Importance of the Concept of "Competency" in Science Teacher Education: What Are the Professional Competencies for Science Teachers?

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Abstract. The idea of competency, which is widely disseminated through science curricula in various countries, has great potential for the professionalisation of science teachers. Moreover, teachers need competencies for introducing these competencies and for supporting students to develop them. In this chapter, we explore a characterisation of scientific competencies that can be productive for the pre-service teacher education. With such a definition, it would be possible to inspect some "paradigmatic" competencies in science teaching.

1 Introduction

In current educational research, the notion of "competency" is considered both problematic and promising [1, 2]. To a large extent, this problematic character arises from its exo-educational, economicist origins. The promising aspect of the concept, on the contrary, may be lying in its power to transform teachers' professional development in the 21st century.

In the context of the European Higher Education Area, one definition of competency that has already become classic characterises it as the general capacity based on knowledge, experiences, and values that a person has developed through their participation in educational practices [3]. Such a definition of competency could be considered, following [4], as "generic". It has the value of placing science as a noteworthy contribution to the integral education of people, but it entails a danger: separating the development of formal skills from the disciplinary ways of understanding the world. Therefore, it would also be necessary to have a "specific" definition of competency, set in context . In the

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case of professional competencies of science teachers, the specific context is the science classrooms, in which the specific activities of science teaching are developed.

One way to understand competencies for science teacher education is to think of them as abilities (cognitive, discursive, material, value-related) that operate on scientific content within a well-defined context, which is that of professional performance. However, this definition does not indicate any criteria for selecting the competencies that would be most relevant for teacher professionalisation. It is here that the need arises to make additional specifications in order to identify the most paradigmatic competencies in the professionalism of teachers.

2 Towards the Identification of Professional Competencies for Science Teachers

We start from the basis that the education of science teachers aims at preparing individuals that are competent in designing, implementing and evaluating a good quality science education in their classrooms. Thus, the competency *par excellence* for science teachers would be that they make their students scientifically competent. This competency is similar to what [5] recognised in her analysis of various national-level teacher competency frameworks, strategies and standards, which typically emphasise professional knowledge and practices in teacher profession. Specific teacher competencies, on the contrary, could be conceptualised as a set of knowledge-based strategies that enable teachers to successfully design a teaching of science directed to different audiences and to tackle with the conflicts and difficulties that arise in their professional practice.

Science teachers of course need scientific competencies aligned with those that they will foster in their students. But they also need competencies for the planning, execution and regulation of their teaching practices, which involve effective actions responding to complex demands. Science teaching, seen from the perspective of professional competencies, entails the integration of very different forms of knowledge–including, but not reduced to, disciplinary knowledge. When science teachers teach, they are expected to mobilise these different forms of knowledge adequately and efficiently.

A competency-based science teaching would include four dimensions [6]:

1. a body of scientific knowledge composed of theoretical models that should be taught;
2. the ability to effectively transform the world using those models according to various human aims;
3. a set of socially shared attitudes and values to meet the demands of citizenship; and
4. a critical understanding of the nature of the scientific activity.

These dimensions, therefore, should be central in pre-service science teacher education. In addition to competencies needed in a science classroom, science teachers need *professional engagement*, which includes teachers' own engagement in professional learning and engagement with colleagues, parents and the community [7].

Therefore, a central trait in the professionalisation of science teachers would be sound knowledge *of* science and *about* science; teachers' professional competencies, in relation to the discipline to be taught, would be both of scientific and meta-scientific nature (using here the Greek prefix "meta" to give an idea of a "second order reflection

on") [8]. Among meta-scientific competencies, we could place the teaching, instructional or *didactical* competency.

School science could be understood as an intellectual and social activity in which students use scientific models to make sense of phenomena. The theoretical ideas carried by the models, together with the specialised language of science and the experimental activities to intervene on phenomena, would constitute "game rules" to explain the natural world and to understand the human aims and values that shape science. With this idea in mind, a key aspect of the professional responsibilities of the teachers is lying on teaching model-based competencies, that is, competencies that mirror the epistemic nature of scientific activities, requiring students to think, talk and act on scientific problems.

