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Mathematics and other disciplines: epistemological issues and their impact on teaching practices at tertiary level

Plenary Panel

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**Q1. To what extent is it possible and realistic to design math service courses to teach "prerequisites" for other disciplines? Is there something missing in this approach?
If so, what?**

Q1. Is it possible and realistic to design math service courses to teach "prerequisites" for other disciplines? What is missing in this approach?

Current model in society

- The naïve point of view **assumes the world of disciplines** as untouchable
- It determines what is to be taught and **justifies a hierarchical view.**

Quora

Related: **Which subject is easier to learn, physics or mathematics?**
 Mathematics is the language of physics. To understand physics you must learn mathematics, but not the vice-versa.

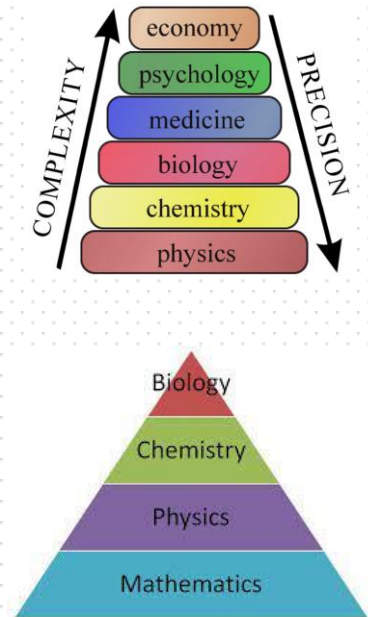
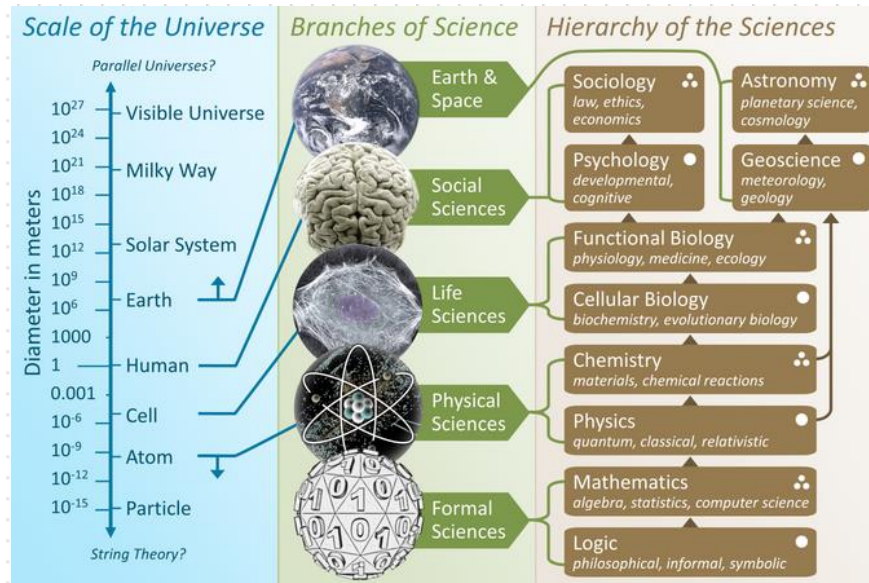
PHYSICS VS MATHEMATICS

MATHEMATICS: Logic applied to all possible universes/worlds

PHYSICS: Logic applied to our universe/world

Therefore, Physics is child of Mathematics!

Advances in Mathematics will usually advance Physics. The converse is not true in general.



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Current model in society

- The uncritical acceptance of this model is associated with the didactic model of teaching **first the notions of mathematics** and then the notions of physics, chemistry, economics, etc.
- This epistemological-teaching model is called ***applicationism*** (Barquero, 2009)

Q1. Is it possible and realistic to design math service courses to teach "prerequisites" for other disciplines? What is missing in this approach?

Applicationism

Barquero et al (2014) define 5 indicators to measure its level in an institution:

- **I1: Mathematics is independent of other disciplines:** mathematical tools are seen as independent of extra-mathematical systems and they are applied in the same way, independently of the nature of the system considered.
- **I2: Basic mathematical tools are common to all scientists:** all students can follow the same introductory course in mathematics.
- **I3: The organization of mathematics contents follows the logic of the models.** It all happens as if there were a unique way of organizing mathematical contents and different ways of applying them.

