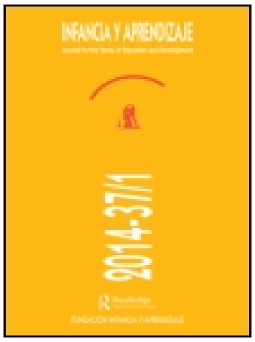

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Assessment for learning: Science teachers' ideas on assessment of core competences in science understanding

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Resumen

This study has two objectives: to describe the nature of the main competencies to acquire in the context of experimental sciences and its implications for assessment, and to analyse the kinds of task preferred by teachers for their assessment. Four basic competencies, whose importance is specially underlined in the Spanish curriculum, have been considered: Conceptual understanding, Scientific text comprehension, Tables and graphs understanding, and Use of scientific thinking. Five different complexity levels for assessing the degree of each competence acquisition have been established. Our data, obtained from a sample of 30 Spanish Secondary School teachers, show that teachers tend to assess mainly Conceptual understanding no matter the level of difficulty, secondly, Use of scientific thinking conceived as solving standard problems, and finally, assessment of Text, Table and Graph understanding presents a great scattering, depending on the level of task difficulty. ANOVA results show that, in general, tasks implying lower levels of cognitive demand are used more often than most difficult tasks. Finally, to identify teachers' profiles in relation to the kinds of task they use, a correlation analysis has been done.

Keywords: Assessment, competencies, text comprehension, understanding of tables, understanding of graphs, scientific thinking.

Evaluar para el aprendizaje: ideas de los profesores de ciencias sobre cómo evaluar competencias fundamentales para comprender la ciencia

Abstract

El estudio tiene dos objetivos: describir las características de las principales competencias a adquirir en ciencias experimentales y analizar los tipos de tareas preferidos por los profesores para su evaluación. En el marco del currículo español se han considerado cuatro competencias básicas: Comprensión de conceptos, de textos científicos, de tablas y gráficos, y Uso del pensamiento científico, estableciendo en cada una de ellas cinco niveles de complejidad para evaluar el grado de adquisición. Los resultados, obtenidos a partir de una muestra de 30 profesores de Educación Secundaria, señalan que la Comprensión conceptual es la competencia más evaluada, independientemente de su nivel de dificultad. En segundo lugar aparece la evaluación del Uso del pensamiento científico, entendido restrictivamente como resolución de problemas estándar. Por último, la evaluación de la Comprensión de textos y de Tablas y gráficos presenta una gran dispersión en función de su nivel de dificultad. El Anova realizado muestra que, en general, las tareas más utilizadas son las que implican un nivel inferior de demanda cognitiva. También se ha efectuado un análisis de correlación con el objetivo de identificar la existencia en el profesorado de perfiles conforme al tipo de tareas utilizadas en su evaluación.

Palabras clave: Evaluación, competencias, comprensión de textos, comprensión de tablas, comprensión de gráficos, pensamiento científico.

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There is growing interest among psychologists and educators in knowing what personal and environmental factors affect learning motivation, understanding and conceptual change in order to favour these processes (Alonso-Tapia y Fernández, 2008; Alonso-Tapia y Pardo, 2006). At the same time, in order to promote educational improvement, educational authorities introduce curricular reforms from time to time. However, the success of such reforms depends not only on how much the content and methodology of such reforms is based on research advances and adapted to students characteristics, but also on the way teachers put them into practice. This factor, scarcely considered, may be responsible of why many educational reforms tend to fail (McDermott, 1991). So, the problem is how to motivate and help teachers to change their methodology.

According to recent developments (Birembaum et al*.,* 2006; Segers, Dochy & Cascallar, 2003) assessment is one of the environmental factors that most influences learning activities and the promotion of learning. So, in order to improve students' learning it seems necessary to change not only instruction but also teachers' perspective on assessment. Instead of "testing" the amount of knowledge that students have, assessment should provide information –to the teacher or the student him/herself– that may help students to overcome their difficulties and to self-regulate their understanding and learning processes. However, there is evidence that the preferred ways of assessment of many teachers have many shortcomings, perhaps because of their dependence on textbooks. Assessment tasks are often not valid criteria of understanding and cognitive ability, as they rely mainly on root learning. In fact many tasks do not allow teachers to identify the source of students' difficulties, and so feedback lacks the necessary quality to be of help for overcoming learning problems. Other times, research has shown that teachers have different perceptions of the kind of competences relevant for achieving according to scientific literature, and that these perceptions are also different from those underlying the PISA programme and considered important by educational authorities (Pinto & El Boudamoussi, 2009), a fact that makes difficult a coordinated work aimed at enhancing this literacy.

In a theoretical paper, Birembaum et al. (2006) point to the shortcomings of current assessment practices and suggest alternative directions to overcome them, such as portfolios, projects and problem solving, alternatives that are not without criticism (Klassen, 2006). Nevertheless, this review does not deal with the characteristics that specific tasks related to different learning objectives should have in order to promote understanding and conceptual change. This was a problem examined for us in a previous work (Alonso-Tapia, 2002). According to this work, when trying to promote understanding and conceptual change, assessment contexts should have several characteristics from which three of them are relevant for the purpose of this paper: a) Most suitable tasks are those demanding the application and use of knowledge for solving problems implying some degree of novelty (analogous and transfer tasks); b) tasks should be designed to allow teachers to identify specific factors in students that hinder understanding; and c) the assessment process should cover the different nodes and links of the conceptual or procedural network that the students are supposed to have construct. Nevertheless, do teachers' assessment practices approach this ideal?

In order to know how to help teachers to improve their assessment practices, it is necessary to take into account that teachers will not change their assessment practices unless they are aware of the discrepancy between the kinds of evidence adequate for showing the competencies their students should acquire, and the kinds of information provided by the assessment procedures they usually employ (Pérez-Landazábal & Moreno, 1998). So, to facilitate such awareness it is necessary to know the characteristics of teachers' assessment practices. However, before evaluating whether assessment tasks used by teachers are adequate or not, it is necessary to establish what competencies students need to develop to achieve a meaningful understanding and learning of science principles and procedures, as well as its nature. Knowing the characteristics of such competencies will allow us to establish different complexity levels in which such competencies can be acquired by students. It will also facilitate teachers to understand the causes of students' difficulties and to develop assessment tasks for identifying them. So, the objective of this study will be twofold. First, we will describe the nature of the main competencies to acquire in the context of experimental sciences and its implications for assessment, and second, to analyse teachers' preferred ways of assessing such competencies and to evaluate their adequacy.

