CULTURAL CONTENT KNOWLEDGE – THE REQUIRED ENHANCEMENT FOR PHYSICS TEACHERS

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Abstract

Involvement of the History and Philosophy of Science is considered of making physics knowledge cultural. The materials produced within the HIPST project suggested historical excurses to some topics of school physics curriculum. They intend to upgrade teachers' knowledge of the subject matter. The concepts chosen to be addressed were of central importance for learning. We exemplify these units by two that address the concept of optical image and that of weight. Making knowledge cultural is defined and advocated as important.

Introduction

One may identify two tendencies in physics education. The first is the steep reduction of student population in physics classes. The second is prevailing orientation to problem solving, modeling and numerical account. The two tendencies can be related. Both demonstrate polarization of the educational system between professional occupation with science (the one which requires computational account) and the other dealing with qualitative account of Nature. The former matches the image of normal science (Kuhn's sense of "puzzles resolving"), whereas the latter represents the general interest to the world around, its account by physics concepts, ideas, and rules, in a way, approaching humanities and arts. The situation might resemble the prophecy of C.P. Snow (1962) regarding the Two Cultures as essential feature of our society.

Neither of these trends represents alone the entire nature of physics as a human endeavor. The conceptual, more holistic approach was the intention of the founders of physics who strived to reveal the regularity of the world and its organization and thus explain natural phenomena. This goal attracts wider population of students than we currently have in physics classes. Within this agenda the role of the history and philosophy of science (HPS) becomes central. It bridges between science and humanities. How exactly it could be done in pedagogically effective and physically meaningful way is not a trivial question. HIPST (History and Philosophy in Science Teaching) European project served us a framework to investigate the way which would not only involve HPS material but could essentially contribute to students' construction of the qualitative disciplinary knowledge of physics.

Background

Facing the abundance of materials in physics curriculum, any teacher or learner needs a sort of hierarchical and functional structure of pertinent knowledge. Lacking such presents a major obstacle to the novice in physics. Tseitlin and Galili (2005) suggested a structure for a fundamental theory in physics that comprises three areas of knowledge elements (Fig. 1): nucleus, body and periphery.

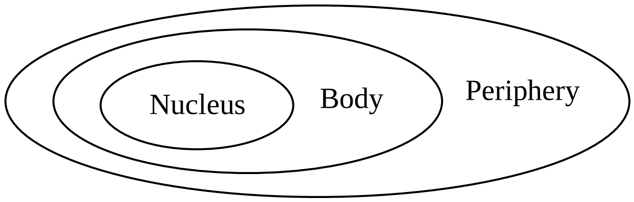

Figure 1. The structure of a theory perceived as a culture

Nucleus incorporates the central principles – the paradigm of the theory, its fundamental principles and concepts of ontological and epistemological nature. The *body* incorporates various applications of the nucleus: solved problems, explained phenomena, algorithms for problem solving, phenomena explanations, experiments, apparatus and machinery and so on. *Periphery* incorporates all kinds of elements in opposition to the nucleus, its rivals from the past (old theoretical claims, concepts), present (alternative theories and learners' misconceptions) and future (the more advanced theories surpassed the claims of the nucleus).

Currently, the generic curriculum in physics is *disciplinary* restricted to the contents of nucleus and body. Adding periphery makes the knowledge in certain domain *cultural* and creates *discipline-culture* representing cultural content knowledge (CCK) (Galili, 2010). This approach was illustrated in a special course of optics for high schools (Galili & Hazan, 2004, 2009). Within the HIPST project, we also treated subjects of classical mechanics aiming to create CCK in this domain (HIPST, 2010).

To establish the required format we analyzed the discussions at our national meetings of physics teachers and considered the previous research experience of applying HPS materials (Matthews, 1994). It appeared to us that:

1. Physics teachers generally lack background knowledge both in history and philosophy of science. This should not surprise since teachers' training program and the standards of knowledge have no such requirements. Apparently, the situation in Israel repeats the one in Europe (Buchberger et al., 2000) and the US (AAPT, 1988). This is despite the claim of the *Benchmarks for Science Literacy* (AAAS, 1993) that the history of science should be included in science teaching.

