SCIENCE CONTENT TRANSFORMATION: VIEWS, CRITICISM, EXAMPLES AND PROPOSAL[1]

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In this work an old problem of Science Education is addressed and discussed, that of didactical transformation of the content to be taught. This procedure is investigated by researchers without details, while it is implicitly employed by teachers on an everyday basis. With this term we mean every change in the content (systematic transformation, elimination of difficult points, simplification etc.) in order to be meaningful for the target population. The term was introduced by Y. Chevallard in Mathematics Education and this has been extended into Science Education, despite the reactions provoked by the side of Epistemology. In this article, some examples of application, the criticisms that have been heard, the validation of the DTC and its limits, and mainly the necessity of systematic study are presented.

Keywords: science content transformation

BACKGROUND

Everybody recognizes students' difficulty in understanding scientific concepts, as well as, aspects of the scientific method (Viennot, 1993; Zoupidis, Pnevmatikos, Spyrtou, and Kariotoglou, 2016). Two decades of students alternative conceptions' systematic study revealed such difficulties, which is a common secret not only among researchers and teachers, but also among many citizens. When a teacher teaches he / she tries to transform the scientific content in order for the students to understand it. Although some examples are existing in the textbooks, usually each teacher implement this approach on his / her own, since there is not systematic empirical or epistemological documentation. This big problem is the concern of this work.

With the term, didactical transformation of the content (DTC) we mean any change or choice of the scientific content, in a type of knowledge appropriate to be taught to the target population in order to become meaningful. It may concern systematic change of the content, as a consequence of the treatment of alternative conceptions (Kariotoglou, Koumaras, and Psillos, 1993); or, it may concern elimination of some part of the content or simplification, for instance verbal or mathematical formalism, e.g., qualitative introduction of density instead of mathematical one (Smith, Snir, & Grosslight, 1992).

The DTC was introduced by Chevallard (1985), as transposition didactique, with the meaning of the transposition of knowledge from the area of science to that of education and with this approach it is considered that school knowledge or science is constructed. This proposal has been strongly criticized by Freudenthal (1986), also coming from the area of Philosophy of Mathematics. Main criticism focuses on the phrase: *"... the scientific knowledge is not constant since it is changed through the everyday new knowledge produced ..."*.

RESEARCH CONTEXT

[1] the revision of your proposal has been completed and we are pleased to inform you that your abstract ID **4364473** entitled **Science Content Transformation: Views, Criticism, Examples And Proposal** has been accepted for Single Oral Presentation at the 2019 ESERA Conference, that will be held in Bologna, Italy, from 26 to 30 August 2019.

The aim of the paper is to reveal the need for didactical transformation of the content to be taught in most of the main scientific streams of Science Education (SE) and on the other hand the lack of systematic approach for that kind of research on SE, despite its great necessity for the everyday educational praxis of SE. In order to accomplish the aforementioned aim, we searched the main journals and books of SE for papers dealing with this issue: the transformation of the content for SE. Moreover, we searched for examples of this issues in relevant studies. For the sake of brevity, our findings are limited in some indicative cases.

RESULTS AND DISCUSSION

The main findings of the literature review are classified in two categories: a) indications of the necessity of DTC across the known streams of SE, and b) examples of DTC explicitly or implicitly described in many teaching proposals. Indeed, both in the stream of discovery 1960-80, as well as in the current one of inquiry the choice of the appropriate content so that the teaching intervention is successful, is implied. The same happens with the constructivist approach, where in order for the conceptual change to be successful, an appropriate DTC is needed (Duit & Treagust, 1998). Moreover, in the area of Teaching Learning Sequences, one of the main design steps is the choice and the transformation (or elementarization) of the content (Psillos and Kariotoglou, 2016).

