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SCIENCE TEACHER COMPETENCIES IN A KNOWLEDGED BASED SOCIETY

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Abstract. Science teachers' competencies are analyzed in this paper. The importance of teachers' competencies is underlined and also the importance of competencies in so called "good practices" obtaining, is studied. The definition of science teachers competencies and their taxonomy are very important in understanding the educational reform in European context. . The recent literature and many reforms in the field of science teacher education suggest that teacher preparation has a "threefold structure" with the anchoring pillars being Subject Matter Knowledge (SMK), Pedagogical Knowledge (PK) and Pedagogical Content Knowledge (PCK). Science education programs should pay more attention into the learning of science in social and technological context. The reform in the educational field has to pay a special attention on science teachers' competencies.

Zusammenfassung: In diesem Artikel sind die Kompetenzen der Naturwissenschaftslehrer analysiert. Die Wichtigkeit der Kompetenzen der Lehrer und die Kompetenzen in den sogenannten "gute Praktiken" werden studiert. Die Definition der Kompetenzen der Naturwissenschaftslehrer und deren Taxonomie sind sehr wichtig für das Verstehen der Reform der Schulbildung im europäischen Kontext. Die neueste Literatur und viele Reformen im Bereich der Wissenschaftslehrerbildung lassen vermuten, dass die Vorbereitung der Lehrer eine „Dreifachstruktur" mit den Schwerpunkten Fachkenntnis, pädagogische Kenntnisse und Kenntnisse des pädagogischen Inhaltes. Die Wissenschaftserziehungsprogramme sollten mehr auf das Lernen der Naturwissenschaft im gesellschaftlichen und technologischen Rahmen achten. Die Reform des Erziehungsbereiches muss ihre Aufmerksamkeit speziell auf die Kompetenzen der Naturwissenschaftslehrer richten.

Key words: science teacher, subject matter knowledge, competencies, good practices

1. Introduction

Many researchers, trainers and associations, currently working on proposing standards for science teachers' education and profession, have tried to analyse the new role characterising the science teacher by focusing on the involved "*competencies*". This concept is considered relevant in all professional fields and particularly in education research, given the fact that these processes are based on interactions amongst human beings.

A definition proposed by De Ketele (1996) is the following: "A competence is a set of organized capacities (activities), which act on contents in a given category of situations in order to solve a problem." In this definition a competence is described as an ability to carry out a specified task or activity to predetermined standards of attainment. According to De Bueger-Vander Borght C. (1996) : "competence refers to a state of being well-qualified to perform an activity, task or job function. When a person is competent to do something, he or she has achieved a state of competence that is recognizable and verifiable to a particular community of practitioners. A competency, then, refers to the way that a state of competence can be demonstrated to the relevant community".

In such definitions the notion of competency is confined to the ability to perform a discrete task or "discrete workplace requirement". The notion that tasks and workplace requirements can be discrete from knowledge, skills, values, attitudes and context is problematic.

A parallel evolution of a more complex view of competency from many researchers in the last decade recognises a concept which incorporates "the ability to transfer skills and knowledge to new situations and environments" as well as the performance of tasks expected in the workplace. This "broader" concept can include among others: the performance of tasks, the management of a series of tasks, the ability to respond to irregularities and contingencies, the capacity to deal with the complexities of the workplace including taking responsibility and working with others, the ability to put one's knowledge, skills and attitudes to new tasks and to new situations, not putting aside respect of others human beings or tolerance of other values.

Pellerey (2001) has reconstructed the evolution of the competency concept during the last years; now it means not only the mastery of knowledge and methods, or the ability to manage them, but also the ability to integrate different kinds of knowledge, and to use them synergically. Therefore to be competent in a certain area implies the ability to mobilize one's own knowledge and to transform it into concrete doing: competency is an individual characteristic and is built (through self-experience and formation) in a given field and in a given area of problems. It includes the content of the learning process as well as the context where it happens and the ability to apply the grasped content (Coggi, 2002).

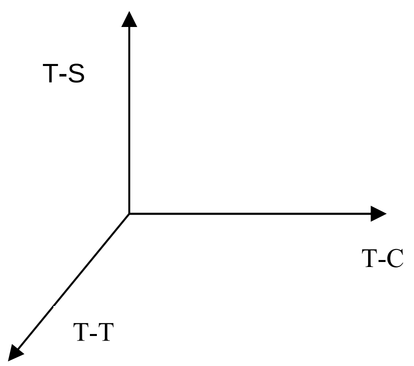
A "competence" has been defined as a collection of resources (knowledge, know-how, knowledge to be) mobilized to solve problems in a particular context. (Roegiers 1997, Jonnaert & Vander Borght 1999).

2. Competencies' classification

All the researchers involved in the study of competencies in different professional fields have focused on the concept of mobilization (Le Boterf 1994), i.e. the ability to make operational (ready) the one's own resources in order to solve a category of problems (problems with similar characteristics).

