KNOWLEDGE ASSESSMENT
AND CONCEPTUAL UNDERSTANDING

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Abstract. This chapter outlines the main characteristics of assessment tasks, processes and contexts that can affect understanding and conceptual change. In doing so, it is intended to widen the perspectives on conceptual understanding and change by considering factors present in classroom practice but not necessarily in research studies: the kinds of assessment task employed by teachers, whether or not teachers make explicit the goals for which understanding of particular content is relevant, the design and coverage of assessment processes, the degree of feedback allowed by assessment design and planning and actually given by teachers, the degree of self-regulation allowed by assessment tasks, etc. The chapter includes many examples coming mainly from research on Social Sciences that illustrate the ideas presented. Special consideration is given to analogous and transfer tasks, and to portfolio-assessment in the context of project-oriented learning. The chapter also outlines some questions researchers should answered in order to make assessment more effective for conceptual understanding and change. These questions refer to the need to define task characteristics that constitute adequate criteria of conceptual understanding and that allow for the identification of students' sources of misunderstanding, to portfolio design and coverage, and to the need to test empirically the effects of assessment on conceptual change.

1. THE PROBLEM.

There is growing interest among psychologists and educators in understanding how knowledge is acquired and represented in memory and, especially, in knowing how it changes in the light of new information and experiences and in identifying which factors promote or hinder this change, as many recent publications –including this book- attest (Carey & Spelke, 1994; Chinn & Brewer, 1993; Dole & Sinatra, 1998; Guzetti & Hind, 1998; Siegler, 1996; Thagard, 1992). Achieving these objectives is important not only from a theoretical point of view, but also from an applied one, as teachers and educators strive to help students to understand and change their world

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conceptions where necessary. Scientists and teachers, however, do not pose the problem in the same terms. If the question for scientists is what factors determine or affect understanding and conceptual change, teachers ask themselves what can be done to favour such change. The two questions are related, as knowing how different factors affect knowledge construction and change can help to decide where, when and how to act to promote such change. Nevertheless, the question posed by teachers forces researchers to consider the role of factors defining real contexts in order to reach a deeper understanding of the process of knowledge construction and knowledge change.

In trying to produce the above mentioned effects, teachers confront the problem of creating learning environments that favour and do not hinder understanding. Dealing with this problem involves considering the role of assessment, one of the characteristics of learning environments that most influences learning activities and the promotion or hindering of conceptual understanding, evolution and change. Assessment not only indicates learning and conceptual change. It is also an activity that, depending on its characteristics, may affect knowledge construction positively or negatively. Therefore, it is worth considering which tools, procedures, criteria and contexts –which assessment conditions- are most appropriate for assessing and fostering the process and outcomes of conceptual change. Thus, the objective of this chapter is to outline the main characteristics of assessment tasks, processes and contexts that can affect understanding and conceptual change, as well as to identify the questions that need to be answered by researchers in order to improve the effects of assessment on conceptual understanding and change.

2. THEORETICAL FRAMEWORK.

2.1. Perspectives on knowledge, conceptual understanding and conceptual change.

Given the different perspectives on conceptual understanding and change, in dealing with them it is necessary to make explicit which perspective we shall employ.

In a recent paper, Dole and Sinatra (1998) reviewed the contributions of cognitive psychology, science education and social psychology to conceptual understanding and, especially, to conceptual change. In this review they showed that though there are important differences between authors from different theoretical traditions, their points of view are complementary and can be tentatively integrated within a new heuristic framework.

According to Dole and Sinatra, cognitive psychologists have conceptualised knowledge as memory representations in the form *of scripts, frames* or *schemata* (Anderson & Pearson, 1984; Rumelhart & Ortony, 1977: Shank & Abelson, 1977). Most of them have studied the nature and structure of these representations, though some have also studied processes of change. They have referred to these processes as *assimilation* –the addition of new information to existing knowledge structures- and *accommodation* -the modification of existing knowledge structures- (Piaget, 1937);

accretion –the assimilation of factual information that fits into existing knowledge structures- (Rumelart & Norman, 1981); *weak restructuring or conceptual change* – the knowledge acquisitions that results from mechanisms such as addition, deletion, discrimination and generalization- (Chi, 1992); and finally, *radical restructuring or conceptual change* –change in knowledge that involves the creation of new structures to reinterpret old information or to account for new information (Vosniadou & Brewer, 1987). All these researchers, however, coincide in pointing out that the mechanisms of change are not well known.

As regards work on science education, researchers have tried to explain why so many students maintain their existing conceptions in spite of instruction and under what conditions these conceptions change (Posner et al., 1982). In doing so, they have shown, first, that when knowledge structures are crystallized, coherent and firmly entrenched, they are highly resistant to radical change, even when confronted with data that contradict the existing theories (Chan, Burtis & Bereiter, 1997; Chinn & Brewer, 1993; Dole & Sinatra, 1998; Limon & Carretero, 1997; Posner & al. 1982). Due to such resistance, radical restructuring requires a great deal of cognitive effort, effort that will not take place:

> 'unless students are dissatisfied with previous ideas, …unless they find that the new conceptions are intelligible and make sense, …unless they perceive that the new conceptions are plausible ones, which implies that they must fit into existing and related ideas, …and unless they find that the new conceptions are open to new areas of inquiry´ (Posner et al. 1982, p. 214).

Let us now consider the work of social psychologists (Eagly & Chaiken, 1993; Olson & Zanna, 1993). They have traditionally been interested in *beliefs,* the thoughts that people have about attitude objects, and *attitudes,* dispositions to act regularly and in a particular way in relation to a class of objects, people, actions, ideas, etc., due to the positive or negative emotional valence that they have for the subject. This valence may stem from the knowledge or beliefs people have about the object of the attitude. Thus, knowledge is at the base of beliefs and attitudes, and social psychologists carried out a lot of work aimed at identifying the conditions under which this knowledge and the corresponding attitudes change (Kuhn and Lao, 1998).

According to Dole and Sinatra, social psychologists have borrowed the theory and methodology of cognitive psychology to explain how attitudes and beliefs are represented in memory; however, they have been more interested than cognitive psychologists in identifying the conditions of change. Thus, Petty and Cacciopo (1986) have shown that changes in beliefs and attitudes may occur in one of two ways. First, though a process motivated by personal involvement due to one's personal stake in the outcome or to the need for cognition and its consequences, a process called "*the central route to persuasion*". Second, even if there is not a great deal of personal involvement, information characteristics may induce a peripheral shift which, depending on different factors –message comprehensibility, background knowledge, etc.-, may vanish or may

activate a deep change in beliefs an attitudes, a process called *"the peripheral route to persuasion"*.