Theoretical framework

Different authors (Alonso-Tapia & Pérez-Landazábal, 1997; Lawson, 1994; Pinto & El Boudamoussi, 2009; Tamir, 1996) have described the capacities that are necessary for understanding science concepts and thinking as a scientist. McDermott, for example, pointed that when studying physic or chemistry, students should be able: a) to acquire descriptive knowledge, b) to interpret new situations using scientific concepts, c) to relate scientific concepts with their formal representations, especially when reading text, tables and graphs, d) to develop scientific reasoning (it implies, for example, variable definition, hypothesis formulation, proportional reasoning, analogical reasoning, etc.), and e) to solve problems. So, in the context of these ideas, our study is centred on four basic competencies –not in all possible competencies–, whose importance is specially underlined in the Spanish curriculum:

1. *Conceptual understanding.* It implies being able to describe phenomena and to interpret everyday situations using scientific concepts.
2. *Text comprehension,* that is, texts in which scientific concepts, principles and formalisms are used.
3. *Tables and graphs understanding*, that is, sources of information whose content and structure demand the use of specific procedures to be understood.
4. *Use of scientific reasoning*, that is, planning and carrying out small experiments.

Next, the nature of these competencies will be described.

Conceptual understanding

All along the history, scientists have created concepts and models to explain the structure of nature as well as the way it changes. This knowledge allows us to predict and have some control of our world. However, to be useful concepts, theories and models have to be understood, and not only learned by heart. So, the main educational objective of teachers of Physics or Chemistry is that their students are able to achieve a real understanding of the content taught. However, what does "*conceptual understanding*" imply?

In the first place, *conceptual understanding* implies *concept formation*, the construction of categorization rules that "allow considering equivalent things that appear different" (Bruner, Goodnow & Austin, 1956). In the second place, *conceptual understanding* implies *concept identification*, the association of the rule underlying a verbal term to that concept, an association that requires prior formation of the concept. Sometimes students may have formed a particular concept, as can be inferred from their reactions to exemplars and non-exemplars of it, but they do not know the verbal label. Other times, they associate a verbal label to conceptions different from those that experts attach to this label. This fact is due to the existence or previous or alternative ideas whose effects on understanding are well known (Duit & Treagust, 2003). In the third place, and as a part of the process of concept identification, conceptual understanding implies *concept differentiation.* For instance, students have to be able to differentiate heat and temperature: identify the meaning of one of them implies being able to distinguish it from the other.

The base of conceptual understanding relies on the fact that things –objects, phenomena, processes, etc.– can be considered equivalent on the base of their *structural, functional or relational proprieties*.

For example, the fact that a student is able "to enumerate the kinds of energy he or she knows" or "to calculate the kinetic energy of an object in motion" does not imply to have understood adequately the concept of energy. It is also necessary to recognize that every kind of energy can be transferred or transformed by means of work or heating processes and that, at the same time, its quantity remains the same even if it has become degraded: these qualities are the structural proprieties of the "energy" concept.

Moreover, a student must be able to recognize and apply the main *functional propriety* of "energy": that it can produce changes, that any change implies a degradation of energy –a part of energy is dissipated in form of heat–, but also that energy changes imply an energetic balance: no energy is lost.

Besides, conceptual understanding implies also becoming aware of the way *concepts relate each other, often in hierarchical ways,* as the phenomena to which they refer are also related. For example, work, forces, speed, etc., are related concepts, as they refer to phenomena that are also related: To increase the energy of an object by means of work, it is necessary to apply forces able to change its position (for instance, its height) or its speed, but all these magnitudes are related in predetermined ways.

Finally, conceptual understanding implies also being able to recognize the processes underlying the phenomena, as well as to be able to detect patterns of interaction between them. For example, understanding the concept "combustion" referred to the combustion of a candle implies to identify as intervening and necessary factors the energy of the heating focus (for example, a match) and the presence of oxygen in the air: both are necessary but insufficient factors, as the process would not occur if one of them was not present. Another example of interaction between factors is the boiling of a liquid: water boils at 100ºC at sea level, but in the Everest mounting ebullition temperature decrease considerably due to the lowering of atmospheric pressure.

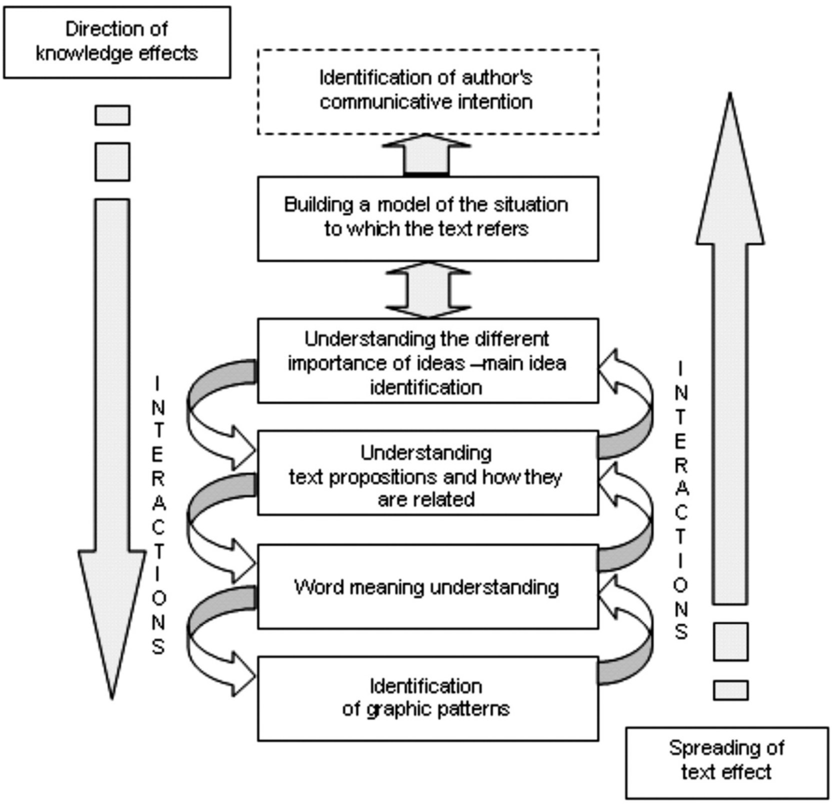
According to the characteristics of conceptual understanding just described, the degree of understanding achieved by students could be categorized in five complexity levels, as described next.