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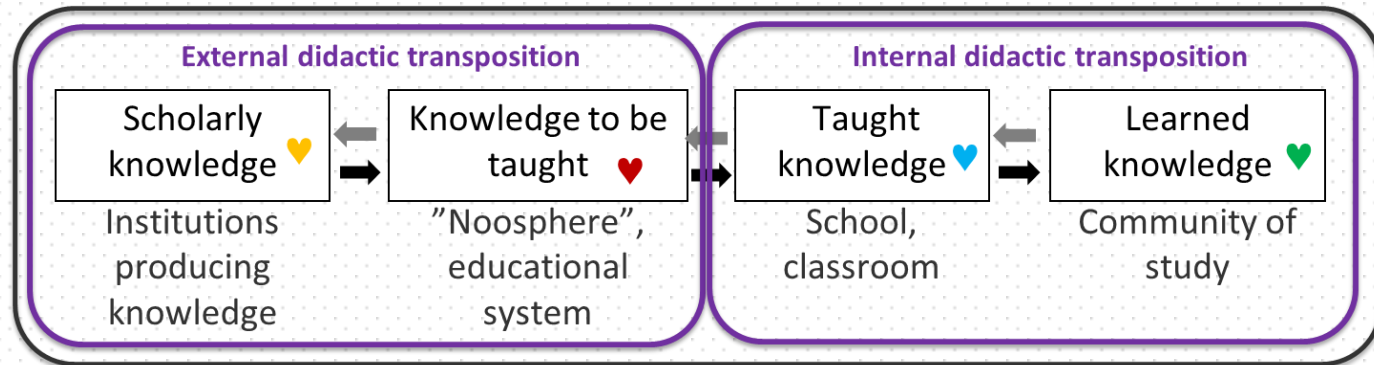
Applicationism

Barquero et al (2014) define 5 indicators to measure its level in an institution:

- **I4: Applications always come after the basic mathematical training:** The first thing is to learn how to manipulate the mathematical concepts and later about their use. The models are built from concepts, properties and theorems of each of them independently of any extra-mathematical system.
- **I5: Extra-mathematical systems can be conceived or built without almost any reference to mathematical models:** The belief that natural science can be taught without any mathematics.

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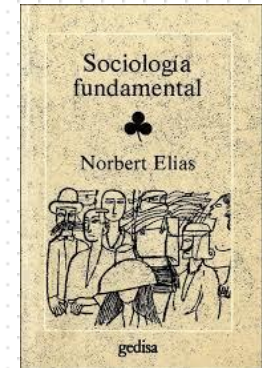
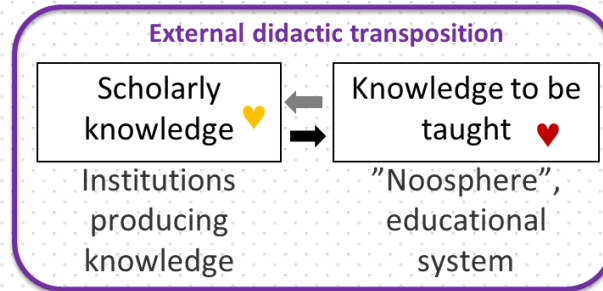
LOOKING BACK



As researchers, using the didactic transposition, we can see how the **disciplines of scholarly knowledge are evolving and transforming.**

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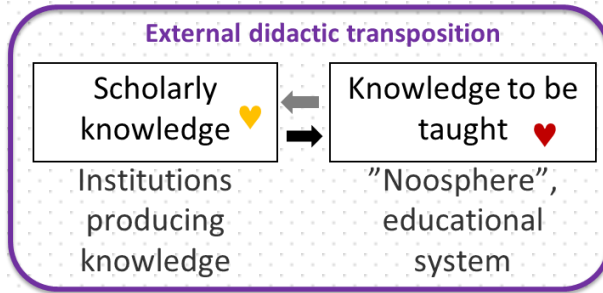
LOOKING BACK