In their paper, Dole and Sinatra (1998) integrate the different approaches to conceptual understanding and change within a new model. They point out that conceptual change depends on the interaction between learner characteristics, message characteristics and peripheral cues. In the first group of variables they include existing conception characteristics and motivation to engage in the elaboration process due to dissatisfaction or cognitive conflict, to the personal relevance of the topic, to the need for cognition or to social context influences. They suggest that such characteristics interact with characteristics of the message, such as its comprehensibility, its coherency and its plausibility. Moreover, they also suggest that even if such interaction is not sufficient to stimulate engagement capable of producing strong conceptual change, the existence of different peripheral cues may stimulate at least weak conceptual change.

From our point of view, in one way or another, all of the above approaches recognize that acquiring or organizing knowledge implies constructing some sort of mental representation –ideas, scripts, schemata, beliefs, etc. Nevertheless, it is important to point out that that this construction implies two different processes: a) *concept formation,* the construction of categorization rules by which:

> "to render discriminably different things equivalent, to group the objects, events and people around us into classes and to respond to them in terms of their class membership rather than their uniqueness" (Bruner, Goodnow and Austin, 1956, p.1),

and b) *concept identification,* the association of the rule underlying a verbal term to that term, 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. For example, they may react to the listening or reading of pronouns by looking for their referents without associating the word "pronoun" with them. Other times, they associate with a verbal label conceptions that are different from the conceptions that experts attach to that label. For example, this is the case with the concept of "alive", which evolves from meaning "to be in motion" to "be born, to grow and to die" (Delval, 1975; Piaget, 1926). It is not difficult to associate the correct verbal label to a concept *as long as* a person has formed the correct categorization rule. Thus, from our point of view, if assessment is aimed at deciding which instructional aids should be given to students in order to favour conceptual change, assessment activities should focus on the first aspect of conceptual understanding –the student's rules for categorizing phenomena. These rules become manifest in categorizing or predicting behaviour, and their change can be detected if they are assessed before and after instruction.

The above referred models also recognize that conceptual change depends on subjects´ characteristics and those of information or message. However, no model considers the effect of characteristics defining real learning contexts on conceptual understanding and change, as many of the studies have not been carried out in such

contexts. Of course, as long as real situations had the characteristics that, according to research findings positively affect conceptual understanding and change, they might induce these outcomes. Nevertheless, other conditions might also be necessary. One of these may be the characteristics of assessment, as will be shown next.

2.2. Perspectives on assessment

In a recent paper, Dochy (2001) distinguished between two different perspectives on assessment, the *testing culture* (Wolf et. al., 1991) and the *assessment culture*. The testing culture developed around the purpose of identifying the amount of knowledge "deposited" in students' minds. In this culture instruction and assessment are considered as separate activities; planning of tasks, writing of items and evaluation criteria are not shared with students, and the tasks are usually unrelated to the student's life experience. The assessment culture, on the other hand, has as its main goal to 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. Teachers working from each one of these perspectives create assessment contexts that can affect the extent to which students strive for understanding, and therefore, the likelihood of conceptual change. Thus, in order to promote conceptual understanding and change it is necessary to consider the characteristics of such contexts.

When talking about assessment we refer not so much to assessment scores obtained by students or to the different assessment activities, but to the whole assessment process. There are different kinds of assessment activities. First, there are assessment activities aimed at identifying the prerequisites of learning -the ideas or mental representations that students bring with them, the strength and coherence of these ideas and the student's commitment to them; second, there are those that take place during the teaching-learning process with the aim of monitoring students' progress and diagnosing their difficulties, or with the aim of aiding their self-assessment, self-monitoring and self-regulation; and third, there are those aimed at final or summative assessment. However, in all of these cases the assessment process may differ depending on the specific configuration of characteristics such as the extent to which assessment goals are made salient by teachers; the nature and sequence of assessment tasks; the frequency and distribution of occasions for assessment; the amount of time available for performing assessment tasks; the frequency and kind of feedback based on quality of assessment outcomes, etc. These differences constitute one of the main contextual factors affecting students' motivation and learning activities -on which conceptual understanding and change depends, at least in part.

The existence of these differences raises some questions related to the issue under discussion: Do assessment processes exert any influence on conceptual understanding and change? If so, what kind of assessment characteristics can affect these outcomes in the most positive way? Are the assessment characteristics that supposedly best foster

conceptual understanding and change also adequate for showing this change? Are these kinds of task commonly used by teachers for assessing their students? If not, how can we promote the use of them by teachers so that assessment improves understanding and conceptual change? These are the questions that will be dealt with, mainly in relation to assessment in History and Geography.

3. ASSESSMENT CONDITIONS FAVOURING CONCEPTUAL CHANGE.

In order to answer the first question -whether assessment processes exert any influence on conceptual change-, we should take into account the following points. Knowledge can be considered an instrument or a tool that is useful in different contexts, such as taking an exam, solving a practical problem, persuading someone, etc. As human conceptual knowledge is "situated" (Caravita & Halldén, 1994), the nature of the context in which knowledge is expected to be used is likely to affect the kind of activities students perform in order to achieve such knowledge. Thus, for example, if students expect to take a multiple-choice exam requiring recall of facts and information, they are likely to study it in a way different from the way they would study if they expected to have to solve open problems. If this supposition is correct (and studies with high school and university students would seem to suggest that it is) (Alonso-Tapia, 1999; Alonso-Tapia & López, 1999), then assessment tasks and design will affect the degree of commitment and thus of conceptual understanding and change following study activities, as does any instructional task (Schnotz, 1997). Therefore, teachers should know and use the kind of assessment activities most likely to promote this change.

What kinds of assessment process characteristics are most likely to promote conceptual understanding and change? In our view, the following characteristics, that will be discussed next, should be considered:

- Most suitable tasks: those demanding the *application and use* of knowledge for solving problems implying some degree of novelty (*analogous* and *transfer tasks*).
- Teachers make explicit for what goals understanding of particular content is relevant.
- Tasks designed to allow teachers to identify specific factors in students that hinder conceptual change.
- The assessment process covers the different nodes and links of the conceptual network students are supposed to construct.
- Teachers give specific help based on assessment, whether this takes place before, during or after instruction.
- Teachers avoid messages and classroom practices stressing the relevance of assessment for goals extrinsic to understanding.

