What is new in teaching science structured around the notion of 'scientific competence'?

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Prologue

The notion of 'competence', very much cited in the current international science education research literature and policy documents, brings new opportunities and, at the same time, challenges.

In spite of challenges related to the notion of 'competence', several countries have started to use the notion "competence" in order to describe "learning outcomes" in curriculum documents. However, the notion of 'competence' is a contradictory concept and there are several hundreds of definitions or interpretations of the notion of 'competence'. Actually, in the English language, the concept "competence" does not exist, instead there are the concepts "competent" and "competency". In Germany several researchers interpret the notion of 'competence' in a similar way to the concept "skill". Researchers in education point out that the discourse around competences probably constitutes a most welcome movement towards curriculum reform, but with the risk of being reduced to a new wave of void educational jargon.

Part of the problem with the use of the notion competence emerges from the descriptions' economic origins, which should not be totally overruled. For example, European Union Lifelong Learning document recognizes eight key competences needed for personal fulfilment, active citizenship, social inclusion and employment [7]. [2] document Definition and Selection of Competencies (DeSeCo) analyzes competences, which individuals need in the 21st century in order to be able to use a wide range of tools—including socio-cultural (language) and digital (technological) ones—to interact effectively with the environment, to engage and interact in a heterogeneous group, to perform inquiry-oriented work and problem solving, to take responsibility for managing their own lives, and to act autonomously. Also, UNESCO analyzes in its Universal Learning document, what kind of competences are important for all children and youth for the 21st century and for a good life. Consequently, various competence descriptions have different connotations and describe in a different way the competences needed in future and the reasons why these competences are needed, for example, for good life or employability. The possibility for the idea of competence to be seen as a step forward in educational practice then depends of a theoretical re-signifying, under the principles of a quality education for all, democratic and equitable.

The idea of scientific competence emerges around thirty years ago as an attempt of 'reorienting' science education towards a more meaningful contribution to the preparation of children for future real life. Today, the idea can be understood as referring to a set of skills, abilities or capacities based on knowledge, experience and values. Scientific competences have a 'transversal' character directed towards the preparation of individuals for work, professional development and the exercise of citizenship. Such a 'foundations-based' approach to competences, although extremely fruitful, may divorce them from the disciplinary modes of understanding reality (in our case, the natural sciences).

Most well-known description of scientific competences is done in the PISA documents. The original 2006 PISA science framework [3] defines three competence fields that describe the use of subject matter knowledge of science and knowledge about science and, moreover, willingness to use this knowledge (attitude) in three situations: in identifying scientific issues, in explaining scientific phenomena, and in drawing evidence-based conclusions. Scientific competence also was the primary domain of the 2015 PISA (Programme for International Student Assessment) cycle, which means that items related to this skill occupied most of both the competency tests and the non-cognitive results of the context questionnaires. Scientific competence is defined in the framework of PISA [4] as the ability to deal with science-related issues as a reflective citizen. A scientifically literate person is willing to participate in a reasoned discourse on science and technology, which requires skills for:

- Explain phenomena scientifically: recognize, offer, and evaluate explanations for a variety of natural and technological phenomena.
- Evaluate and design scientific research: describe and evaluate scientific research and propose ways to approach questions from a scientific point of view.
- Interpreting data and evidence scientifically: analyzing and evaluating data, statements and arguments presented in various representations and drawing appropriate scientific conclusions.

These PISA science competences are based on the DeSeCo document [1][2]. The descriptions of competences in the DeSeCo and PISA documents have been utilized in the curriculum work of various countries. [5][7]. For example, the Australian science curriculum regards the PISA framework in terms of the competencies dimension: identify and investigate scientific questions, draw evidence-based conclusions and explanations about phenomena to teach students. In several European curricula, motivation and interest as the attitudinal dimension are emphasized in the curriculum to arouse students' interest science learning and to encourage them to act responsibly toward natural resources and their environments. The knowledge dimension could be met in the science curricula of all countries either as integrated or separate fields, like physics, chemistry, biological science and earth and space science. Finally, the contexts dimension, especially everyday contexts, is typically introduced in science curricula of various countries. Accordingly, an operational, ‘content-anchored’ definition of scientific competences is perhaps needed for teachers, politicians and researchers; it might be useful to consider that competence is a rather formal capacity to operate on scientific content in a meaningful context of performance.

Such a more concrete conception of the scientific competences could be of course more easily connected to the notion of ‘scientific models’: we would be seeking in students for the competent application of models to well-defined, relevant problems. From a competence-based perspective, the most important aim of science education would be that students give meaning to natural phenomena or make sense of phenomena through the use of robust abstract ideas or scientific concepts and models that become meaningful for them. Another important view the competence-based thinking offers to science education is the emphasis on the use of knowledge in various situations where scientific knowledge is met and used. Theoretical ideas, abstract languages to express them, and the corresponding know-how to intervene on the world would be at the core of this potentially valuable notion of competence.

The community of researchers in science education studies the question of what the essential competences for science classes in compulsory science education are; a wide range of responses to this crucial question is being generated. Proposals can be located in a continuum with two very recognizable ends: considering competences that are ‘privative’ for the natural sciences and help distinguish these disciplines from common-sense thinking or other human activities, and competences that are ‘generic’, belonging to general education, for which science would be a tool or a context just like any other. For example, in the PISA scientific literacy competence descriptions, both views are present: they describe, first, competences needed while making sense of phenomena and, second, they describe competences needed in continuous learning. The later view is easy to understand because the PISA competences have been designed based on the competence descriptions of the DeSeCo documents [1] As a third way in between these two poles, we could define ‘paradigmatic scientific competences’ through identifying, with the aid of the history and philosophy of science, core capacities in science. Paradigmatic competences in school science would then satisfy two complementary requirements: retrieving the most central and fruitful aspects of scientific activity and helping students understand the nature of science. PISA scientific literacy competence descriptions include also this view because the knowledge dimension emphasizes both knowledge of science but also knowledge about science.

According to our view, students will be ‘scientifically competent’ when they can operate not only in school situations, but also in a variety of conditions, demonstrating the autonomous applicability of the PISA skills. Scientific literacy competence descriptions include also this view because it emphasizes contexts, like personal local and global contexts. However, this would not mean, of course, defending the need to teach capacities that are deprived of recognizable scientific purposes, which suggest contents and contexts to work. Or, on the contrary, that it is necessary to adhere to an 'ultra-specific' view of competences that reduces scientific education to the technical issue of achieving efficient performance, in which creativity, critical thinking, values and emotions are absent [6].

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