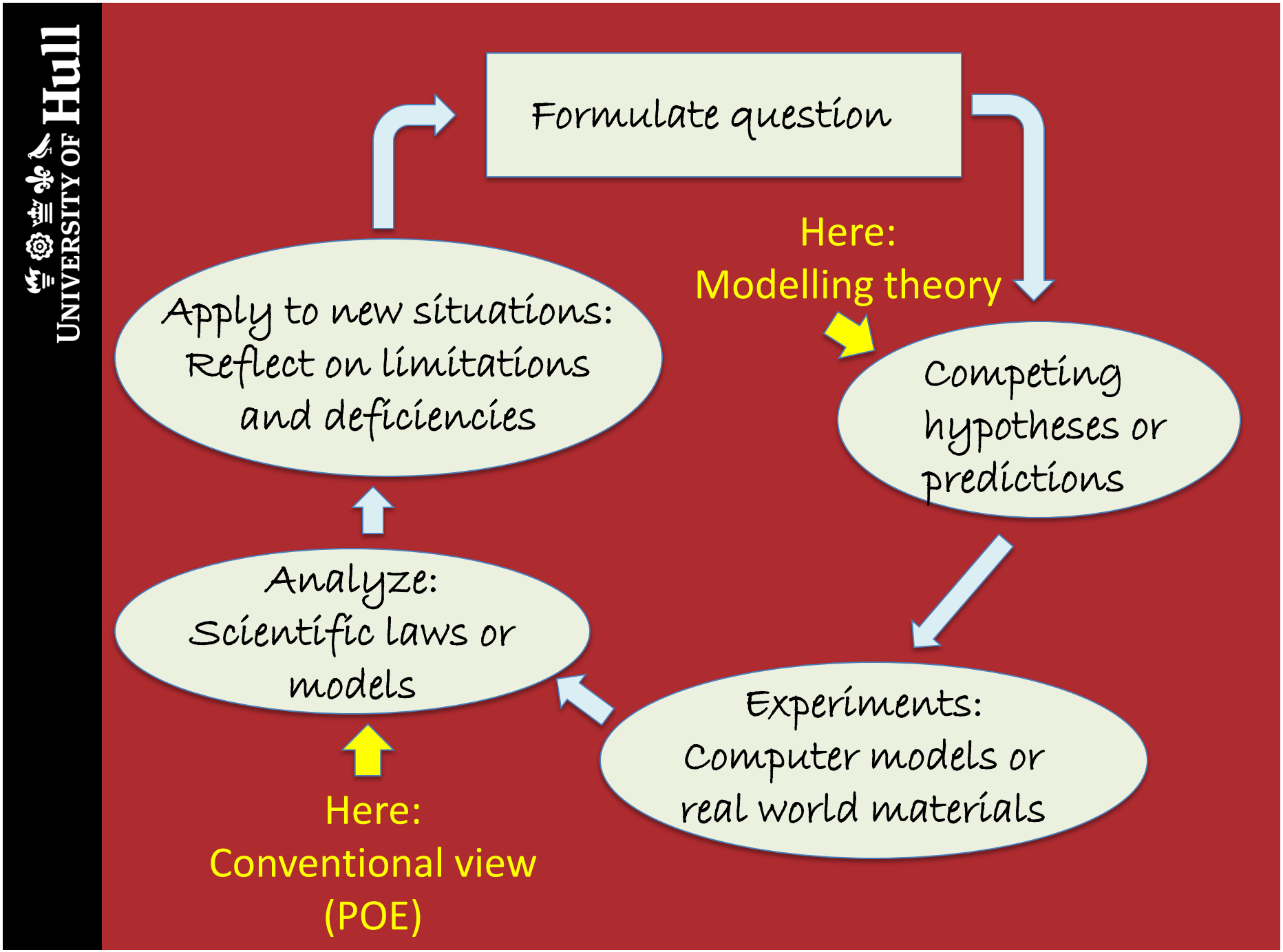
improves students' learning of science concepts as well as their ability to apply them to new situations.

appears to change students' views on aptitude for learning and understanding science.



White & Frederiksen1 (1998)

Where do we model in the enquiry cycle?


Formulate question
Here:
Modelling theory
Competing hypotheses or predictions
Experiments: Computer models or real world materials
Analyze: Scientific laws or models
Here:
Conventional view
(POE)
Apply to new situations: Reflect on limitations and deficiencies

A concept is a model !

Or

A model might be a collection of concepts

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How does modelling fit into our ideas of education?

"PER has come to see learning as an active process of engaging in directed cognitive activity to construct useful knowledge structures while practicing skills and mental processes."

(Gerace & Beatty, 2005)

Conceptual change

di Sessa (1987) reported successful computer interventions for both school children and MIT post-physics course students;

“unnerving similarity in … non-Newtonian expectations”.