According to the "Future of Education and Skills 2030 (https://www.oecd.org/education/2030-project/)", proposed by the Organization for Economic Co-operation and Development (OECD), "competency" refers to flexible applications of knowledge and skills in daily life, which can be expressed in self-learning, problem-solving, and adapting to the future [9]. Interdisciplinary STEM/STEAM education seems to be an effective model for competency-based teaching and learning. According to these authors, STEM/STEAM education facilitates interdisciplinary applications of science, technology, engineering, art, design and mathematics so that students can achieve meaningful learning for their daily life. Some effective teaching models for STEM/STEAM education are recommended for science teachers to put into practice in their classroom. For example, the DDMT teaching model, which includes four steps: discover, define, model and modelling, and transfer, provides a scaffold for teachers to develop their competency-based and interdisciplinary STEM/STEAM teaching activities [9, 10]. The DDMT teaching model was adopted as the key teaching model for STEM/STEAM curriculum development in the "Tsing Hua STEAM School (https://tsinghuasteam.org)" alliance, which was initiated by the National Tsing Hua University (NTHU) in Taiwan. The "Tsing Hua STEAM School" emphasises K-12 students' gaining of interdisciplinary learning experiences by solving and understanding daily life phenomena and problems via maker practices.

What would then be some of the important competencies for teachers to teach, which they would therefore need to learn during their professional education? When we face this question, we are located on a continuum with two very recognisable ends: 1. competencies that belong to science, working as a sort of "Ockham's razor" to demarcate science from common sense and from other human activities, or 2. more general competencies directed to citizenship, for which science would be an instrument or a *context*.

Mid-way in between these two positions, we could talk about "paradigmatic" scientific competencies, modelled on central traits of science. Such competencies would satisfy, at the same time, two requirements: 1. they would show the most characteristic elements of the scientific activity (and this does not imply that we naively believe that such characteristics are exclusive of science); and 2. They would enable students to acquire ways of understanding the world with scientific concepts and, at the same time, to critically discuss the nature of science as a human endeavour.

Among the "good candidates" for paradigmatic competencies, we could identify those related to:

1. grasping the methodological dimension of science;

2. producing texts in the different scientific "genres" in order to elaborate, justify and communicate scientific ideas;
3. using models while understanding their nature as representations, and
4. producing and defending solid arguments in favour of established scientific understandings of phenomena. It is worth noting that these four competencies have a hybrid cognitive-linguistic nature.

The aforementioned competencies, and other instances that science teacher educators could collective define, are perhaps key constituents of the definition of a scientifically educated citizen: they help meet current social demands such as engaged social participation, informed decision-making, critical thinking, or the ability to critically manage information in mass media.

In the particular case of the competency of scientific argumentation, the careful selection of the (socio-) scientific problems and issues on which students are going to argue would help them to apply and evaluate the scientific models and, at the same time, to discuss and incorporate an educationally valuable "image of science" that presents it as a deeply human activity of enormous social relevance.

3 Concluding Remarks

Adopting an operational definition of competency for science teacher education requires the identification of content to be taught ("big" scientific ideas that are essential), but also of "modes of thinking" that give support to scientific activities and are valuable in order to educate our students of different educational levels. In this sense, it is interesting to cite Díaz Barriga [2] idea that "the best way to see a competency" is in the "amalgam" between abilities, data and information, situations, aims, etc.

Students could be characterised as scientifically competent when all those elements can be put into action not only in school situations, but also in a wide variety of new conditions, thus demonstrating a high level of "transversal" applicability to a diversity of contexts [11, 12]. In accordance with this, science teachers would be genuinely competent when they can guide their students in the application of what they have learnt to *meaningful and relevant* contexts. This would require for them the competency of carefully designing science classes that accompany the whole process.

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