3.1. Types of assessment task that favour conceptual change

With regard to assessment tasks, existing evidence suggest the use of open tasks

demanding the *application and use of knowledge for solving problems involving some degree of novelty* (*analogous* and *transfer tasks*), as these problems require the use of knowledge schemata for the construction and even reconstruction of mental models to guide the solution process (Alonso-Tapia, 1997; Schnotz, 1997). The need to build such models may help the student to detect conceptual deficits and may stimulate his/her subsequent efforts to overcome them. Most importantly, however, if students know beforehand that they must solve certain types of problem, they may attempt to confront these in advance. Such attempts increase the possibility of detecting and overcoming conceptual deficits, and thus of understanding and conceptual change. Nevertheless, the use of open tasks may not be sufficient for producing such outcomes, as they seem to depend on the interaction between personal characteristics –knowledge, ability and motivation.

What kinds of tasks are we referring to? It depends, among other things, on the subject matter being assessed, as the subject defines the kind of knowledge representations –schemata, scripts, mental models, etc.- that students are expected to construct and the particular situations to which these representations are expected to be applied. Nevertheless, Baxter and Glaser (1998) have developed a working analytic framework for organizing assessment tasks in two dimensions on which expert competence depends. The first of these, related to content, defines the subject-matter knowledge necessary for carrying out the task. According to this dimension, assessment tasks can demand rich, integrated and usable knowledge –students need to be able to identify the conditions under which concepts and processes should be used-, or can be "lean" with respect to knowledge. The second dimension defines the process skills underlying performance. According to this dimension, assessment tasks can be open or constrained. Thus, we can divide tasks in four categories: content rich-process constrained, content rich-process open, content lean-process constrained and content lean-process open.

According to Baxter and Glaser, tasks in the first category, such as "Describe the main causes of political revolutions, such as the French, and explain how they are related" or "Describe the process of erosion and explain the physical and chemical sub-processes that produce it", emphasize knowledge generation and recall. They are therefore unlikely to stimulate the use of study strategies promoting conceptual change. The same occurs with tasks in the third group, content lean-process cons-trained, such as doing an exercise following very specific directions. However, if assessment tasks are open, that is, if there is no direct way of proceeding to reach the solution, the need to reconstruct knowledge schemata favours conceptual change, though the beneficial effect may depend on the interaction between the amount of content required and other variables such as motivation to gather, activate and transform it. The following example, taken from our research on causal understanding in History, can illustrate this kind of task. Examples corresponding to science assessment can be found in Alonso-Tapia and Pérez (1997), Pérez and Moreno (1999), Baxter and Glaser (1998) and Duschl and Gitomer (1997), among others.

In History, students have to learn not only what happened in the past and why, but also how different categories of facts tend to affect historical changes when certain conditions are met (Alonso-Tapia et al. 1997; Alonso-Tapia & Villa, 1999). This learning implies the construction of conceptual schemata dealing with multicausality. Thus, we can assess the degree of conceptual understanding of causal relations -and, at the same time favour understanding and conceptual change if necessary- if we ask students what is likely to happen in situations -real or hypothetical- more or less analogous to that found when studying a particular historical change, and why they think this is the case. Answering this kind of question involves the use and transfer of previous representations to solving problems analogous to those on which mental models have already been built. The following example illustrates this possibility.

Figure 1 shows "a simplified model" of the main factors that caused the French Revolution. It is not "the model" explaining the French Revolution, but only a tentative one that usually guides instruction in Spanish schools. Understanding this model implies not only being able to say that this or that factor contributed to the revolution. It also implies understanding that the historical events included in the Figure belong to different categories: natural, technical, economic, social, political, military, personal and ideological events, to mention only a few; furthermore, it implies understanding that, if similar conditions were met, they would usually contribute to historical change in the same way. For example, demand being constant, scarcity increases prices; war causes the state to run up debts, etc. Thus, in relation to the study of the French Revolution, what kinds of task may be used to assess whether students' conceptual understanding has evolved in the expected direction?

Table 1 shows some of the hypothetical situations designed to assess conceptual understanding of some causal relations included in the figure. Each situation is followed by questions asking for inferences about what might happen in relation to prices, impoverishment of peasants, problems of city dwellers, etc. Students have to justify their answers, so that the mental representations determining them can be detected.

The way students perform the tasks described provides information about the conceptual representations related to causal understanding in History, and about the way they reason according to such representations. These tasks constitute good criteria of attainment of learning goals. However, as most secondary school pupils are not used to this kinds of task –most assessment tasks are constrained- (Villa & Alonso-Tapia, 1996), their performance reflects a very poor and fragmented conceptual structure (Alonso-Tapia & Villa, 1999; Alonso-Tapia, Asensio & López, 2000*a*). However, if students know in advance that they had to carry out tasks such as these described, and if they have been introduced to the kind thinking and study strategies suitable for coping with the difficulties of such tasks, the likelihood of using such strategies and thus of changing their mental representations increases.