- *1st Level: Basic categorization.* The first indicator of conceptual understanding is the capacity of considering similar phenomena that appear different at a first glance as, for example, to recognize that the different kinds of energy that can be identify in an electric hairdryer are different exemplars of the concept "energy".
- *2nd Level: Concept differentiation.* This capacity in fundamental in science learning. Students have great difficulties to distinguish between magnitudes such as speed and acceleration, force and energy, etc. (Pérez-Landazábal & Moreno, 1998).
- *3rd Level: Building hierarchical relations between concepts.* Teachers must help their students to build an integrated view of science, not a compartmentalized one. This objective can be achieved, for instance, working with conceptual maps.
- *4th Level: Explaining everyday physic or technical situations using the scientific language*. The use of scientific concepts in daily situations implies a first transfer of conceptual understanding. For example, students should be able to recognize what kinds of energy transformation are possible and what are not in a loudspeaker taking into account the principles of energy conservation and degradation.
- *5th Level: Recognizing complex cause-effect processes.* Understanding physical, chemical, biological or geological processes imply not only identify their causes, but also knowing the reasons that makes a factor cause a given effect.

Text comprehension

Experimental science teachers try that their students understand physical and chemical concepts, relations and processes. To achieve this objective, students have to understand the information included in different kinds of document, from which the most important are texts. Besides, the development of text comprehension ability is an objective to be achieved by its own sake according to the Spanish curriculum. As a review of research on text comprehension has shown (Alonso-Tapia, 2005) and as it is shown in Figure 1, the vast amount of research on text comprehension coincides in pointing that this process implies the construction of a mental representation of text meaning at different levels, each one of these influences the final representation of the whole meaning (Kintsch, 1998). As reading is an intentional activity, the result of it will depend on the interaction between text characteristics and reader's activity –the processes and inferences that he or she does conditioned by his or her previous knowledge, purposes and expectancies. Along this interaction, comprehension depends on variables acting bottom-up –text characteristics– and variables acting top-down –previous knowledge or mental representations activated while reading. Comprehension, then, is not an all-nothing process, but a process taking place at different levels:

FIGURE 1
Levels of text comprehension



To understand word meaning. Without knowing word meaning it is impossible to understand a text. It happens often that readers meet unknown words. However, if they are able to deduce their meaning from textual context, the comprehension process is not obstructed (Sternberg & Powell, 1983). Word understanding, however, does not warrant text comprehension, even though it is what many readers use to believe.

To understand text propositions and how they are related. According to Kintsch (1998), the reader construct the meaning of a text through a cyclic activity in which he or she realise different kinds of inferences to represent the meaning: 1) of each proposition in a paragraph, 2) of the relations between them on the base of syntactic and semantic clues,

3) of the relations between the meaning of different paragraphs, etc. This activity allows readers to arrive through a progressive integration of text ideas to a global representation of text meaning. Therefore, text comprehension assessment should try to identify the kind of propositional representations that students build as a result of their inferential activity, as well as the factors that determine comprehension difficulties at this level –the syntactic and semantic clues that are not taken into account due to a lack of previous knowledge or of adequate reading strategies –for example, lack of identification of antecedents and consequents–, factors that have been identified and described in different studies (Carriedo & Alonso-Tapia, 1995).

To understand the different importance of ideas and to identify text main idea(s). Thematic progression in expository texts –the kind of text most used in science teaching– can follow different organisation patterns or structures. Depending on the kind of textual structure guiding text thematic progression, the relative importance of ideas varies. For example, in a generalisation text, in which a general statement is followed by several ideas or more specific examples included to clarify its meaning, the main idea is the general statement. However, in an argumentative text the main idea is the conclusion that the author is trying to defend by means of the argument.

To build a model of the situation to which the text refers. People usually represent the propositional meaning in the context of their personal experience. This representation that changes as text reading progresses constitutes what has been called a situation model (Kintsch, 1998). This situation model may or may not be adequate. For example, students' alternative conceptions of physical phenomena may obstruct the building of an adequate mental model.

To identify author's communicative intention. When writing a text, its author writes it whit a purpose –the communicative intention– more or less explicit but always identifiable from the structure and the content of the text and from the context in that it was written.

Table and graph understanding

Science books, reports and articles include often tables and graphs with information of different types. These communication tools make easy that students of different levels of competence understand information though not always, not even at university level (Körner, 2005; Schnotz & Bannert, 2003). Due to this fact, one of the objectives explicitly stated in the academic curriculum of some countries as Spain is to achieve the capacity of understanding information in tables and graphs. The curriculum states also that the achievement of such objective must be favoured through work carried out from the different curricular areas. Nonetheless, many secondary school students experience difficulties in understanding information in tables and graphs.

According to authors that have analysed table and especially chart and graph as communicative tools (Schnotz, 1993), these tools contain three kinds of information, no matter the differences in their way of presenting information (univariated or bivariated tables; bar, line or pie charts, etc.) or in the nature of data (nominal, ordinal, etc.): explicit, implicit but easily deducible and conceptual, causal o consequential information that need different levels of previous knowledge to be understood. This understanding is not an all-or-none question. The degree of understanding will depend on whether students process or not each kind of information, what in turn depends on whether the cognitive operations described next are carried out or not:

1st Level. Search and reading of title (explicit information).- This process allows the identification of the theme the tool deals with, activates different representations, and triggers different inferences depending on subject's previous knowledge.