[...] In the developed sciences the main criterion is the **relationship between the new research results available in each case and the older existing knowledge**. It is not something that can be expressed by static polarities of the "right" or "wrong" type, but related to what lies between them, on the basis of the dynamics of scientific processes in the course of which **theoretical-empirical knowledge** becomes greater, more certain, more appropriate (Elias, 1982:63) (*our translation*)

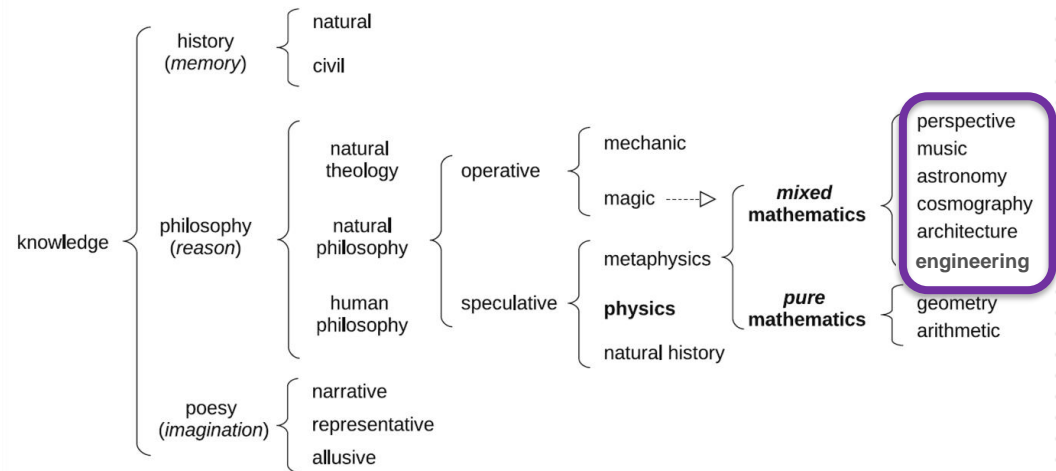
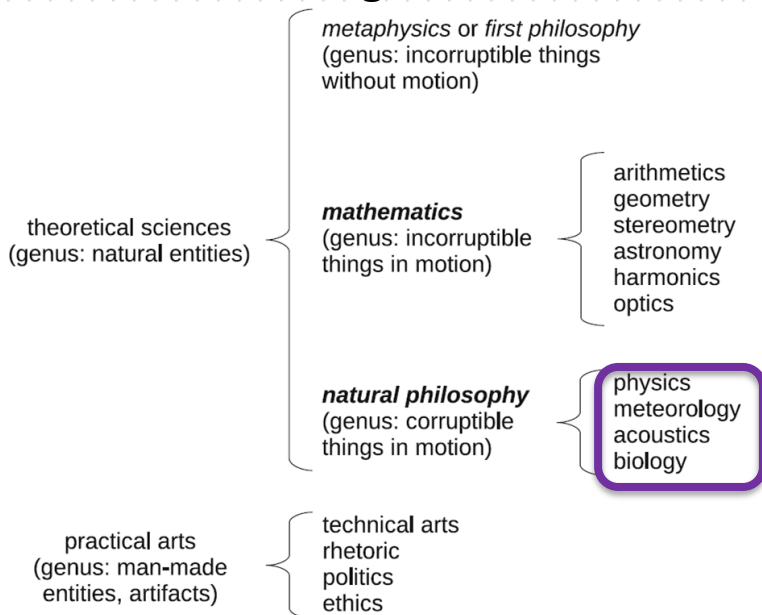
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LOOKING BACK



If we compare Aristotle's and Bacon's proposed organisation of the sciences, the place of "physics", which deals with things in motion, **changes its status**, placing it in the so-called mixed mathematics.