Figure 1. Basic conceptual map of "The French Revolution. A) Causes "for students 13 to 15 years old. (Alonso-Tapia, Asensio & Salguero, 1997).
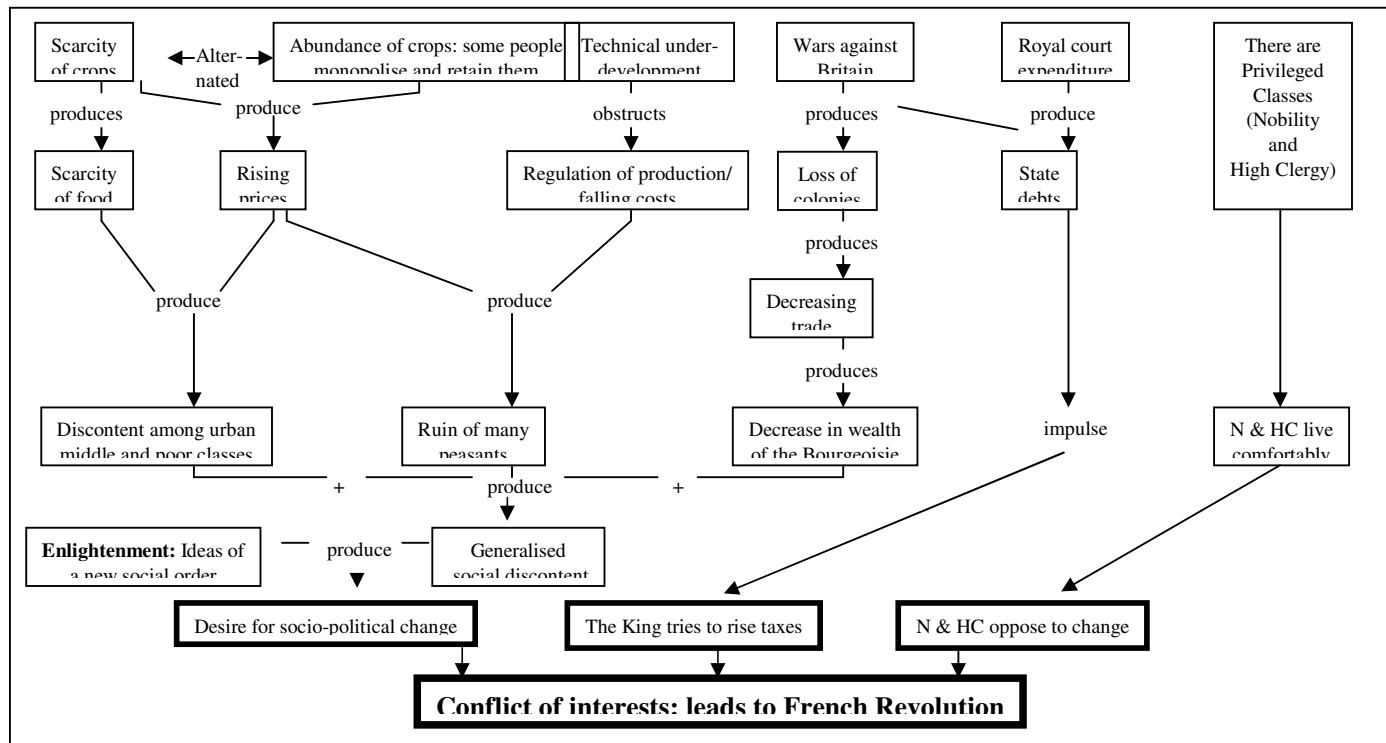
Table 1. Example of task and questions designed for assessing conceptual understanding and change. (Alonso-Tapia, Asensio & López, 2000ᵃ).

A.. Imagine the situation described in Box 1. There are four countries differing in the amount of crops they harvest over several consecutive years. In some of these countries there are groups of people that monopolize and retain most of the crop, whereas in other countries there are no such groups. (The situation of some of these countries is similar to the French situation just before the French Revolution) Thus, taking into account this fact, answer the following questions.

Box 1	There are people that monopolize and retain crops	Annual crop		
		First Year	Second Year	Third Year
Country A	Yes	Scarce	Average	Scarce
Country B	Yes	Abundant	Scarce	Scarce
Country C	No	Abundant	Scarce	Scarce
Country D	No	Scarce	Average	Average

a.1.   In which of the countries will agricultural prices rise most? ___ Why do you think this?
How does the crop affect prices? ___ Why?
How does the monopolization and retaining of crops affect prices? ___ Why?

a.2.   In which of the countries will peasants to become impoverished more likely? ___ Why?

a.3.   In which of the countries will urban middle and poor classes become discontented? ____ Why?

B. I imagine five countries each one equal to the other in everything except the characteristics described in Box 2. Answer   the following questions.   (Taking into account what you have learned during the study of the FR)

Box 2	Country				
	A	B	C	D	E
It has lost its colonies	Yes	No	Yes	Yes	Yes
Other countries sell at lower prices	Yes	Yes	No	Yes	No
Crops have being worsening	Yes	Yes	No	No	Yes

b.1   In which country is trade more likely to diminish? ___ Why do you think this?

(It continues)

Table 1. (Continuation)

C. Imagine five countries each one equal to the other in every thing except the characteristics described in Table 1. Answer the following questions.   (Taking into account what you have learned during the study of the FR)

Box 3	Country A	Country B	Country C	Country D	Country E
Trade with other countries	Flourishing	Diminishing	Diminishing	Flourishing	Diminishing
Prices	Rise	Rise	Rise	Established	Rise
Taxes	Rise	Rise	Established	Rise	Rise
Rights and duties of social groups	Different	Different	Different	Equal	Different

c.1 In which country would be more likely that some group was interested in changing the way it was governed?
     Why do you think that?

c.2 Why not each one of the other countries?

D. Imagine three countries whose economy is bad –prices rise, there are many people almost starving, etc.- and where taxes are high due to state expenditure and debts, as in the epoch of the French Revolution. Imagine also that citizens of each one of these countries differ in their way of thinking, being the dominant ideas in each country the following:

Country A	Power must be hold by only one person. He/she must legislate, has to be able to force law accomplishment and, if this is not the case, has to be able to punish those being guilty.
Country B	Goods belong to everybody. Let us organize production collectively and give them to each person according to his/her needs.
Country C	The right to private property is fundamental. Therefore, every government has the obligation of making it to be respected.

 d.1. Would it be likely or not that in any of these countries the way of government changed as it happened in the epoch of the French Revolution?
       If such a change took place, would it be similar or not to that of the French Revolution?
       Why do you think in this way?

3.2. Making explicit the relevance of learning goals assessed favours conceptual change.

The applied nature of assessment tasks is probably a key factor in fostering conceptual change. However, in our view, this factor is unlikely to be sufficient in real situations. First of all, students do not usually strive to understand unless they perceive that the tasks their teacher uses will be relevant for class or exam assessment, research in both cognitive and social psychology have shown (Olson & Zanna, 1993; Schiefele, 1991). Thus, if teachers do not help students to perceive the relevance of understanding the kinds of concepts and procedures involved in the solution of the selected tasks (in spite of the actual usefulness of such knowledge), then students are unlikely to make the effort required by the study strategies needed to acquire it. Knowledge assessed has to be perceived as relevant by students for them to try hard enough to work on it in such a way as to achieve a better understanding and, eventually, change their mental representations. How, then can teachers make relevance more salient?

Teachers can make salient the relevance of knowledge to be acquired and assessed through assessment task design and contextualization if these meet two conditions: a) if they confront students with authentic problems (Duschl & Gitomer, 1997), and b) if the solution of these problems allows the acquisition of some competence whose value the student is able to appreciate (Alonso-Tapia, 1997). An example will illustrate this point.