2. The lack of background is often accompanied with the view that HPS are irrelevant and take students astray to wrong ideas, surpassed barriers, and obsolete problems, views not valid any more. This popular view among educators implies the need of those who design the HPS-based materials to demonstrate the relevancy of the suggested.

3. Finally, the teachers stated that the overloaded curriculum does not leave them any space to deviate from the material that is tested in the matriculate examination prevailed by problem solving and lacking aspects that would draw on the HPS. This orientation of the assessment rules out, in views of many, the HPS from physics classes. This view matches the pessimistic comment by Monk and Osborne (1997):

> *… 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 …*

The same can be said about textbooks. Despite the renowned examples from the past (Mach, 1893; Taylor 1941, Rogers 1960, Rutherford et al., 1970) the contemporary textbooks for schools and universities did not follow their course. Many HPS based materials are left in oblivion and the question *why* deserves an answer from those who continue to believe in the great potential of the HPS in physics education.

Excurse to the HPS as a suggested genre of making knowledge cultural

In light of this background we understood that on our contribution to match the following constraints:

1. to display and comprehensively explain that the developed materials are relevant to the adopted curriculum;
2. to present, as far as possible, self-explained materials, in the sense of minimal contextual dependence on the external resources;
3. to preferably address the conceptually "critical points" (Viennot, 2004) of the curriculum (those determine students' success in general sense).

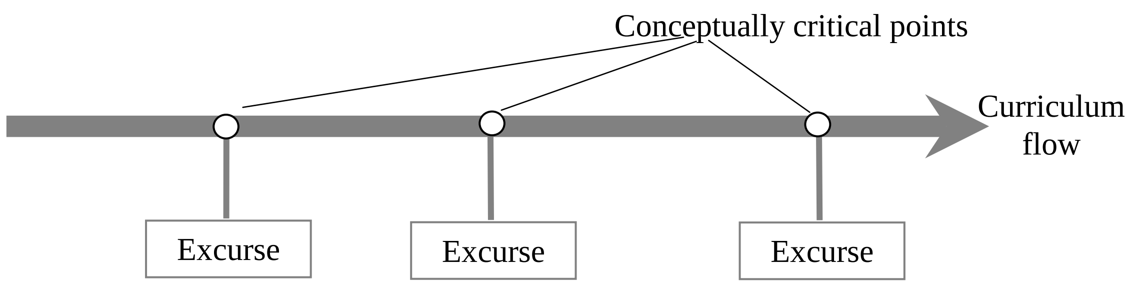

Figure 2. *Schematic presentation of incorporation of historical excurse into curriculum.*

We saw *historical excurse* to be an appropriate genre matching these constraints. Figure 2 may represent the idea of reinforcement of regular curriculum with provided excurses.

We appealed mainly to physics teachers helping in upgrading their knowledge of the aspects usually out of textbooks. After familiarizing with the contents of a particular excurse, the teacher will be in a position to integrate this knowledge to the way he or she presents the considered topic in his/her instruction. Thus, we suggested neither additional topic nor additional unit to be included in teaching. The change should be of quality rather than quantity matching the time constrain.

Our excurses included:

1. Description of the conceptual history of a certain concept;
2. Elaboration of historical and philosophical aspects of provided description, including aspects of the nature of science;
3. Elaboration on the relevance of the considered topic for the curriculum, including research evidence of students' difficulties and pertinent misconceptions.
4. Advises of activities and teaching method;
5. Short list of resources and further reading and expanding of the knowledge.

The produced modules aim to familiarize teachers with knowledge usually missed in their training although directly dealt with the subject. The scientific discourse displayed formation of the physical concepts and their introduction.

Addressing the historical discourse creates *diachronic dialogue* including contribution from different times, countries, worldviews, values, manners and norms of knowledge organization. And despite of all these differences these contributions created the *space of learning* (Marton *et al*., 2004) essential for students understanding.