In an innovative teaching intervention, Psillos and Kariotoglou (1999) both in High school and in primary teacher's students introduced the concept of pressure as a primary concept, qualitatively and with measurement. The measurement of hydrostatic pressure led to the law of hydrostatics, while it also enhanced the introduction of pressure to students: "…the pressure exists since we measure it….". All the above in contrast with the textbooks which introduce pressure mathematically $P=F/S$, and give examples such as pinch, stiletto heels, etc., which refer to tension inside the solids and not to fluid pressure. The researchers were led to this approach because after studying students' views and the teaching of relevant issues, they found that most of the students confound pressure with force.

Fazio, et al. (2008) simulate natural phenomena with simple everyday situations. E.g. the mechanical waves with the waving movement of fans on the pitch, as the standing up and siting down in order to acclaim their group. With a similar way, the authors simulate the behavior of solids with a simple harmonic oscillator (an object hang on a spring), which can explain the waves propagation.

Savinainen et al. (2004) for teaching Newton's Third Law propose a diagram called SRI (symbolic representation of interactions) which represents contact and distance interactions, with double side arrows, and it helps students to distinguish interactions of the body under study. Next in a free-body diagram the vectors of the forces, velocity and acceleration are placed in the body. The authors consider that the diagrams help students to identify the interactions.

Guisasola et al. (2009) state: *"... This means that our sequence does not start from theoretical knowledge about magnetic forces, as usual in textbooks for this topic. Instead, in order to tackle the problem, it first develops a series of empirical generalizations, in the following terms: (a) Recognizing magnets as sources of magnetic field, ... (b)Recognizing that moving charges produce a magnetic field. ... (c) Technological applications. ..."*. From this extract we can see a change from the traditional (textbooks) introduction of the magnetic field, as well as the addition of some historic issues and some applications.

According to the hydrological service of USA, the water cycle consists of 17 phenomena. In some interventions concerning the introduction of this issue in different levels of compulsory education, the phenomena were eliminated in 4 for pre-school, 5 in primary and 7 in high school. Main criteria for this elimination were the closing of cycle, the conservation of the amount of water and the specific significance of each phenomenon in the cycle (Fotiadis, 2017).

In an innovative intervention, the concept of density was introduced, in primary school (10-11 years old) via the model "dots in the cube" in combination with the rule "… if the body has more dots (density) than the liquid then the body sinks...". This is a way to avoid the mathematical introduction of magnitude $d=m/V$. In the same work Control of Variables Strategy (CVS) was introduced via the explicit teaching of its reasoning and application, initially by the teacher and then by the students. This approach has been proved to have positive impact both in CVS method acquisition and in explanations of floating – sinking (Zoupidis, Pnevmatikos, Spyrtou, and Kariotoglou, 2016).

From the above we observe the following: the transformation of the pressure concept was guided by the finding of students' alternative views, which led the research team to serious changes, such as the change of introduction series. Similar are the cases of Newton's 3rd law as well as the wave propagation. In the case of the water cycle, the transformation had the meaning of reducing the factors that affect the phenomenon. This was accomplished by merging similar factors, and omitting of some others contributing less to the phenomenon. In the case of density at an early age (10-11 years), it was considered that the mathematical introduction lead to misunderstandings, such as the molecules that are closer or farther apart would be unsuccessful. In the case of procedural knowledge, like the CVS, the decisions were made have been directed also by students' difficulties in understanding and implementing the method.

From the limited research of both theoretical references and experimental examples, some useful conclusions came out which cannot be generalized. It seems that DTC could, at least, concern concepts, phenomena and processes. We met two main types: a) change of the content in two directions: i) systematic content reconstruction as a consequence of reconstructions of alternative conceptions, and ii) simplification, e.g., mathematical formalism or terminology, and b) choice of aspects of the content or elimination of some others which are considered as more difficult or with less scientific value.

From the aforementioned analysis and discussion, a need for systematic study of the DTC across age group is addressed, as in the case of alternative conceptions, e.g., preschool, primary, high school, etc., aiming at creating teaching modules per age group, enriched with relevant social practices.

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