2nd Level. Reading of legend and entries (explicit information).- The reading of legend and entries and the realization of inferences from this information in most educated adults is a complex process that affects comprehension, though people are often not aware of its complexity. Subjects need to identify:

– *Who or what is the information about*, that is, the "subject" the table, chart or graph are saying something about.

– *What kinds of information are given about the subject*. Tables and graphs can give more than one kind of information on the "subject" they are about.

– *What are the information characteristics*. In all cases, but some times in the legend and others in the body of the table or graph, their authors use to indicate whether data are frequencies, averages, percentages, proportions, or quantitative or qualitative information of any other kind of non-numerical entities.

3rd Level. Data identification and comparison, and identification of the basic information they are conveying (direct deduction of implicit information). The reader must be able to identify whether there are differences, tendencies, covariations or lack of them between data corresponding to different variables, as well as possible structural or causal relations between them. This step should allow the identification of the basic meaning the communication device is trying to convey.

4th Level. Deep interpretation of table, chart or graph (conceptual, causal or consequential information). This is the point in which is most likely to find differences between experts and novices. Even if the basic meaning of the display has been correctly identified, this identification may not be enough for its interpretation. At least in the context of experimental sciences, data tendencies, covariations, structure, etc., may arouse questions and inferences about their causes and potential consequences, inferences that are tied also to previous knowledge (Kintsch, 1998).

5th Level. Data evaluation. Understanding data implies also an evaluation of their credibility. This characteristic depends on whether the source is trustworthy or not, and on other characteristics as their degree of generality or specificity. Sometimes these factors may lead to erroneous inferences, especially to novices. This comprehension level implies additional previous knowledge as, for example, knowing what makes a data source credible.

Use of scientific thinking

According to the science curriculum, students should learn to think following the steps of scientific thinking. This competence is very important for two reasons, first, it allows the application of scientific knowledge to new situations; and second, it contributes to students' understanding of the nature of scientific research –to acquire *Knowledge about Science* according to PISA 2006 (MEC-IE, 2007)–. So, teachers should help the students to acquire this competence and should also assess the degree of acquisition in order to help them when necessary (Martínez & Varela, 2009; Varela & Martínez, 1998). However, which criteria should they take into account when assessing this competence?

A useful guide for teachers in this task is the model developed by Lahera and Forteza (2005). These authors consider that students need three kinds of abilities to be able to think following the steps of scientific thinking: Cognitive, instrumental and methodological abilities.

Cognitive abilities include *Basic* and *Integrated Processes*. The term *Basic Processes* refers to observation, to the realization of inferences and predictions, and to the process testing them. In turn, observation includes the identification, classification and measurement of variables. As for the term *Integrated Processes,* it refers to processes that allow to *solve problems* by means of research and *to build and use scientific models. Problem solving* is the scientific process most used in Secondary and High School Education. However, if the aim is that students learn to use scientific reasoning, it is necessary to propose *problem solving as an authentic research*, following the next steps: 1) *to ask research questions*, process that imply to give students the opportunity of asking themselves questions on what might happen in an open situation; 2) *to formulate hypotheses*, defined as ideas that can be generalized and tested; 3) *to make experimental designs* with an adequate control of variables that allow testing the hypotheses, and 4) to reject or accept the hypotheses on the base of the interpretation of results. *Building and use of scientific models,* the last step in the hierarchy of processes, implies to recognize the need of theoretical models to relate and explain in an integrated way the different phenomena, laws and empirical principles. Students should internalize that theory building is a part of scientific research, as empirical laws are not enough to relate and organize all the known phenomena (Klopfer, 1975).

Instrumental abilities are those abilities necessary *to use measurement instruments* –to select the adequate one, to read scales, etc.–, and to *data management* –to represent data by means of symbols, graphs, etc.

Finally, *methodological abilities* are those implied in using the scientific language for building argumentations and communicating results, and in using the math language for expressing the functional relations between variables.

Assessing the degree and adequacy in which students use the scientific thinking implies to test whether the student is competent in each of the above mentioned processes. However, as the capacity to think as a scientist is a gradual process, it is necessary to sequence its learning and to make explicit the grading criteria used in assessment activities (Nieda, Cañas & Martín Díaz, 2004). So, in order to evaluate the degree in which teachers' assessment practices when assessing this competence are adequate, following the proposal of Lahera and Forteza above described, we have established the following complexity levels for categorizing assessment tasks:

1st Level. Identification of variables and principles needed to solve problems. This is a basic process that also implies the adequate understanding of concepts and principles, and the correct use of scientific language.

2nd Level. Applying principles. Tasks assessing this process demand methodological abilities such as the adequate use of math language for identifying functional relations between variables, in addition to abilities described in level-1.

3rd Level. Carrying out experiments to test theories: basic level. This complexity level includes assessment tasks in which students are asked to solve problems implying observation, measurement, comparing magnitudes and data management. It includes also abilities described in previous levels.

4th Level. Solving problems carrying out an authentic research. These tasks demand greater cognitive ability than those of previous levels, as students must be able to ask research questions, to establish plausible hypotheses, and so on, such as described before.

5th Level. Building and using scientific models. Tasks demanding the student to relate different phenomena, laws or principles by means of a theory correspond to this complexity level.

Implications of previous models for evaluating the adequacy of assessment procedures

The theoretical models just described in relation to each of the basic competences implied in learning experimental sciences provides a framework that allows, first, to describe the preferred ways of Secondary Science teachers for assessing their students' knowledge, and second, to evaluate its adequacy. According to these models, teachers should design and use assessment tasks covering the different complexity levels if they want to identify not only whether students possess or not a given competence, but also the reasons of their failures when these happen. Nevertheless, as superior levels provide the most complete criteria of each capacity, tasks covering these levels should be used in a regular way. Do teachers' assessment practices adjust to this ideal? Answering this question is the objective of the following study.