Aristotle's ontological classification of sciences



Bacon's epistemological classification of sciences

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LOOKING BACK



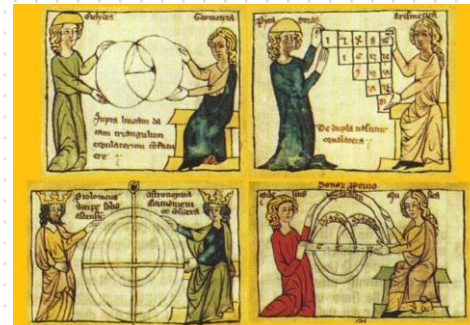
We find in history evidence of how the organisation of knowledge has conditioned the study of knowledge.

In medieval times in Europe, universities developed the standard curriculum consisting of the "seven liberal arts" (subjects/disciplines).



Trivium

grammar, logic and rhetoric



Quadrivium

arithmetic, geometry, music and astronomy

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LOOKING BACK



The reverse influence is less evident. That is, how learning leads to the emergence of new disciplines or the reorganisation of existing ones.

Changes in society call for the need of workers trained in certain aspects, in other words, new professionals.



The industry needs mine engineers
(1765 Technische Universität Bergakademie Freiberg)



The ports need experts in maritime and shipping management

New technologies need experts in digital marketing

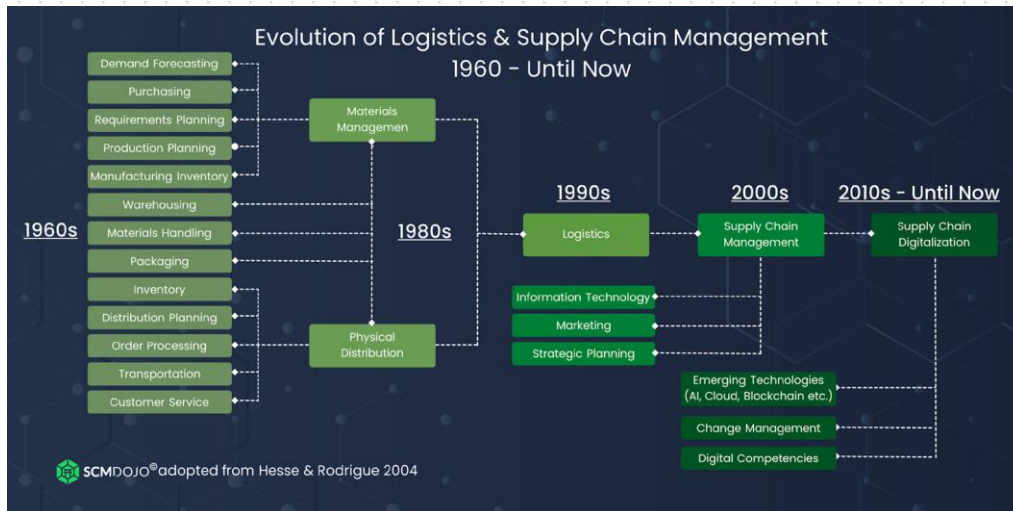


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LOOKING BACK



The configuration of new careers leads to the emergence of new fields of research, of congresses and of scientific journals.



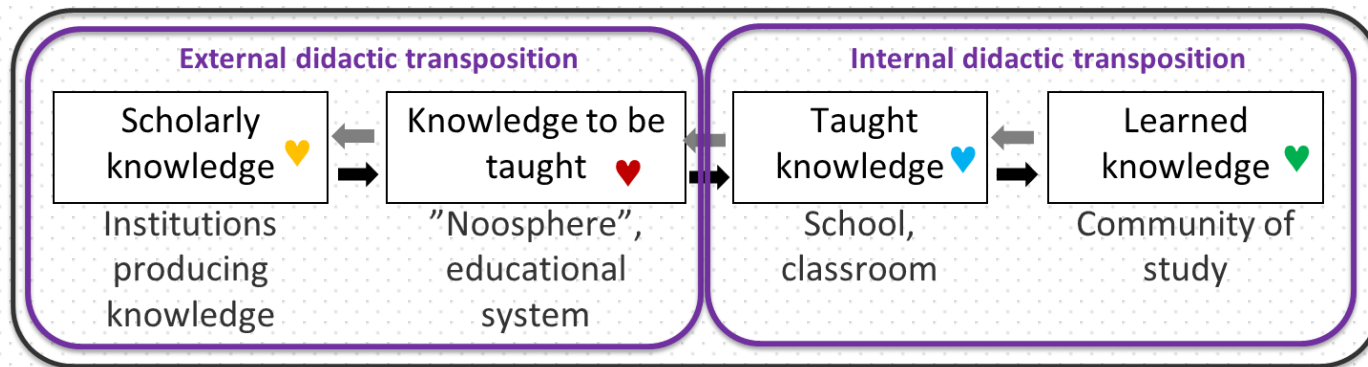
Undergraduate study program in Business Management