Consider, for instance, the task in Table 2 taken from our research on Human Geography understanding. The answer to each question included in the task depends on al least three kinds of factor: a) student's mental representation of phenomena to which simple concepts such as infrastructure, capital, advanced technology, etc., refer; b) on student's mental representation of causal processes to which each question refers –for example, a student may think that "giving grants to the best students to go abroad to prepare and specialise is generally negative for the progress of a country because "all students should be given the same opportunities"; and c) the particular conditions of the country or the way the measure stated in the question should be applied –what may be good for one country, may not be good for another. Due to this last factor and to the hypothetical and open character of the questions, there are not right or wrong direct answers. Thus, students must make an effort to imagine different scenarios in order to decide when the causal relation between the action considered and economic development would apply, and when it would not. However, the specific tasks designed for assessment are "situated" in the context of a more general and authentic problem: the need to be aware of the implications of our decisions when we vote in a general election. The perceived relevance of this problem may contribute to increasing students' efforts to understand, and thus increasing the probability of conceptual change.

3.3. Task design allowing the detection of specific conceptual gaps, misconceptions and reasoning deficiencies favours conceptual change

However, understanding and conceptual change may not occur even if students perceive the relevance of acquiring the knowledge necessary for solving the assessment tasks. Often, understanding cannot take place without help. Sometimes

Table 2. Task designed for assessing how students 14 to 16 year old understand which factors can affect the transit from poverty conditions to economic development. (Alonso-Tapia, Abad & Sánchez, 2000).

Imagine that you live in a poor country. Imagine, also, that you have to support with your vote the measures that politicians propose in order to transform your country into a wealthy one. In this context, after considering the potential effects of each measure, say whether it should be supported or not, or if your support would depend on some condition. Explain your answer saying why you think in such a way.

1. To invest mainly in infrastructure that facilitates the access to drinking water.

   Should this measured be supported? (Yes / No / Depends on conditions)

   Why do you think in this way?

   The same questions are asked in relation to the following measures:

2. To invest available capital in advanced technology

3. To allow foreign companies to exploit the country's mineral resources

4. To allow foreign companies to fish inside your fishing areas

5. To allow tree felling to increase arable land

6. To give economic aid to families with three or more children

7. To give grants to the best students to go abroad

8. To promote the access of women to education

9. To create an office to promote emigration

10. To create taxes allowing for the investment in education and infrastructure

11. To ask for credit to invest, as a priority, in renewable energy sources

12. To promote migration from big cities to small ones

13. To promote the building of residences for old people.

14. To promote migration to underdeveloped parts of the country

15. To ask systematically for medical and food aid from international institutions

students lack the specific prerequisites necessary for conceptual change to occur, such as when they have well rooted pre-existing conceptions that may vary in *strength* –the richness or amount of connections of a student's idea-, in *coherence* –the conceptual

organization of such connections and their capacity to provide explanations for new phenomena-, or in the student's degree of commitment to the existing conception (Posner et al., 1982). To deal with this problem effectively, a condition should be met: teachers should be able to detect when there is a lack of such prerequisites and why, and to identify the specific factors that hinder students' understanding and conceptual change-.

There are various assessment strategies for managing this problem: asking students for an explanation of their answers, as shown in the tasks included in Table 2; designing assessment tasks as experiments capable of showing directly the causes of students' problems, as exemplified by the tasks included in Table 1, where even if the student does not answer the open question, the structure of the information given allows us to make a reasonably confident inference, when the answer is wrong, about the gap in the students' conceptualisation of causality, etc. These strategies allow for the detection of different kinds of knowledge characteristics that may constitute an obstacle to understanding (Alexander et al., 1991). Furthermore, conceptual maps can be used to identify the strength and coherence of previous knowledge (Jonassen, Beissner & Yacci, 1993).

If the assessment strategy used by a teacher meets this condition, then this strategy will contribute to conceptual change as long as the teacher uses the information gathered to help the students later. If this is not the case, the teacher will only be able to tell the student that he or she has failed, which is of no help in promoting the student's conceptual change.

The condition for conceptual change just described may not be sufficient if used only occasionally. Conceptual understanding and change often appear to take place through a gradual transformation of mental representations –schemata, models, scripts, etc.-. This seems to be especially true in cases in which students have to learn complex conceptual models after examining different sources of information, as occurs, for example, when trying to understand the causes of historical changes, when they have to make sense of data from experiments in order to understand scientific concepts, or when they have to make sense of data that is anomalous with regard to their existing conceptions (Limón & Carretero, 1997; Chinn & Brewer, 1993). Thus, *in so far as the set of tasks used throughout the assessment process covers the different nodes and links of the conceptual network students are supposed to construct*, teachers will be able to help in the building of such a network through provision of the aids specifically needed –pointing out information not considered, contradictions implied by anomalous data, etc..

Duschl and Guitomer (1997), for example, have developed a set of tasks and suggested a set of criteria in the form of questions to be used in Science classrooms through which teachers can assess and scaffold students' thinking –which must be based on valid reasoning inferences- in order to improve their conceptual understanding. These questions are aimed, for instance:

a) At helping them to establish relationships (What goes together? Is there anything

that does not belong? Why? How are things alike?, etc.).

b) At improving clarity (Does it say what you want it to say? Will it be clear to someone else?, etc.).

c) At inducing the student to examine the consistency between inferences and evidence (Is the statement supported by observations? If so, which ones? Is it supported by the observations of others? If so, which ones?, etc.).

d) At helping the student to back up their representations with the use of examples (Can you give an example? Is it a good example for this purpose? Can you think of an original example?, etc.)

e) At helping them to make sense of the information available (Is this what you expected? Is there anything that does not fit? Can you predict the outcome?, etc.).

f) At encouraging the consideration of alternative explanations (Is there another way to explain it? Is your explanation plausible? What does this explanation say that the other doesn't? etc.).

g) At favouring elaboration of the theme (Is this term related to something we did before? Is it related to something you did in another class?, etc.).

h) At improving accuracy (Is the statement consistent with other information on the same topic? How does the model compare with other models? How does it compare with other representations?, etc.).

Similar sets of questions can be developed in relation to the process of analysing and integrating information in Social Sciences –History, Geography, Economics, etc.-. These questions can favour understanding and conceptual change, as they encourage students to process their knowledge more deeply (questions *a, b, d, g* and *h*), focus their attention on data not considered and on contradictions (questions *a, c, e*), and draw attention to the possibility of and need to look for alternative explanations (question *f*).