Methodology

Sample. The sample of our study was formed by a group of 32 Secondary School teachers. Of them, 17 were males and 15 females. The mean age was 44 years, with a standard deviation of 5.9, and an age range from 31 to 50. They were the only ones from 125 that answered a mail sent from the Spanish Royal Society of Physics. This fact implies a limitation in order to generalize the conclusions of the study, but it is a practically unavoidable situation in studies of this kind. All of them teach to students of different academic levels –Secondary or High School–.

Materials. A test including nine open tasks that can be used for assessing students' knowledge was developed for the study. Teachers were asked to point, in a Likert scale ranging from 0 (never) to 6 (habitually), in what degree did they use each of the tasks for assessing their students.

The test is included in the Appendix. As it can be seen, the tasks were developed in relation to the four competencies whose nature and characteristics have been previously described. There are two or three tasks for each complexity level. Some of them correspond to elementary levels (second and third) and others to superior levels (fourth and five). No tasks were designed to cover level one because it was too easy for Secondary School students. Task corresponding to elementary levels were selected from textbooks very used, while those corresponding to superior levels were designed by the authors or taken out from PISA-2003 (MEC-INECSE, 2005). Task categorization is shown in Table I and described next.

TABLE I
Assessment task categorization

	2nd Level	3rd Level	4th Level	5th Level
I. Conceptual understanding	Task 3		Task 6	
II. Text comprehension	Task 8			Task 1
III. Table and graph understanding		Task 2		Task 7
IV. Use of scientific thinking	Task 5	Task 4	Task 9	

a) Conceptual understanding. Task 3 implies being able to distinguish a physical from a chemical change. So it belongs to the 2nd level of complexity, whereas Task 6 implies being able to recognize energy transformations that take place in an everyday situation including physical, chemical and biological phenomena. So it belongs to the 4th complexity level.

b) Text comprehension. Two fragments taken from scientific disclosure books were used. Task 8 implies recognising explicit information and providing answers that demand information not included in the text. So it belongs to the 2nd level of complexity. Task 1 includes questions covering all important components of text comprehension: word recognition, proposition understanding, main idea comprehension, situation model building and recognition of author's communicative intention. So it belongs to the 5th complexity level

c) *Table and graph understanding.* Tasks 2 and 7 assess this competency. For solving correctly Task 2, the student must apply the mass conservation principle. Without this prerequisite, he could not be able to complete the table. So, this task assesses the conceptual comprehension of a principle more than the capacity of comprehending the meaning that the table, as a whole, is trying to communicate. Therefore, it only reaches the 3rd complexity level. Task 7, on its side, does not require specific conceptual knowledge: it is enough to be familiar with alimentary diets (everyday knowledge). It has been designed to assess the five complexity levels, as it demands not only being able to compare data, but also to evaluate them from a critical perspective.

d) *Use of scientific thinking.* Three tasks of increasing complexity were designed for assessing this competency. Task 5 belongs to 2nd complexity level, as it only implies being able to identify the kinematic magnitudes related to the task and to operate mathematically on them. On Task 4, students are guided by mean of questions during the realization of an experiment. Then, they are asked to compare data obtained in the laboratory with data expected from theory and calculated from the stoichiometry of the reaction (experiments for testing the theory). This task demands the use of basic thinking processes as well as knowledge of techniques for experimental work, what places it in the 3rd complexity level. Finally, Task 9 requires being able to solve, following the experimental methodology, a problem proposed in an open way –without giving him or her any theoretical framework–. This fact forces the student to formulate hypotheses on the basis of his previous knowledge on the problem. So, it covers solving problem processes of higher order implied in carrying out a research, a fact that places this task in the 4th complexity level.

Data analyses. First, in order to know how often teachers use each kind of question, a descriptive analysis was carried out. Then, the significance of differences between the mean use of questions was assessed using Anova of repeated measures. Finally, in order to detect preferences in the use of task combinations for assessing students' knowledge, correlations between answers to each question were analysed.

Results

Descriptive analysis

Table II shows means and standard deviations corresponding to the use of each question for assessing the students' competencies under study, as declared by teachers. Table content has been arranged in descending order according to the frequency of use of each kind of task.

TABLE II
Use of each kind of assessment task. Means and standard deviations

Task	Competency	Level	*N*	Mean	*SD*
T5	IV. Use of scientific thinking	2	32	5.31	0.97
T3	I. Conceptual understanding	2	30	4.90	1.32
T2	III. Table/Graph understanding	3	32	4.50	1.44
T6	I. Conceptual understanding	4	30	3.93	1.64
T8	II. Text comprehension	2	30	3.57	1.91
T4	IV. Use of scientific thinking	3	32	3.34	1.95
T9	IV. Use of scientific thinking	4	32	3.28	2.05
T1	II. Text Comprehension	5	30	2.40	1.75
T7	III. Table/Graph understanding	5	32	2.19	2.05

It can be seen that tasks in the first five positions are those corresponding to the two low complexity levels –the only exception correspond to Task 6–. Tasks less used are those corresponding to the highest complexity levels. A more detailed analysis allows identifying tree tasks very frequently used (mean over 4): 1) "Standard or traditional" problems (T5). These tasks imply the correct application of mathematical equations previously learned; 2) Conceptual questions (T3) demanding concept differentiation, and 3) Table analysis (T2), a task that imply being able to identify and compare data, but that cannot be carried out without specific conceptual knowledge.

In the second place, we find Tasks 6 (*Conceptual understanding*) and 8 (*Text comprehension*) that are used in a similar degree. The examination of Task 8 shows that it includes questions on information that is explicit on the text (corresponding to 2nd complexity level), and questions on conceptual comprehension outside the text. This fact, habitual in tasks of text comprehension used by teachers, could explain the similarity in the degree of use assigned to Task 6 and 8.

In the third place we find problem solving Tasks 4 and 9, categorized in the 3rd and 4th complexity levels. Their degree of use is two points lower than that of T5, a standard problem solving task. This fact suggests that, generally speaking, teachers do not use almost never higher order tasks: experimental tasks (T4) and problem solving task implying the *Use of scientific thinking* (T9).