di Sessa again

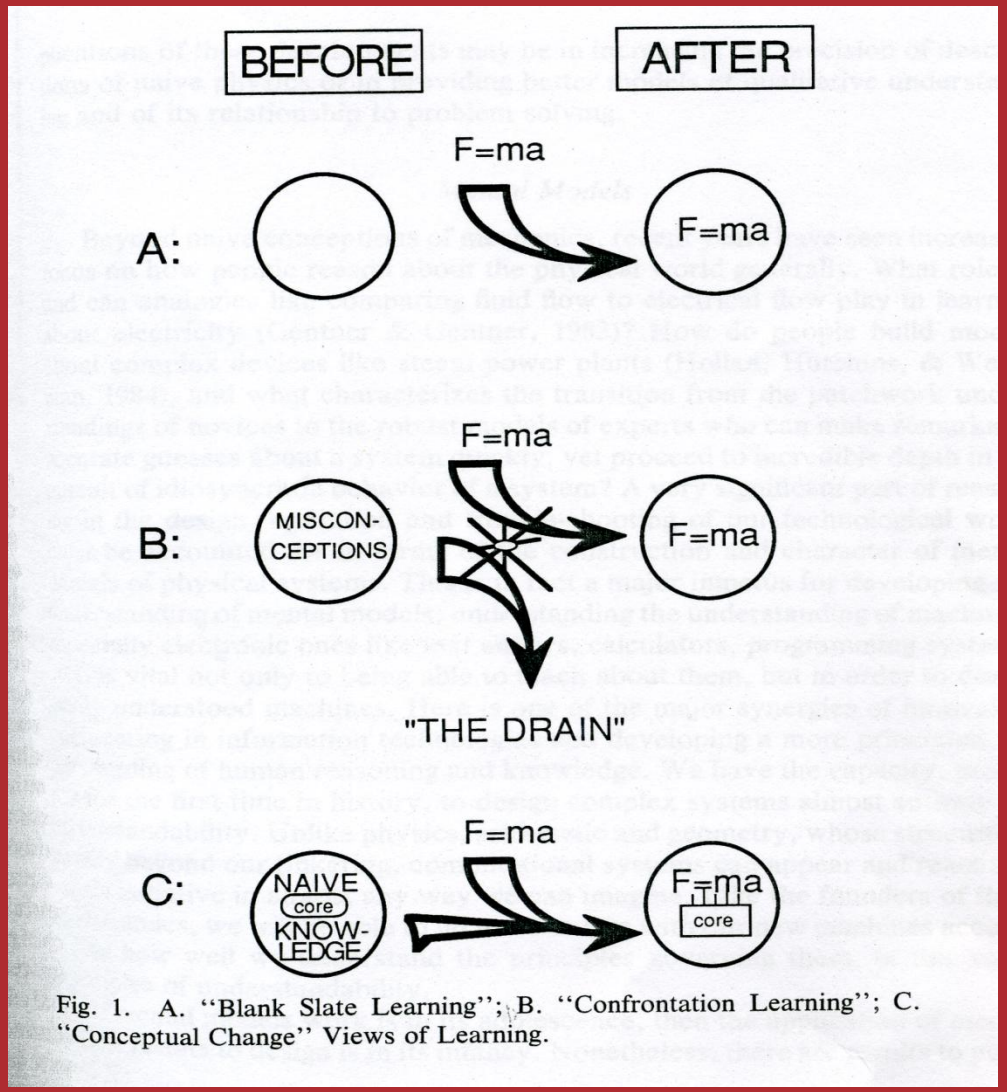

Fig. 1. A. "Blank Slate Learning"; B. "Confrontation Learning"; C. "Conceptual Change" Views of Learning.

qualitative and quantitative knowledge

Andrea di Sessa, (1987)

Argues for the importance of qualitative knowledge: intelligent systems in AI have been constructed on the basis of qualitative knowledge.

These systems can undertake very specific activities;
“Such flow of control from qualitative dependencies into calculation seems quite general”

“Novice physics students have been documented to display the kind of inefficient blind search through equations that … programmes avoid by using qualitative knowledge.”

Modelling as problem solving

Up to the 1970s – general search mechanisms

c. 1980 - domain-specific knowledge

- Importance of representations
- Structure of knowledge
- Qualitative reasoning

Glaser on representations

"We define a problem representation as a cognitive structure corresponding to a problem that is constructed by a solver on the basis of domain-related knowledge and its organization. At the initial stage of problem analysis the problem solver attempts to 'understand ' the problem by constructing an initial problem representation".

The use of representations constitutes part of the thinking!

M Suwa and B Tversky:

"External representations contribute to the dynamic construction of ideas"

M Hegarty, B Meyer, H Narayanan, Diagrammatic Representation and Inference, Proc. Inference 2002 Lecture Notes in Artificial Intelligence series, Springer p341-343

- Free working memory
- Cue retrieval from long term memory
- Allow perceptual judgements about spatial relations
- Allow the generation of new ideas

David Hestenes

Modelling theory of physics education

For the most part, the *modeling theory* should appear obvious to physicists, since it is supposed to provide an explicit formulation of things they know very well. That does not mean that the theory is trivial or unnecessary. Much of the knowledge it explicates is so basic and well known to physicists that they take it for granted and fail to realize that it should be taught to students. A systematic explication of basic knowledge is an obvious prerequisite to the development of an instructional program which assures that the basics are adequately taught. When an instructor takes certain basics for granted and fails to teach them, the students flounder until they rediscover those basics for themselves or, more likely, develop inferior alternatives to cope with their difficulties. I submit that this unfortunate state of affairs is rampant in physics courses and contributes heavily to their legendary difficulty.

David Hestenes, Am. J. Phys, 55(5) 1987, 440-454

Mathematical models in physics have 4 components:

A set of names for the objects and agents that interact with them

A set of descriptive variables representing properties of the objects

Equations of the model; structure and evolution

Interpretation

Elements of a Theory of Modelling

- Structure of a model - Hestenes
- Domain-specific knowledge; qualitative and quantitative reasoning
- Spatial reasoning – Diagrammatic as well as visualization
- Model-based reasoning – iconic, analogical
- Application and transfer:
  - qualitative; other situations
  - quantitative; mathematical or computer models

To answer the question,
Why Model?

Modelling is a natural aspect of thinking. It is the process by which we construct concepts

Thank you for your time