The assessment conditions described up to this point *may* contribute directly or indirectly to conceptual change. We say "may" and not "will" because, in order for the student to strive to understand, the assessment context created by teachers must make salient -which is not always the case- that this is the goal at stake. The nature of the assessment task, the way in which information deriving from assessment outcomes is provided for students, the amount of stress put on grades, etc., can make goals other than understanding more salient. When this occurs, such as when a teacher stresses the importance of assessment scores for goals extrinsic to understanding and significant learning -grades, competition among peers, etc.-, students tend to avoid the use of study strategies favoring conceptual elaboration and understanding, as many studies have shown (Alonso-Tapia & López, 1999; Blumenfeld, Puro & Mergendoller, 1992; Covington, 2000; Garner, 1990). As a consequence, in order for assessment to contribute to conceptual change, teachers should avoid messages and classroom practices stressing the relevance of assessment for goals extrinsic to learning and understanding.

4. PORTFOLIO ASSESSMENT AS A GENERAL FRAMEWORK FOR INTEGRATING CONDITIONS THAT FAVOUR UNDERSTANDING.

The assessment conditions favouring conceptual understanding and change are most effective if they take place in the context of an assessment process that integrates assessment and instruction, such as portfolio assessment in the context of project-oriented instruction (Duschl & Gitomer, 1997; Tierney, Carter & Desai, 1991). This context increases the possibility of helping students to become aware of the relevance and benefits of trying to understand and of using learning strategies that favour conceptual change. However, the term *portfolio* has been referred to as a "chameleon", as there are different ideas of how portfolio assessment should be contextualized and carried out (Calfee & Perfumo, 1996; Underwood, 1998). Therefore, we shall illustrate our conception with an example, taken from one of our most recent works (Alonso-Tapia, Asensio & López, 2000*b).* Due to its length, this example is included in the Appendix to this chapter.

As can be seen in the example, portfolio assessment in the context of project-oriented instruction has several characteristics that increase the probability of conceptual change:

- First, the project itself that constitutes the context for assessment derives from the need to solve a problem through the active construction of a mental representation that must be firmly based on reasons linking available information to conclusions. There is no single answer to the problem. Thus, the need to "build a case" acts as a driving force for understanding and conceptual change.
- Second, the discussion of initial representations creates the context for a "cognitive conflict" that forces the student's initial self-assessment of his/her own ideas against the pattern provided by the explanations of his/her classmates.
- Third, the projects are not carried out without instructions. On one hand, students have the guide shown in the Appendix, a guide designed to promote reflection and self-regulation. On the other, instructions, questions and tasks, some of them similar to those presented in Table 1, provide a structure that allows the teacher to assess more or less "on-line" the students' work and to give them accurate feedback. This can be carried out in a quite systematic way following guidelines similar to those developed by Duschl and Gitomer (1997) for the *assessment conversation* in Science classrooms (described above). These guidelines state the type of question it may be appropriate to ask at different points throughout the course of the project depending on the specific difficulties experienced by the students. The use of such questions helps them to consider aspects of the problem that have been forgotten or misinterpreted, and thus to improve their conceptual understanding.
- Fourth, the structure of the portfolio, the stress put on self-assessment, on receiving feedback from peers and on retaining original pieces of work as well as those improved through reflection (Appendix, step 4, points 1 and 2) help to make

students aware of the way they represent reality and how these representations change, which widens and deepens their conceptual understanding.

- Fifth, even if students have to be graded (which is unavoidable), several factors make salient the progressive nature of conceptual understanding and change, thus stimulating students to reconsider their ideas whenever they can, which obviously creates new opportunities for change and progress in understanding. These factors are: 1) the need to include in the showcase portfolio examples of the different tasks carried out in the course of the project; 2) the fact that students have to consider why such pieces of work best reflect the correct conceptualization of causality in relation to the problem stated; 3) the fact that students are graded in relation to a profile of capacities –for example: quality of inferences from texts, tables, graphs, etc., conceptual explanation, causal understanding, quality of argumentation, etc.; and 4) the fact that students discuss with the teacher the objectives on which they should concentrate in future project work.

5. A WORD ON THE WAY TEACHERS ASSESS THEIR STUDENTS.

A final but no less important question is: how do teachers actually assess their students' knowledge? Results from three recent studies (Villa & Alonso-Tapia, 1996; Alonso-Tapia & López, 1999; Alonso-Tapia, 1999) have shown that the assessment processes employed by secondary, high school and university teachers in Spain are far from adequate for fostering understanding, conceptual change and learning self-regulation in general. Sometimes -especially throughout secondary education- assess-ment tasks do not have the above-mentioned characteristics.

For example, 68% of assessment tasks and questions in Social Sciences imply rote learning. In other cases, such as those of Math and Physics, more than 70% of the tasks and questions students have to deal with are "exercises", which are not the same as "problems": exercises require algorithmic knowledge, whereas problem-solving implies using knowledge schemata for constructing a representation of the problem and planning the solution process (Villa & Alonso-Tapia, 1996). Even more importantly, many teachers believe that their tasks and questions assess conceptual understanding, when in fact such questions assess knowledge learned by heart (Alonso-Tapia, Asensio & López, 2000*c*).

On other occasions, the problem stems from the remaining assessment conditions: the extent to which assessment goals are made salient by teachers; the frequency and distribution of occasions for assessment; the amount of time available for performing assessment tasks; the frequency and kind of feedback based on the quality of assessment outcomes, etc. These conditions are often far from being suitable for favouring understanding and conceptual change (Alonso-Tapia, 1999; Alonso-Tapia &

López, 1999).

The implications of the way in which teachers usually assess their students' knowledge is clear. Even if teachers use instructional strategies favoring understanding, the fact that students adapt their study strategies and learning self-regulation to the way they expect their knowledge is going to be assessed constitutes one of the main obstacles to understanding and conceptual change. Thus, if we wish to improve conceptual understanding, we should concentrate on changing assessment practices instead of simply focusing our attention on instructional strategies.

6. IMPLICATIONS FOR FUTURE RESEARCH.

As it can be seen, there are many aspects of the assessment process that may directly or indirectly influence understanding and conceptual change. However, empirical research aimed at identifying the specific effects of assessment tasks and contexts on learning, understanding and conceptual change is scarce. As Calfee (1999-2000) has pointed out, assessment has undergone enormous development during the last decade. However, though this development includes many of the characteristics that, according to the ideas described above, can improve motivation, self-regulation, understanding and conceptual change, there is almost no empirical research devoted to identifying the conditions under which real assessment practices have the expected positive effects. Thus, let us point some problems to consider in the future research agenda.