Finally, tasks corresponding to the 5th complexity level are clearly the least used (means are lower than 2.5). The first of these tasks implies reading a text and answering questions covering all the main comprehension levels (T1). The second one is a task whose realization demands being able to integrate different kinds of information not related in an explicit way to contents studied in the classroom.

Analyses of differences between the degrees of use of each kind of competence assessment task

Anova of differences between the degrees of use of the nine tasks shows that they are highly significant ($F_{Gl: 6.7, 173.7} = 11.479$; $p < .0001$). Then, as our main interest is to study differences in the use of assessment tasks related to the same competence, we analyzed the significance of such differences carrying out four ANOVAs, on for each kind of competence.

Results of these analyses are shown in Table III. As it can be seen, there are significant differences between low and high complexity tasks in the first three competencies, and also in two of the tasks for assessing the *Use of scientific thinking*. The examination of tasks corresponding to each pair of means related to the first three competencies shows that preferred tasks are those of low complexity levels, that is, those that are less cognitive demanding for the students. This difference is specially marked in the case of *Table and Graphs understanding* tasks, a fact that underlines the rather limited use by teachers of tasks like those of PISA, a kind of tasks that are related to everyday situations, and that demands the integration of different kinds of information.

TABLE III

Anovas of differences in use of tasks assessing the same competency

Competencies	Task	Level	Means	*SD*	*F*	Sig.
I. Conceptual understanding	3	2nd	4.90	1.32	12.25	.002
	6	4th	3.97	1.67		
II. Text comprehension	8	2nd	3.57	1.91	15.55	.000
	1	5th	2.40	1.75		
III. Table/Graph understanding	2	3rd	4.50	1.44	41.16	.000
	7	5th	2.19	2.05		
IV. Use of scientific thinking	5	2nd	5.31	0.96	29.81	.000
	4	3rd	3.34	1.94		
	5	2nd	5.31	0.96	26.76	.000
	9	4th	3.28	2.05		
	4	3rd	3.34	1.94	0.02	.896
	9	4th	3.28	2.05		

In relation to the tasks designed for assessing the *Use of scientific thinking*, the results show significant differences between Task 5, on one side, and Tasks 4 and 9, on the other. Task 5, a standard problem, presents the highest mean and the least dispersion, what implies that it represents the kind of assessment tasks most used in Spanish Secondary School. Tasks 4 and 9, on its side, did not differed in the degree of use by teachers.

Correlation analyses

In order to detect preferences in the use of task combinations for assessing students a correlation analysis was carried out. Results are shown in Table IV.

TABLE IV
Correlations between the degree of use of different assessment tasks

Tasks										
Task	Level	Competency	T2	T3	T4	T5	T6	T7	T8	T9
T1	5th	Text Comprehension	-	-	-	-	-	.549**	.611**	-
T2	3rd	Table/Graph understanding		-	.421*	-	-	.361*	.372*	-
T3	2nd	Conceptual understanding			-	.352*	.545**	-	-	.453*
T4	3rd	Use of scientific thinking				-	-	.371*	-	-
T5	2nd	Use of scientific thinking					-	-	-	-
T6	4th	Conceptual understanding						.390*	-	.394*
T7	5th	Table/Graph understanding							-	-
T8	2nd	Text Comprehension								-

*: $p < .05$ **: $p < .01$

As can be seen, with the exception of questions related to the *Use of scientific thinking*, correlations between tasks of the same competency are significant. The greatest values correspond to *Text comprehension* (T1-T8: $r = 0.611$), followed by *Conceptual understanding* (T3-T6: $r = 0.545$) and by *Table and Graph understanding* (T2-T7: $r = 0.361$). These results suggest that when teachers have to assess concepts, texts and tables, they tend to use different kind of tasks though, according to data in Tables II and III, they use low level complexity tasks much more than the others. The high coefficient found between *Text comprehension* tasks, in spite of the difference between the degrees of use of them, suggests that there are two teachers' profiles: teachers who use texts no matter how difficult they can be, and teachers that do not use texts as assessment tasks. In the case of *Table and Graph understanding,* the picture is less coherent. So we cannot define profiles. In general, all teachers use tables, but they prefer those of low level of complexity. In the case of tasks designed for assessing the *Use of scientific thinking*, the lack of significant correlation between the standard-problem (T5) with the other two tasks is logical given the great use that all teachers make of this kind of problems.

As for correlations between tasks designed for assessing different competencies, it is worth pointing the high value reached by 5th level complexity tasks (T1-T7: $r = 0.549$). This result means that, though these tasks are not very used, there is a profile of teacher that uses these kinds of question that allow a best identification of students' difficulties.

Finally, teachers tend to assess conceptual knowledge using different kinds of tasks, as it is shown by the correlation between scores corresponding to task assessing stoichiometric contents (T2-T4; $r = 0.421$). We would have expected differences between them, as in one case students have to analyze a table whereas in the other they have to carry out an experiment. However, teachers seem to use them in the same degree. And the same can be told of questions related to everyday situations. (T6-T7: $r = 0.372$).

Discussion and conclusions

At the beginning of this study we asked ourselves whether teachers' assessment practices were adequate for identifying factors in students that hinder understanding and competence acquisition, and for giving them the kinds of feedback they need to overcome their difficulties. It was advanced first that, in general, most suitable tasks were those demanding the application and use of knowledge for solving problems implying some degree of novelty (analogous and transfer tasks). Then, after revising theory and evidence on the nature of basic competences to be acquired when working in experimental sciences, five different complexity levels for assessing the degree of each competence acquisition were established. It was also specified that unless students achieved the superior levels, they cannot be said to have acquired the competence. So, do teachers' assessment practices should systematically include tasks covering these levels? How much do they approach this ideal? What can be concluded form our data?

First of all, *which competences are assessed most often?* Our data have shown that teachers tend to assess mainly "*Conceptual understanding*", no matter the level of difficulty. This conclusion comes not only from questions designed for this purpose, but also from tasks designed for assessing other competencies with a great conceptual weight. Then the next competence most frequently used is "*Use of scientific thinking*" conceived as solving standard problems whose solution implies using mathematical equations, and not solving problems planning and carrying out experiments. Finally, the assessment of *Text comprehension and Table/Graph understanding* present a great scattering depending on the level of task difficulty. Teachers assess these competencies quite often, but mainly with tasks of low-level of difficulty, and not with complex tasks.

