Physics as a culture in physics education

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There are very few, if at all, new things in this world. Therefore, the agenda of a person is to find a new, fresh interpretation of them.

Giorgio Morandi (1890-1964)

Let’s try a new perspective on the known knowledge of physics for its teaching.
Two problems we currently face in physics education:

1. Reduction of interest to physics education

   Population in physics courses, selective at Israeli high school
   Less than 8% in AP courses
   Less than 2% in other courses

   Migration of good students to humanities

2. Pragmatic orientation of the physics curriculum, one for all

   Prevailing of problem solving activity over conceptual knowledge as a world view
Humanization of physics curriculum

To orient the introductory course to the conceptual knowledge and cultural perspective

The European project – HIPST - to humanize physics course by using the history and philosophy of science [HPS]
History and Philosophy in Science Teaching

HIPST
2008-2010

Research & Developmental Project sponsored by the European Union
University of Bremen (scientific lead)
University of Oldenburg

Instituto Tecnico Toscano and Fondazione Scienza e Tecnica

Budapest University of Technology and Economics

The University of Lisbon

Nicolaus Copernicus University Torun

The University of Reading

Aristotle University of Thessaloniki

The Hebrew University of Jerusalem
Many researchers in different countries claim that the History and Philosophy of Science [HPS] possesses significant potential for science education.

However:

“… even materials produced for teachers, for example, those produced in the UK … are not used. Attempts to produce restructured courses that put history at the center of the enterprise … have enjoyed only marginal success, as have those that have sought to introduce a more rigorous and current view of the philosophy of science …” (Monk & Osborne, 1997)
• Previous attempts to teach historical materials:
  Mach – Mechanics and Optics (1890),
  Taylor – Physics (1940),
  Rogers – Physics (1960),
  Harvard Project – Physics (1970)

• Plenty of available historical materials –
  What, how and why to chose? How to use?
Findings of the HIPST national meetings in Israel

I. Physics teachers often consider the HPS materials as **irrelevant** and taking students astray to the **wrong ideas**, surpassed barriers, obsolete problems not valid any more in science.

**inference**

**Relevancy** of the HPS to school curriculum is to be demonstrated
II. Our school teachers normally lack any background in the HPS (not a subject in teacher training programs)

Teachers and students need summarized presentation in self-explained units (with limited references)
III. The frequently stated problem: lack of time and obligation of training for the matriculate exams (solving standard problems)

inference

The change of assessment standards
“To humanize physics curriculum”
we intend to show physics as a culture

What does it mean?
Physics Teaching establishes a culture

This idea is rather developed in science education research (STS)

Physics Knowledge comprises a culture

This idea is often considered to be the realm of historians, non-relevant for physics learners (HPS)
Cultures could be of two types

- Culture of Rules
  - Science, Law, Technology

- Culture of Texts
  - History, Philosophy, Art

One can learn the culture in two ways:

- From inside
  - Mother Tongue,
    Science as a Practitioner

- From outside
  - Foreign Language,
    Science as a Student

Lotman

Vigotsky
Teaching physics knowledge as a culture implies explicit demonstration the hierarchical structure of knowledge
Discipline-Culture

Triadic code of the culture of rules

- Nucleus (center) – paradigms, axioms, principles, concepts
- Body area – knowledge produced basing on the nucleus
- Periphery (margins) – knowledge contradicting the nucleus
Scientific research program

Hard core

Solved problems - protection belts

Imre Lakatos (1922-1974)

Unsolved problems
Principle of Correspondence
between fundamental theories in physics
Examples

1

\[ V_{O2} = V_{O1} + V_{S1} \]

\[ v \Rightarrow \infty \]

\[ V_{O2} = \frac{V_{O1} + V_{S1}}{1 + \frac{V_{O1}V_{S1}}{c^2}} \]

Classical mechanics is not a special case of the theory of relativity

2

Classical mechanics is not a special case of quantum theory
Physics presents a **dialogue** of fundamental discipline-cultures.
How to teach history?

Without history

Background

Historical narrative

Excurses at critical points
Excurse to the History of Understanding of Motion – De Motu

Relativity, kinematics

External push

Impetus, internal push

Laws of change of state...

Charge of motion

Vortex push, conservation

Titubando

Diachronic discussion
Paradigmatic changes in motion understanding

I

Outside driver

II

Inside driver

III

No driver

Time
Encouraging understanding of the basic idea of the classical mechanics

- Old theory of motion
  Impetus (Hipparchus, Philoponus, Buridan)

- Classical dynamics
  (Galileo, Newton)

Scientific revolution of the 17th century

- Rest-motion opposition

- Rest-motion equivalence

Relevance: students’ strongest misconception (motion is an absolute quantity like charge) (McCloskey 1983, DiSessa 1983, Galili & Bar 1992)
Is diachronic discourse of motion possible (beneficial)?
The beginning of science

The fundamental principles must be self-evident (simple)

The contemporary science

Principle of Bohr:
The truth is complimentary to simplicity (complexity)
Excurse to the History of Optical Image

Moving eidola

Active vision

Visual rays

Mapping by light flux

Similarity to camera obscura

Mapping by light rays

Colors tens the air…
Conceptual development of optical imagery

Atomists

Alhazen

Kepler

Time
Holistic tracing of image transfer

Annunciation in the icons of the Eastern Christianity
Annunciation in the icons of the Western Christianity

Fra Angelico, Annunciation, 1437
Image on the rails of light rays

Fra Angelico - detail
Holistic ⇒ By light rays ⇒ By light flux

**Relevance**: the old conception of image transfer appear spontaneously in students’ misconceptions (holistic, vision rays, image projection schemes of knowledge) (Galili & Hazan 2000, 2001)

Example
Excurse to the History of Weight

It can be due to two forces…

Natural and accidental impetus

Natural inclination

Measurement determines

We need two concepts

One cannot distinguish...

Centripetal push of medium

Force of gravitation

Natural inclination

One cannot distinguish...

Measurement determines

We need two concepts

Centripetal push of medium

Force of gravitation
Conventional presentation

Newton's gravitational force

Principle of equivalence

Measurement determines

Newton's gravitational force

Centripetal push of the medium

Centrifugal force equal to gravity

Natural inclination

Wiggish history
Weight and Gravitational force — conceptual history

Gravity, weight, mass

Gravitation force = Weight force

Newton 1687

Einstein 1916
Reichenbach 1927
Relevance for education:

Two frameworks of weight instruction

**Gravitational definition (17\(^{th}\))**

Weight is the gravitational force exerted on the body.

**Operational definition (20\(^{th}\))**

Weight is the result of weighing.

Situation among the textbooks in English.
Gravitational force and weight force are independent
Cultural Content Knowledge
as a dialectic view on the nature of science

- Science is subjective
- Science is tentative
- Science starts with a question
- Science is an algorithmic procedure…
- Science is problem solving

- Science is objective and bases on cumulative process
- Science is certain and predictive
- Science starts from learning about …
- Science is a culture

Currently often stated: the genus of science!
Conclusion

Cultural Content Knowledge (CCK) presents our present knowledge in a diachronic discourse of major paradigms, makes it meaningful

CCK presents the nature of science both in ontological and epistemological aspects

CCK humanizes physics

CCK benefits those who want to be physicists as well as those looking for scientific literacy
Who knows to create physics curriculum? (Schwab 1962)

Subject matter

History of Science

Philosophy of Science

Physics teaching

Cognitive Science Learning theories

Pedagogy and Didactics

The importance of physics teaching researchers
Physics knowledge is a culture

Thank you