<https://www.its.ac.id/mb/academics/study-programs/undergraduate-program/>

A new discourse, terminology, definitions, etc. need to be developed.

Q1. Is it possible and realistic to design math service courses to teach "prerequisites" for other disciplines? What is missing in this approach?

Any design includes an (implicit) **epistemological analysis** of the emergence, roles and relationships between disciplines in the didactic transposition process.



Research in didactics  Reference epistemological models 

Q2 (changed a little bit). What role do modelling processes play in the relationships between disciplines?

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From the perspective of the Anthropological Theory of the Didactic (ATD) (Chevallard, 1989), we consider modelling as **a dialectical process between a system and a model:**

$$\mathcal{S}_0 \Downarrow \mathcal{W}_1 \Uparrow \mathcal{S}_1$$

- Systems and models do not possess inherent, **predetermined qualities**, nor do they stand as independent entities by themselves.
- Systems and models function in accordance with **the role(s) they assume** within the modelling process: models are used to produce knowledge about systems.
- **Recursivity** of the modelling process: $\mathcal{S}_0 \Downarrow \mathcal{W}_1 \Uparrow \mathcal{S}_1 \Downarrow \mathcal{W}_2 \Uparrow \mathcal{S}_2 \dots$
- **Reversibility**: when the system is used as a model.

Q2. What role do modelling processes play in the relationships between disciplines?

Modelling is an **epistemological tool** to understand and describe the relationship between mathematics and other disciplines.

However, if one or the other discipline is taken as an end or imposed as an objective, one can fall into a **false dialectic of the system-model of the modelling process**.

E.g. “Mathematics are only models, never systems.”

In the end, this leads to the epistemology of the ***applicationism*** mentioned above.

The modelling process helps describe possible **types of interventions of mathematics** in different reality domains.

Q3. How can mathematics as a discipline and mathematical practices from other disciplines be integrated? Who is responsible for introducing these new aspects? Which didactical solutions and collaborations can support these changes?

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All of us, institutions, teachers, researchers and society, must share the responsibility.

It depends on the functions given to knowledge (and disciplines) in society and universities: as “precious works to visit” or as “tools to question the world”.

Two radical paradigms from **visiting works** to **questioning the world** (Chevallard, 2006, 2015).

Knowledge and study processes based on
{~~Questions~~, Pre-established answers}



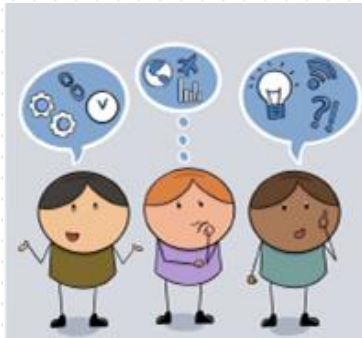
Knowledge and study processes based on
{**Questions, Answers**}



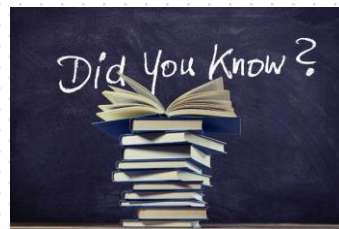
Q3. Which didactical solutions and collaborations can support these changes?

The ATD perspective proposes to address it in terms of:

Herbartian schema, inquiries and study and research paths (SRPs)



$$[S(X; Y; Q_0) \rightarrow M = \{Q_1, Q_2, \dots, Q_j, A_1^\diamond, \dots, A_n^\diamond, O_{n+1}, \dots, O_m\}] \hookrightarrow A^\heartsuit$$



Infrastructure





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Thank you very much!

Moltes gràcies

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