Second, *which difficulty levels are mainly assessed?* Anova results have shown that, in general, tasks implying lower levels of cognitive demand are used more often than most difficult tasks. This occurs, from higher to lower degree, when assessing *Table and graph understanding,* then *Use of scientific thinking,* then *Text comprehension,* and finally, *Conceptual understanding.* In relation to these results, two facts deserve special mention. First, the scarce use made by teachers of complex tasks for assessing *Table and graphs understanding*. As the task used is similar to the task included in the study PISA 2003, one should expect a greater use by teachers of this kind of task. The fact that it was not the case suggests that teachers' conception of what kind of tasks and evidence are valid indicators of this competence differs from the conception of educational authorities. Besides, it should be mentioned also the great difference between the use of tasks demanding standard problem solving for assessing *"use of scientific thinking"* compared to the use of experimental or research work. This fact may be due to the scarce use of lab work in the Spanish schools or to the effect on teaching assessment practices of the kinds of assessment tasks use in exams for accessing university studies.

Third, *can we identify teachers' profiles in relation to the kinds of task they use?* To answer this question it should be considered, on one side, whether *there are questions referred to the same competence used by the same teachers.* That is, when a teacher designs and uses a kind of question for assessing a given competence, does him or her also tend to use the other kinds of question referred to the same competence? As showed by the analysis of correlations, teachers tend to be systematic in the assessment of competences such as *Text comprehension* and *Conceptual understanding*, that is, if they assess these competences, they assess them using the different kinds of questions related to it, though in different degree. However, they are not so systematic when assessing *Table and graph understanding,* as they tend to use only low-level tasks. On the other side, it should also be considered whether *teachers tend to differ in the level of questions they prefer to ask*. The answer is affirmative. There are teachers that ask high-level questions no matter the competence, whereas there are others that ask mainly low-level questions. In summary, many teachers tend to assess only some competences, and they tend to use mainly questions of only one complexity level. However, in order to help students to acquire the different competences that the experimental science curriculum establishes, teachers should assess all kinds of competences using questions covering the different competence levels, especially the high ones, as the answer to questions in these level are the most valid indicators of competence.

Once arrived to this point, it can be asked why teachers do not assess all kinds of competence, why they do not use questions covering the different levels of cognitive complexity and why their assessment profiles tend to fell in categories that imply the use either of easy –low-level– or of difficult –high-level– tasks, but not of both. There can be several explanations. First, it may be that experimental science teachers do not know the cognitive processes implied by each one of the specific competences that are to be acquired to understand and apply scientific knowledge. Knowing and applying knowledge is not the same as knowing how such knowledge is acquired and applied. In the same way that being a good football player is not enough to be a good football trainer: this implies a different kind of knowledge. If this was the case, this lack of knowledge should be deal with in teacher's training courses. Second, it might be that some competences were nor assessed, and questions of high complexity levels were not used, because they were not covered by class activities.

In any case, the fact that the different kinds of competence included in the curriculum are not assessed according to a model that covers the different difficulty levels, and that allows teachers to identify students' difficulties has theoretical and practical implications. The main theoretical implication is that it is necessary to clarify the nature of the different competences to be acquired. This implies to identify the cognitive processes to be carried out and the difficulties the students can find when realizing a task. This could help teachers to know the kinds of specific characteristics that tasks related to different learning objectives should have in order to promote understanding and conceptual change. The present work is a step in this direction.

As for the practical implications, they have to do with teacher training related to assessment. It is not enough to show the possibilities offered by different assessment procedures –portfolios, problem solving, projects, etc.–. It is also necessary to make teachers to reflect 1) on the nature of the different competencies to be acquired, 2) on the strengths and limitations of their own assessment tasks in the light of the nature of each competence to be assessed, and 3) on the kinds of task that can help to overcome such limitations. The present paper offers specific component models for four competencies –*conceptual understanding*, *text comprehension*, *table and graph understanding*, and *use of scientific thinking*–, as well as examples of tasks that make assessment possible according to such models. However, it is only a first step, and much more work should be done in this direction.

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Appendix

Test for assessing teachers' assessment preferences in the area of Physics (Pérez de Landazábal, Varela & Alonso Tapia, 2011)

Indicate the degree in which you use the kinds of task next included for assessing your students' knowledge and competencies. Use the following scale:

Never 0.....1.....2.....3.....4.....5.....6 Habitually

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1. Read the following text and answer the questions posed.

Georg Simon Ohm (1787-1854) was born in Bavaria. It was the son of a mechanic, and became a high-school teacher after working very hard, but he ambitioned to become a university professor. It was necessary to present an important research work to obtain a university appointment. So, Ohm, that was aware of the work of Volta, elected the new field of electricity supply. As he was poor and the equipment was very difficult to obtain, he had to manufacture it himself.

Ohm decided to apply some discoveries made by Fourier on the propagation of heat to the case of the flow of electricity through a wire, drawing analogies between the electric current flow and the heat transfer such as: If the heat spreads more quickly between two points as grater are both, the difference of temperature between them, and the thermal conductivity of the material that connects them, in the same way the flow of electric current will depend on the difference of potential between two points and the electrical conductivity of the wire used. In his research he used a set of Volta batteries and a galvanometer as the one designed by Ampere.

The relationship between voltage, intensity and resistance, and the factors on which the resistance of a metallic conductor depends, were the discoveries that Ohm published in a paper entitled: "The Galvanic circuit mathematically investigated. In this text, Ohm introduces the idea that the intensity of current flow is directly proportional to voltage and inversely proportional to the resistance of the conductor. Furthermore, the resistance of the conductor depends on the nature of the material (resistivity) and on its geometrical characteristics (length and section).
I. Asimov. *Biographical Encyclopedia of Science and Technology*. Alliance Dictionaries.
a) Explain the meaning of the following words:
- Propagation of heat
- Thermal conductivity
- Volta Battery
- Directly proportional
- Inversely proportional

b) To understand that you correctly understand the text, do answer the following questions:
- What determines the speed of heat transfer in a material?
- With which other concept does the text relate the concept "*difference of potential between two points*"?
- To what variables does the expression in the text "as greater are" refers?

c) Summarize briefly the main ideas of the text-
d) What strategy did Ohm use in order to establish the functioning of an electrical conductor?