First, some difficulties for such studies derive from a lack of clarification of the task characteristics that constitute adequate criteria of conceptual understanding and that allow for the identification of students' sources of misunderstanding. Information conveying the meaning of concepts and theories is included in texts, graphs, tables, maps, diagrams, objects, drawings, etc., but understanding the information from these sources implies particular processes that pose specific problems for students. However, assessment designs do not take into account this fact, which makes it difficult to identify whether students' answers show a lack of conceptual understanding or a lack of the required abilities to process and integrate information from such sources (Alonso-Tapia, 1997). Thus, it is necessary to define clearly the characteristics that assessment asks should have in order to be accepted as criteria of understanding, reasoning and conceptual change.

Second, in the case of portfolio assessment, the portfolio guide should ensure that the set of assessment tasks included in the portfolio covers the different nodes and links of scripts, schemata or mental models whose understanding is to be assessed in such a way as to make possible the determination of the type and coverage of schemata constructed by the student. However, and despite some exceptions (Marshall, 1993), there is a lack of systematic research on the structure of the set of tasks on which teachers base their assessment decisions and on the effects of using these sets with regard to students' understanding.

Third, in order to identify the effects of portfolio assessment in the context of

project-oriented learning, it is necessary to collect information on how the teaching process has been carried out. As Underwood (1998) has shown, portfolio assessment is not what it was intended to be, but what it really has been. If teachers have in mind not the portfolio assessment system but the kind of external assessment tasks their students will have to deal with later, then their teaching practices and assessment criteria will led not to understanding and conceptual change, but to students' performing in a predetermined way, regardless of whether really understand or not. This last point is reinforced when the standard-setting assessment methods used by educational authorities correspond to the testing culture (Dochy, 2001), as these methods constitute a contextual factor that teachers and students have in mind while working. Thus, in order to determine the effects of portfolio assessment on understanding, researchers should also take into account the kind of context defined by standard-setting assessment practices.

Finally, we should point out before concluding this chapter that research on the effects of assessment on understanding and conceptual change is important not only for practical purposes, but also for theoretical reasons. Studies on conceptual understanding and change often do not produce significant results. This may be due to the fact that, though research is carried out in experimental situations, students may confront experimental tasks with strategies and attitudes shaped by teaching and assessment practices that do not favour motivation to understand. Thus, it is necessary to take into account the potential effects of real assessment practices in order to clarify which factors and conditions affect conceptual understanding.

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APPENDIX

Example of portfolio assessment design in the context of project oriented instruction in the social sciences (Alonso-Tapia, Asensio & López, 2000*b*).

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STEPS

First step: Activation of learning motivation by means of problems than can be solved following different paths.

At the beginning of the term, the teacher explains the meaning of the work to be carried out and shows how this work can help students' personal development. To achieve this purpose, he/she introduces a problem that can help to arouse pupils' curiosity and to show the relevance of achieving the learning objectives.

"Before we start work, let me tell you the story of Alan, Eve, Barbara and Paul. They are more or less the same age as you. They are worried because their families are poor, they come from poor towns, and they would like to be better off. One day they get together and discuss why things are the way they are and what can be done to improve them. Alan thinks the problem is that those in charge are unfair, that they burden people with taxes and don't try to help them. He thinks new people should be in power. Eve thinks differently. She thinks the problem is that there are no industries in the town; if there were, things would be different. So she asks herself what could be done to create industry in the town. Barbara has a still different view. She says that there are too many people in the town. There are not enough resources for everyone, and if some people left and went to other places, there would be more opportunities. She wonders what could be done to encourage emigration. Paul, meanwhile, thinks the problem is that the poor are not united, and that if they were they could change a lot of things. He asks himself how they could be brought together. What do you think? Which of the four is right, and why?

The teacher leaves the pupils some time to express and discuss their opinions in order to discover the mental representations underlying them. Then he goes on:

"The problem of Alan, Eve, Barbara and Paul could be your problem. Whether we are rich or poor, we all want to improve. But to do so, we have to know which is the best way. Would you like to know who's right and why? Well, if you really want to, you can, but you'll have to do some investigation. Where? In the past. How? By looking for information that allows you to answer the questions included in each one of the following projects. You can carry out the projects in whatever order you like. I will provide different cues to guide you in your work.

Second step: Presentation of alternative work projects.

Project 1. Sometimes, in the past, there have been periods in which many people emigrated from one place to another. It happened, for example, when America was discovered and colonised or later, when the American west and Australia were also colonised. What motivated these people to emigrate? What conditions facilitated emigration? Who emigrated? What consequences did emigration have? Did emigration improve the way people lived, or not? Why? What lessons can we learn from what happened then? Would emigration have the same consequences today as in that era, or not? Why?

Project 2. Throughout the XVIIIth and XIXth centuries some countries, the first of which was Great Britain, industrialized rapidly. What caused such rapid industrialization? Did industrialization improve the way people lived, or not? Why? What lessons can we learn from what happened then? Would the industrialization of a country or region have the same consequences today as it had in the past or not? Why?

Project 3. Sometimes in the course of History –for example, at the times of the American, the French or the Russian Revolution- the political system of a country changed drastically for the better: the new system was fairer, at least in theory. What factors caused such changes? Did those political transformations improve the way people lived, or not? Why? What lessons can we learn from what happened then? Would a political revolution have the same consequences today as it had in the past, or not? Why?

Project 4. In the course of History poor people, especially those belonging to the working class, have united to defend their rights and to try to free themselves from poverty. This happened, for example, when the Trades Union Movement developed in the XIXth century. What factors gave rise to this movement? ? Did the movement improve the way people lived, or not? Why? What lessons can we learn from what happened then? Would a social movement like that have the same consequences today as it had in the past or not? Why?

"The idea is that each one of you (the task could also be assigned to small groups of students) starts one of the previous projects, explaining and justifying his/her conclusions as the work progresses. Why? What are you going to learn and achieve through this? What will it be useful for? And how are we going to organize the work?

Third step: Clarifying objectives and procedures for carrying out the projects.

"This project work has several objectives. First, it will help you to answer the questions included in each project and, therefore, to solve the initial problem. Second, it will also help you to think for yourselves, to improve the quality of your reasoning and to learn criteria that will allow you to decide in an informed way".

"Your work on the projects will involve obtaining, analyzing and organizing

information about the problem from different sources -texts, graphs, tables, pictures, maps, objects, and so on. And you'll have to do this properly so that you don't make mistakes in your inferences or reach the wrong conclusions. You'll have to take into account important factors, such as the historical moment and conditions, how long things took to develop, to change or to happen, and so on."

"How am I going to help you? First, I'll give you a work-guide".(Included below). "And, more importantly, I'm going to teach you how to look for information and how to analyse and organise it properly. Together, we'll analyse the way you reason and argue in favour of or against different hypotheses to see whether they can be backed up or not".