Several starting viewpoints may be used when addressing the problem of identifying the main competencies required to teachers. As when defining hierarchies, the definition is not unique and several types of classification and/or categorisation are valuable

A general framework that can underlay whatever type of competencies' classification is show in Figure 1. Thinking of the <u>interactions</u> a teacher is involved, a representation in a 3D orthogonal Cartesian space can be useful (see Figure 1).



The three axes can represent, respectively, the <u>interactions</u> of the teacher with him/herself (T–T), the ones with the individual student and the class (T–S), the ones with the global context of the school (T–C).

Figure 1. Interactions in which a teacher is involved

Several competencies refer mainly to interaction of type T-T, for instance those related to personal beliefs, ideas, opinions, attitudes, practices, as: - the action of reflecting upon strength and weakness of one's own teaching strategies and techniques; - the identification of weak disciplinary knowledge areas that need to be reconstructed and/or re-thought; - the action of eliciting one's own intuitive epistemologies and models about what teaching processes are; - one's location in a continuum ranging from an extreme inspired to behaviourist teaching models to an extreme inspired to constructivist or constructionist teaching models; - the aimed goals and interests in implementing the current teaching; - and so on.

Other types of competencies refer mainly to interactions of type T-S, for instance those related to: - owns ideas about learning processes; - the capabilities of implementing different learning environments and tuning them to the class characteristics; - the choice of approaches that enhance the students' motivation and interest; - which assessment methods are chosen and why; - the capability of guiding the class toward a learning convergence, while respecting the learning dynamics of the individual student; - and so on.

Finally, (T – C) is the interaction type to which mainly refer competencies like the ones required to the teacher in order on one side, to interact constructively with: - the school administration; - the central or local educational authorities; - the students' families and the territory/environment and, to make "best choices/practices" in relation to: - the contents of the syllabus (which ones to be emphasised more and less); - and so on.

Metaphorically the dimensions of this 3D space can be thought as three basic colours. A specific competency can be seen as a point in this space. Its' "colour" derives from the mix of different "colours" representing the axes.

The literature about teachers' competencies is very rich (the bibliography reports a non exhaustive list). The articles may be divided in two categories, the ones (group A) whose focus is on "*the individualisation of the main components, the main skills needed to be a good science teacher"* and the others (group B) where the focus is on *"what science education is needed by young people today*". This last group is, in our opinion, interesting since the issue of students' competencies is strictly connected with that of teachers' competencies, even if the two sets are not overlapping.

As far as group A is concerned, the question on how "*to individualize the main components, the main skills needed to be a good science teacher"* is addressed by Barnett and Hodson (2001) with the aim "*to draw together the ideas which can usefully be synthesized into an environmentally based framework to help clarify the knowledge that good teachers possess, and how that knowledge is deployed in diverse ways to suit the particular educational context*". Their starting point involves two key ideas started from the mid-1980s: the Teachers' *Personal Practical Knowledge* and their *Pedagogical Context Knowledge.* As far as the *Personal Practical Knowledge* is concerned, the authors claim that this is basically rooted in the teacher's class experience. The items included in the *Pedagogical Context Knowledge* are: - academic and research knowledge, pedagogical content knowledge, -professional knowledge, -classroom knowledge. A list of the components of *Science Teachers' Knowledge* is also given by the authors quoted above; here are some examples:

- Scientific knowledge
- Personal philosophy of Science Education
- Use of strategies for assessing science learning
- Use of strategies for integrating science with other subject
- Political and sociological knowledge of schooling
- "Psychological" knowledge of students
- Facilitation of learning

As far as group B is concerned, Osborn, J. and Millar, R (2000) answer to the reported question "*what science education is needed by young people today*?", by indicating the main problems related to the science education curriculum: "*young people lack familiarity with scientific ideas…..school science fails to develop and sustain the sense of wonder…"* A list of reasons for such problems are then presented by the authors such as e.g. : *"the science curriculum can appear as a catalogue …it lacks a well articulated set of aims…assessment is based on exercises…"*

One can infer that in order to overcome the problems outlined by Osborn and Millar the science teachers should:

- be familiar with scientific ideas
- present the curriculum in a coherent way
- develop students' sense of wonder and curiosity
- have knowledge of pupils' scientific capabilities (referred to their age)
- have knowledge of the most useful assessment tasks

- integrate science and technology
- know and analyse the scientific issues that permeate contemporary life
- be open to investigation and innovation practices
- be able to adapt the science curriculum to the diversity of interests and aptitudes of young people

Other researches (Magnusson et als. 1999, Loughran et als 2001,) have tried to analyse what Science Teachers (ST) know and what they do in their classrooms in terms of different kinds of *Knowledge* and *Competencies* recognised as relevant. They report that these are very difficult to factorize or to separate in well defined groups and that a picture that can capture them and their relationships is that of a net where, as first order approximation, regions of similarity can be pointed out, evidenced, but not enucleated from the context. The recent literature and many reforms in the field of science teacher education suggest (Tuning Project) that teacher preparation has a "threefold structure" with the anchoring pillars being Subject Matter Knowledge (SMK), Pedagogical Knowledge (PK) and Pedagogical Content Knowledge (PCK).