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2. Different amounts of potassium chlorate are weighted and then heated. Once the reaction is completed, the resulting potassium chloride is weighted. The reaction equation is:

$$2KClO_3 \rightarrow 2KCl + 3\ O_2$$

The results obtained after conducting three experiments are shown in the table.

Mass of reactive (g)	Mass of solid product (g)	Mass of oxygen produced (g)
5	3,0	
10	6,1	
15	9,1	

Complete the table, taking into account that the law of conservation of mass must be satisfied. Verify that the amount of oxygen produced is in a fixed ratio with respect to the original amount of potassium chlorate.

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3. What is the difference between a physical and a chemical change? Give examples of both processes.

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4. The objective is to study the stoichiometry of the reaction:

$$Pb\ (NO_3)\ 2KI \rightarrow PbI_2 + KNO_3$$

in which appears a yellow precipitate of lead iodide (II).

1) After preparing a solution of nitrate of lead (II) with a concentration of 18g/l, 20 ml of this solution are poured in a beaker.
2) In a similar way, it is prepared a solution of potassium iodide with a concentration of 9 g/l. Then, 40 ml of this solution are poured into the beaker containing lead nitrate (II), what produces a yellow precipitate.
3) If you heat the beaker containing the precipitate and the solution, without allowing it to boil, and allowed it to cool slowly, it can be observed that the precipitate reappears in the form of bright yellow flakes. This phenomenon is known as "golden rain".
4) When cooled, the precipitate is filtered. Then, the filter with the solid product is heated in a ceramic capsule (without burning the filter paper) until all the water evaporates. Finally, the obtained solid is weighed.
   - What is the amount of mass of lead nitrate (II) existing in the 20 ml of solution?
   - What is -in moles- the amount of nitrate lead (II)
   - What is the amount of mass of potassium iodide contained in the 40 ml of solution?
   - What is -in moles- the amount of potassium iodide?
   - What is the amount of mass of lead iodide (II) obtained?
   - What is -in moles- the amount of lead iodide (II) obtained?
5) Do data conform to the stoichiometry of the reaction?

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5. A car with a mass of 1000 kg moves at 72 km/h. It brakes, stopping after 15 seconds.
- How much force do their brakes exert?
- What would be the strength of the brakes if it had stopped after travelling for 100 m?

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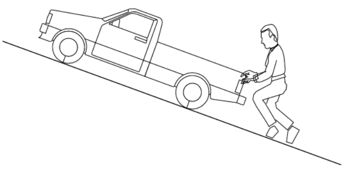
6. A man has had a breakdown, and to get to the workshop, he has to push the car to climb a small hill. Explain the energy transfers that take place between the man, who pushes, and the car that climbs the hill.



7. Jane is a 19 years old high jumper. Her recommended daily diet is 9,820 kJ. Her birthday, one of her friends takes her to dinner at a restaurant. Jane, who writes everything she eats per day, he knew - through the use of diet tables – that she had already reached 7,520 kJ of energy. Below is a table containing the amount of energy –estimated by Jane- of each of the dishes

Menu		Estimation of the energy provided by each plate, made by Joan (in kJ)
Soups	Tomato Soup Cream of mushroom	355 585
Meat	Chicken Mexican Caribbean Chicken Lamb chops	960 795 920
Salads	Potato Salad Cheese salad, pineapple and nuts Pasta Salad	750 335 480
Desserts	Apple and raspberry tart Cheesecake Strawberry tart	1.380 1.005 565
Shakes	Chocolate Vanilla	1.590 1.470

Jane wants that her menu provides her an amount of energy that neither exceeds the daily amount recommended for her in about 500 kJ, nor is below this figure. One possibility is to take the closed dinner menu the restaurant offers:

Tomato Soup / Caribbean Chicken / Strawberry tart

Find out whether this menu will allow Jane to stay, more or less, within the range of 500 KJ she has been recommended. Explain your answer as you make and write the calculations.

8. 1. Read the following text and answer the questions posed.

Now we can examine the question of how atoms, according to Dalton, are formed by elementary particles. The first right answer to this question was given in 1911 by Ernest Rutherford. He was studying the atomic structure of various atoms by bombarding them with positively charged very tiny particles moving at high speed (see the figure below). When observing the deflection experienced by the projectiles after passing through a piece of matter, Rutherford arrived at the conclusion that all atoms should have a very dense positively charged core. Despite the apparent simplicity of the atomic model of Rutherford, their understanding is far from being easy. In fact, according to classical physics, the negatively charged electrons, which revolve around the atomic nucleus, are doomed to lose its energy through a process of light emission, so that the atmosphere of electrons would end up sinking into the nucleus.

George Gamow. *El señor Tompkins durmiendo*. Fondo de Cultura Económica

- What kind of load did the bullets which with Rutherford bombarded the atoms have? Why did they deviate from their path
- Describe Rutherford's experiment
- Explain why their results could not be explained by Thomson's atomic model.
- Why is not stable the Rutherford's atomic model?
- What changes did Bohr introduce in such model?

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9. Imagine the following problem, schematized in the figure: "In a mini-golf, a ball is released down a slope with virtually no friction. how high will the ball get up on the other side?". Design a little research to solve this problem following the experimental methodology.

Help: Remember the criteria you should consider:

1. Formulation of questions related to the ball movement, especially those having to do with the conditions of the problem or the kind of data necessary to solve it.
2. Formulation of the hypotheses that you are to test experimentally.
3. Experimental design and control of variables. It is not enough to design an experimental setup with laboratory equipment. You have to set the variables you will measure, those that you have to change, and those you have to control.
4. Data analysis: You should pay attention to the data tables and charts that you have to build to be able to reach some conclusion.
5. Contrasting the hypothesis in the light of data.