By its nature such a dialogue includes elements of knowledge obsolete and incorrect from the modern point of view. One may thus distinguish in physics history elements of two types. The elements of the first are often mentioned. They passed the ″test of time″ for their correctness. Such are the laws of lever, the buoyancy law (both by Archimedes), Pascal law of pressure in fluids, Eratosthenes measurement of the Earth radius, Aristarchus measurement of size and distance to the Moon, discovery of electron by Thomson. There are however other elements which are incorrect, in the modern view. Such are Aristotelian theory of motion, the medieval theory of impetus, Tycho Brahe's system of the world, Descartes' theory of motion, caloric theory of heat and Alhazen's theory of vision.

It is the latter type, however, that creates the cultural content knowledge (CCK), enlarging the space of learning. By this act the teacher presents the considered concept in its variation, which is the way to effectively and meaningfully learn it. In a way, one may say that ignoring the history of type I is *not* essential (it does not contrast concepts). However, ignoring the history of type II may indicate technical, superficial knowledge without mastering the genuine meaning of the concept.

Excurse to the conceptual history of physics inevitably includes the type II history which belongs to the periphery of the discipline-culture structure (Fig. 1). We may say that excurse to the conceptual history replaces a formal concept by a *conceptual knot* – an inclusive construct incorporating various accounts, aspects and ideas suggested by the bright minds of the past while addressing the same issue.

Examples

Excurse to the history of optical image

This excurse elaborates the genesis of physics knowledge regarding optical image and vision. Several theories were in use to account for optical image (Lindberg 1976). The excurse displayed the knowledge evolution from the Hellenic theories (Pythagorean active vision, Atomists' eidola, Plato's hybrid theory, and Aristotle's media stress), to the Hellenistic theory of Euclidean and Ptolemy's rays of vision, and the medieval theory of Al-Hazen (11^{th} c). The story arrived to the theory of Kepler (17^{th} c), currently taught at school – geometrical optics. Within the excurse, the history of light ray is traced from being the central concept of vision and light to an auxiliary concept in the wave theory.

In the debate between intromission and extramission theories, during more than two thousand years, the extramission theory was refuted by Al-Hazen in the 11^{th} century and served as an intermediate stage before Kepler's account (Fig. 3, Table 1). The excurse utilizes art representations of image transfer and image transformation in a plane mirror.

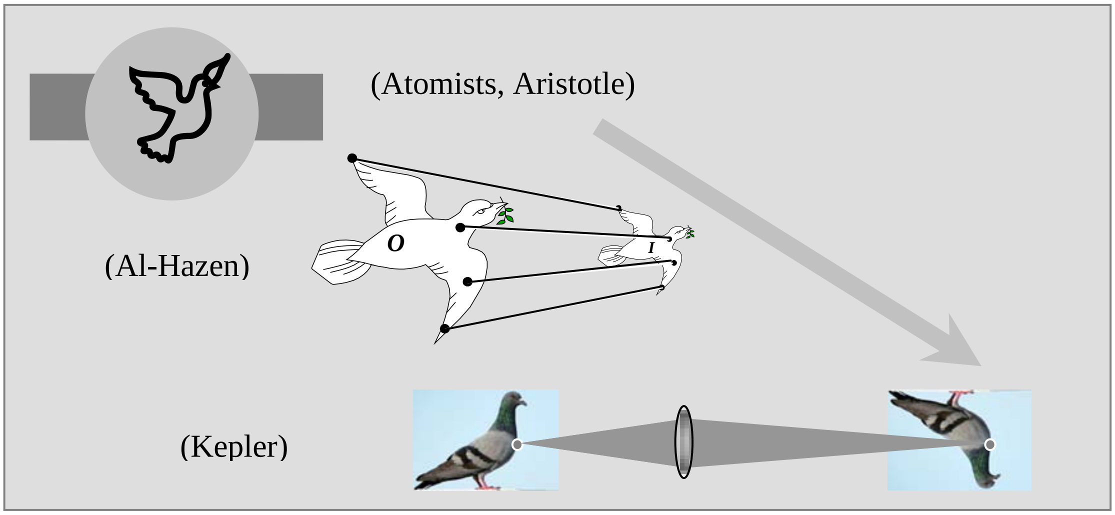

Figure 3. *Transformation of the model of image transfer (Corresponds to Table 1).*