3. Good practices related on competencies

In the perspective of a pedagogy based on competencies, the practices are the main goal of the science teachers training.

(1) Scientific processes (hypothetico – deductive process) for observations, experiments etc;
(2) Research of information (bibliography) and critical analysis of this information;
(3) Realisation of didactical situations (problem based situation, pedagogy of project, etc.);
(4) Management of these situations;
(5) Scientific communication (written reports, oral speeches, drawings, diagrams & other images);
(6) Evaluation

Competence in epistemology
- Epistemological competence on models building, on processes of the students' modelisation, and on the functions and limits of each model.
- Competence in the use of technical and scientific apparatus and engineering.
- Competence to define criteria of categorisation (an important process in different scientific domains, as taxonomy, DNA sequences, …)
- Competence on the history and limits of validity of each scientific concept, and on the social dimension of the science.
- Ability to differentiate a scientific proposition to a non-scientific one.
- Ability to differentiate a scientific discourse to a dogmatic one.
Competence in bibliography
- Competence to use internet, CD-Rom, books library, etc.
- Competence for a critical analysis of documents of science popularisation (journals, magazines, books, radio, TV, etc.)
Competence in Science Education (Didactics of Sciences)
- Analysis of learners' conceptions on a scientific topic, before teaching this topic, and after this teaching to evaluate the eventual conceptual changes.
- Use the learners' errors not to judge them but as conceptions to be analysed and then changed.
- Identification of epistemological (and didactical) obstacles, to define new strategies of teaching focused on these obstacles
- Building of didactical situations adapted to learning. For instance, problem based situations, or projects (to realise individually or by little groups).
- In particular, sequences to learn scientific concepts, and / or scientific processes (laboratories).

- Competence to define the didactical contract and the situation to the learners, and to present them to learners as a space of active autonomy for them.
Competence in Didactics of Sciences and in Pedagogy
- Competence to induce the devolution of this situation by the learners: they must be motivated to be active in this situation. They have to be implied in the choice of their topics and activities.
- Competence to manage the situation, to improve debates and socio-cognitive conflicts.
- Competence to hear the pupils and students, and to take into account their questions.
- Competence to manage problems of violence, disorder and other difficulties in the classroom.
- Competence to analyse his or her own reactions (psychology) and the students' ones.
- Competence of the teachers to analyse their own reactions in these situations; to manage students' practical, theoretical or speculative works.
- Competence to analyse the scientific background of each student activity and to help them to find these theoretical pre-required.
Competence in didactical transposition and use of language
- Adaptation of the scientific language in a language adapted to children; idem for the images (didactic transposition for each scholar level).
- For each scientific notion, proposition of a progression of teaching – learning sequences, in respect with different students' ways and speed of learning.
- Use of good metaphor, examples and other pedagogical strategies.
- Competence to motivate and help students to write reports on their activities.
Competence in Evaluation
- Competence to imagine processes of analysis and validation of the students works, of their hypotheses and conjectures.
- Competence to do evaluation of the students activities at different steps of their work, to help them in their learning and to prepare them for the final evaluation.
- Competence for a final evaluation on known criteria, if possible avoiding the "by heart learning", and corresponding to acquisitions of the taught competencies.

The precedent competencies can't be acquired without previous acquisition of knowledge. It should be paradoxical if the science teachers would be taught by a traditional pedagogy to learn new ways of pedagogy (based on competencies).

A part of their training is mainly practical. Nevertheless, most of the precedent competencies are based on identified knowledge, which can be taught in different fields:

(1) The scientific matter (Physics and / or Chemistry and / or Biology and /or Biology and / Geology and / or Environment, Health). A science teacher must know well not only the science concepts, but also the scientific processes (experiments, models) and their limits of validity;
(2) History and epistemology of the science domain;
(3) Didactics of this science matter;
(4) Computer sciences for the new technology of information;
(5) Psychology and socio-psychology;
(6) Sociology and laws concerning the organisation and functioning of the educational system;
(7) Philosophy, ethics, to analyse the values (see above point –I-).

4. Conclusions

A science teacher should know how to relate science with other subjects and to frame phenomena in a multidisciplinary context. Science teachers who teach one discipline should be able to relate its content to relevant content in other disciplines (inter-disciplinarity) or in disciplines such as mathematics or technology (multi-disciplinarity). Phenomena by their nature involve various disciplines: so a teacher should be able to search for explanations involving the single discipline and at same time frame it in a multidisciplinary scenario.

Therefore, a science teacher training program should offer trainees the knowledge and awareness of the relationships between disciplines. This competency cannot be accomplished in the framework of a strict disciplinary-separate training program. Furthermore, prospective teachers should be provided with instruction that facilitates the identification and development of concepts that unify the traditional science disciplines. In such a training there should be included specific learning opportunities and instruction that would help prospective teachers to develop such interrelationships

Science education programs should pay more attention into the learning of science in social and technological context, such as field trips, arranged visits to museums or to industries and institutions .

Such training programs must allow teachers to develop a deep understanding of scientific ideas and the manner in which they were formulated.

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