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Two dimensions to characterize research-based teaching strategies: examples in elementary optics

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This article deals with the following question: how can research in science education enrich the design of teaching innovations? Two possible answers are examined:

- Students' own ways of reasoning may be taken into account, either as provisional steps towards more elaborate views or as obstacles to be confronted.
- The epistemological framework of episodes using an experimental set-up may be used. This can take different forms, ranging from simple inductions to searches for consistency between given laws or hypotheses and experimental facts.

The new French curriculum provides two examples of strategies concerning elementary optics at grade 8 that can be analysed along these lines. The value of these strategies is discussed. Different combinations of the role of learners' previous ideas and epistemological aspects are also examined. Some elements of evaluation concerning one of the recommended combinations are given. Finally, the role of teachers as 'innovation transformers' is presented as a critical topic for future research.

Introduction

In the last 20 years, research in science education has produced theoretical positions and important results. The question posed in this paper is how these research results can influence teaching, or to be more precise, the design of innovations to be implemented in an ordinary teaching situation.

One can imagine a type of interaction between research in science education and teaching that would consist of introducing teachers to theories and research results without directly suggesting any precise teaching strategy. Such in-depth training seems the best guarantee for an appropriate use of research results by teachers.

But if, for any reason, it is decided to introduce an innovation that is supposed to concern ordinary teachers, and to do so with precise didactic intentions, then the innovators have to be very specific. They must suggest not only the subject matter, in terms of items, but also precise teaching goals and strategies (Driver and Oldham 1986). Lijnse (1994) also pleads for a 'didactic structure' that would be informed in detail by research. If this is not done, one cannot expect the innovation to convey anything particular, nor can one conduct a proper evaluation of the teaching sequence. So the question put in this paper can relate only to an innovation which is specified at the micro-level, as Millar (1989) has also recommended.

The design of research-based innovations involves considering three major elements: learners, teaching goals and teachers.

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Learners have been a major focus of research for the last 20 years. Conceptions and ways of reasoning have been extensively documented, although it would be premature to claim that we now know all we need to know in this field.

Teaching goals have been partly re-examined, but most of the time it has only been suggested that the aim should be to overcome obstacles brought to light by research. Much less in favour among researchers is the idea that the subject matter to be taught should be reconsidered with a view to defining our teaching goals more consciously.

Finally, teachers themselves constitute a difficult research topic. Apart from the fact that we, as teachers ourselves, don't want to be a research topic, we don't know very much about what to look at in teachers. Up to now, some researchers have pinpointed similarities between pupils' and teachers' difficulties (Barnejee 1991, Viennot and Kaminski 1991). Many others have focused on teachers' views concerning epistemological questions (for a review, see Koulaïdis and Ogborn 1995 and also Millar 1988). But, to the authors' knowledge, these results have not yet been taken into account for the design of a precise innovation for pupils or students.

This paper examines different ways of designing didactic structures on the basis of research results. Two examples from the new French national curriculum for grade 8 optics have been used. The reasons governing the choices made in each case are examined (Viennot 1994), and are presented in terms of two dimensions of analysis:

- the role of the learners' common ideas in the episode analysed;
- the epistemological framework in which a given teaching strategy is inserted.

The relevance of using these dimensions to elaborate research-based innovations, or didactic structures, will be discussed, as well as the part temporarily forgotten played by teachers.

Examples from the recent French curriculum

Between 1993 and 1995, a new curriculum was drawn up in France for grades 8 to 12 (Groupes Techniques Disciplinaires de Physique et de Chimie, 1992). This was done on a national scale, in the French tradition of a 'top-down' process. But this time it was decided to explain teaching goals and suggest strategies in much greater detail than before. Documents of various types were produced: texts stating the general principles and goals, detailed lists of items, specific goals and corresponding teaching activities, comments explaining the choices made for critical points, examples of problems and control sheets, and all sorts of documents likely to help teachers understand and implement the innovation (Ministère de l'Education Nationale 1992a, b).

Teaching optics: some conceptual goals at grade 8

The general scope of the curriculum at grade 8, for a six-month course, is a first approach to:

- how one sees objects and optical images;
- how images are formed in thin converging lenses.

The main conceptual goals are

- to convey visual information, light has to enter the eye;
- light travels in straight lines (in a homogeneous medium).

It is proposed to help pupils gain some initial understanding of the subject (including images produced by thin converging lenses) by using only these two basic laws, with emphasis on their explanatory and predictive power. On an epistemological level, the goal is to introduce the idea that a law is a law and does not apply at random. The idea of a restricted domain of validity is not introduced to pupils at this stage.