Forth step: Assessment.

• First of all, the teacher explains how to organise the portfolio that will constitute the information base for assessing the students' work.
"As you know, your work will be assessed. But, the most important point while you're working is to do "your" project, to work "for your own benefit". So, if this is the aim of the task, why assessment? How is the work going to be assessed? Assessment will be, in first place, self-assessment aimed at monitoring and self-regulating your work. Every day you will have to put your work, correctly dated and classified, in a folder: copies of texts, graphs, tables and other documents examined and analysed, with your interpretations and comments attached, as well as your classmates' comments or those that you have received from me. This will be your portfolio. You will also have to include a weekly summary, including the answers you can give so far to the questions stated".
• Second, the teacher introduces the idea and the context for self-assessment and explains its meaning and the criteria for carrying it out.
"We are going to see, in the course of our classes, how to interpret different kinds of document. will give you procedures and criteria for analysis and interpretation, and, you will have to make regular self-assessments of your work using these criteria. These self-assessments will also have to be included in the portfolio, but without taking out the original piece of work. This will help you to check your progress, to know what you have had to change and to understand why.
• Third, the teacher explains the process of assessment for grading.
"When it comes to assessment for giving grades, you will choose from your portfolio the pieces of your work –always correctly dated- that, from your point of view, best reflect your progress. When you make this selection ,though, you must include pieces that represent each one of the kinds of element necessary to give a representation of your progress. For example, essays with your answer to the problems supported by

arguments; tables, graphs, historical maps and other documents analyzed and interpreted; reasoned answers to the hypothetical problems posed in the course of the work (problems similar to those included in Table 1), and so on. You will have to say why you consider them appropriate and I will tell you the aspects that should be reconsidered and why. Then we will discuss the goals for the next project".

SPECIFIC WORK-GUIDE FOR DEVELOPING THE PORTFOLIO

General rules

- Include all your documents and comments always correctly dated and identified with your name.
- If you modify your point of view about a document, do not throw your initial comment away: comparison of the two comments will help you to be aware of your progress.

A) Texts

If you include a text in your portfolio, it would be appropriate to ask yourself the following questions and to include your reflections when trying to answer them:
- Do I understand all the words and concepts in the text?
- What is the main idea the author is trying to convey? Why do I think so?
- What was the author's purpose when writing the text? Why do I think so?
- What has the information in the text to do with the questions I am trying to answer? Why do I think so?
- What kinds of comment have I received from my classmates about my point of view? Do I agree with them or not? Why?

B) Graphs, tables and maps.

If you include a graph, a table or a map in your portfolio, it would be appropriate to ask yourself the following questions and to include your reflections when trying to answer them:
- Do I understand all data included in this document?
- What is the main information the author is trying to convey? Why do I think so?
- What was the author's purpose when developing the document? Why do I think so?
- What has the information in the document to do with the questions I am trying to answer? Why do I think so?
- What kinds of comment have I received from my classmates about my point of view? Do I agree with them or not? Why?

C) Non-written documents.

If you include references to non-written documents that were produced without the intention of communicating any information, it would be appropriate to ask yourself the following questions and to include your reflections when trying to answer them:
- What questions have I asked myself in order to identify the information they can potentially reveal about the socio-economic context in which they were produced? Have I missed anything important?
- What is the most important information this document is conveying in relation to the problem I am trying to solve? Why do I think so?
- What kinds of comment have I received from my classmates about my point of view? Do I agree with them or not? Why?

D) Comparison and integration of information coming from different sources.

In order to solve the problem you are dealing with, you will probably have to relate different kinds of documents and try to integrate different pieces of information. If you have established such relationships, it would be convenient to ask yourself the following questions and to include your reflections when trying to answer them:
- Before integrating the documents, have I asked myself the following questions on each one of them considered in isolation?
  - Do I understand all the data included in this document?
  - What is the main information the author is trying to convey? Why do I think so?
  - What was the author's purpose when developing the document? Why do I think so?
  - What has the information in the document to do with the questions I am trying to answer? Why do I think so?
- When integrating the information:
  - Do the documents I am comparing have anything in common? Why do I think so?
  - Do the kinds of information included in them coincide with, complement or contradict one another? Why do I think so?
  - What kinds of comment have I received from my classmates about my point of view? Do I agree with them or not? Why?

E) Solving prediction problems presented by the teacher. (See Table 1).

• Have I considered all possibilities before choosing my answer?
• What kinds of comment have I received from my classmates about the way I have justified my point of view? Do I agree with them or not? Why?

F) Essay showing your point of view on the problem.

From time to time throughout the project you will have to summarise your point of view on the problem you are trying to solve. In doing so, you will have to point out which factors can be considered as causes –direct or indirect- of phenomena like the one you have studied, what were the immediate and remote consequences, and whether it would be sensible for people to act in the same way today. In relation to these summaries, it would be appropriate to ask yourself the following questions and to include your reflections when trying to answer them:
   • Questions referring to the writing process:
     - What strategies have I used to decide what to say?
     - Does my portfolio include drafts, schemes or products deriving from "brainstorms"?
     - What questions have I asked myself to organize the text?
       Have I considered the purpose of my essay and the readers' needs?
       How have I organized the argument –what are the premises and the conclusion?
       Have I made my point of view and my premises explicit enough?
       What have I done to lead my teacher and classmates to my own conclusions?
     - Have I considered potential arguments against my point of view and accepted them (as far as possible)?
     - Have I revised the written text? What criteria have I used?
   • Questions referring to content:
     - Have I articulated my point of view well enough? Why do I think so?
     - What kinds of comment have I received from my classmates about my point of view? Do I agree with them or not? Why?

GUIDE FOR PREPARING THE SHOW-CASE PORTFOLIO

You have to prepare your show-case portfolio including the elements from your folder which, in your view, best show what you have understood and the abilities you have acquired. You should choose at least one element for each entry in the following assessment profile. Think about them before coming to the assessment session. Then we will discuss each element and set objectives for the future.

Assessment profile.

Document	Why have I chosen this document	My classmates Think…	My teacher thinks…	I think that what my teacher says…	Grades	Future objectives
Text - Comprehension - Relevance - Evaluation						
Graph/Table/Map - Comprehension - Relevance - Evaluation						
Document - Comprehension - Relevance - Evaluation						
Integrating sources - Comprehension - Relevance - Evaluation						
Prediction - Comprehension - Relevance - Evaluation						
Argumentation - Comprehension - Relevance - Evaluation						