Table 1. Ontological changes in the intromission theory of optical image

Holistic **eidola** transfer into the eye of the observer (Atomists, Aristotle)	⇨	Points of an object are mapped to its image by single **rays** of light (Al-Hazen)	⇨	Points of an object are mapped to its image by light **flux** (Kepler)

Relevance of these contents for physics education follows several researches reporting about misconceptions that students held regarding vision and image creation and transfer (Galili & Hazan, 2000). The schemes of knowledge students hold show certain similarity to the conceptions of scientists in the past. Thus, pre-instructed students often show holistic understanding of image (similar to Atomists and Aristotle), whereas novice learners show the misconception of image transfer by means of a single ray per image point (Al-Hazen). It was checked experimentally that addressing the old theories of vision, in other words, cultural curriculum, has remedial effect on students' misconceptions (*ibid*.) and their views about the nature of science (Galili & Hazan, 2001).

The excurse to the history of weight concept

The excurse to the history of weight concept goes through the whole history of physics from its dawn to modern. In this conceptual knot of physics, weight can be presented as formed in three major steps: 1) weight is the characteristic feature *of the body* causing its heaviness and falling; 2) weight is the gravitational force acting on the body from another body and is different from mass, and 3) weight is the result of weighing the body, distinguished from the gravitational force (Fig. 4).

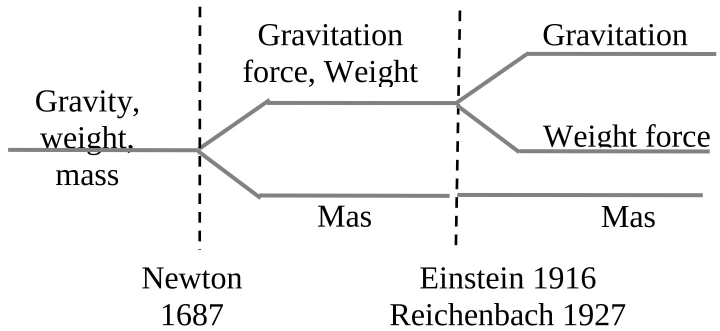

Figure 4. *Conceptual evolution of the weight related concepts in physics history.*

The definition of weight changed through the history showing complexity of the subject matter. Following genesis of the concept and corresponding epistemology the learner reveals the full picture, making the concept more meaningful due to variation in the appropriate *space of learning*. The story ultimately arrives to modern physics and the split between gravitation and weight (*operational definition* of weight) as implied from the principle of equivalence of Einstein (Reichenbach 1927/1958).

A special feature of this discourse is that this story continuous (Galili, 2001). One may see the split between the authors: those who keep with the Newtonian definition (e.g., Young & Freedman, 2004) – the majority in some countries, versus those who define weight operationally (e.g., Marion & Hornyack, 1982; Keller et al., 1993) – the majority in other countries. Seemingly, the cultural presentation comparing the approaches may lead to some consensus.

The excurse relates the ontological change (equivalence principle) with the epistemological change in physics in the 20th century, the introduction of the positivistic philosophy. Within this vision, Mach (1893/1989) performed revision of the classical mechanics, later extended by Bridgman (1927/1952) with the claim that the *operational definition* determines the meaning of any concept by means of measurement. The contemporary philosophy of science established a more mature requirement of two definitions: theoretical (nominal) and operational (epistemic) (Margenau, 1950). The issue is not new, neither in physics, nor in philosophy, but is still under debate in physics education.

The relevancy of the subject to physics teaching at different levels of instruction was reported in several studies (e.g., Galili & Kaplan, 1996; Galili & Lehavi, 2003; Gőnen 2008). Appropriate discussion and new teaching may provide remedy to students' confusion. CCK of weight, by presenting the central role of measurement understood in physics, may lead to students' appreciation of the philosophy of science as the way which makes the scientific knowledge reliable and objective.

Conclusion

We argued that physics knowledge of certain topic becomes cultural – cultural content knowledge –when it obtains a structure of discipline-culture. This way the history and philosophy of science is effectively introduced into physics curriculum. We have illustrated here the meaning of this conception by presenting modules on the topics of optical image and weight concept. Further empirical study is required to show that adoption of these materials in teacher training can contribute to their professional competence and cause the change of the way they present the topics of conceptual importance in physics classes.

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