The idea of the teaching-learning process underlying the proposed sequence is 'guided construction'. Explicit attention is given to pupils' informal ideas. There is no claim that the laws of physics can all be rediscovered merely by contemplating physical reality. This, as Driver *et al.* recently recall (1994), would be to take a simplistic view of learning. Rather, the goal is that pupils should make sense of scientific ideas and realize that they are consistent with experimental facts. These science views may either be first suggested by guided experiments or more directly introduced by the teacher (or 'parachuted in', see Fensham *et al.* 1994: 6).

Some common ideas on this topic

Research results show that at least one of the common ideas in optics in compatible with accepted physics; if a bright spot is seen on a screen, this means that 'there is some light there'. On the other hand, the fact that light has to reach the eye to cause vision is far from obvious (Andersson and Karrqvist 1982, Guesne 1984). Many pupils, university students or even pre- or in-service teachers, talk as if light was visible in itself, without entering the eye. To document this point, Kaminski (1989) and Chauvet (1990) used an experimental set-up involving a lighted bulb, a first screen with a small hole and a second screen with three holes, one of these only being on the path of the light which is emitted by the filament and passes through the first screen.

Not more than 5% in several samples (pupils, secondary school teachers, art students) were able to predict correctly what would be visible through each of the three holes. About half of them predicted that the intermediate hole would appear

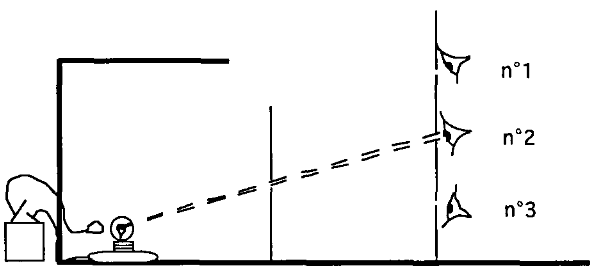

Figure 1. An experimental set-up for the question: what will you see through each hole when the bulb is connected to the battery?

bright when looked at through one of the holes that are not on the path of the light. A preliminary question concerning the impact of the light on the second screen (before the three holes were made) showed that predictions were often correct, thus confirming that rectilinear propagation is not the main difficulty in this situation. This shows that the target idea of non-visibility of light (to put it briefly) is against common sense.

To sum up, one of the two common ideas recalled above, although incomplete, is compatible with accepted physics: some light is on a bright area of the screen. The other common idea illustrated above – 'light is visible' – is clearly not compatible with accepted theory.

Both ideas have been considered for the purpose of constructing teaching episodes, but, as is to be expected, in a different way.

Two different strategies and their rationale

Diffuse reflection

The goal of the first teaching episode is to convince pupils that an illuminated screen (if not perfectly black) diffuses some light. Knowing that it is difficult to admit that the screen is visible only if the diffused light comes into the eye, such a conceptual goal is postponed. The eye is not yet involved. Only the common idea is used, i.e. a bright area on a screen means an impact of light. In this case, colour is employed.

The proposed strategy is to use a second screen to show that the first screen diffuses light. For a more convincing effect, the first (diffusing) screen is coloured, say red. A white screen placed in front of such an illuminated (red) screen appears pink when the first one receives white light.

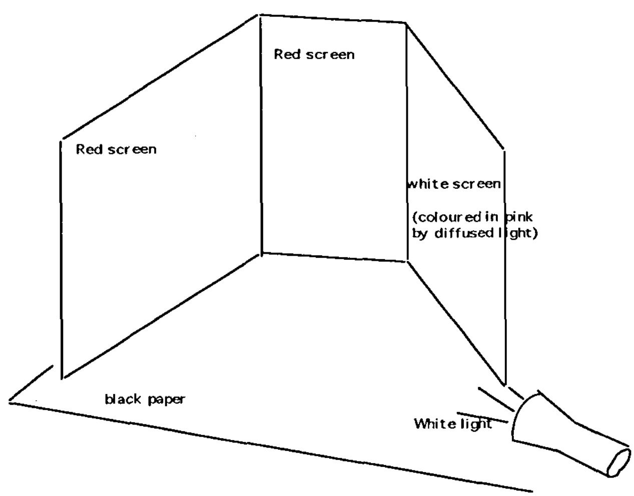

Figure 2. Using a secondary screen to show the light diffused by a first (coloured) screen.

If the first screen is changed to a green one, the colour of the second screen turns green, an effect that is intensified by a perceptual effect of successive contrast. There is clearly a link between the colours of the two screens. The creators of the episode expected that it would be directly suggested by observation that the second screen had received something from the first. Pupils are expected to say that this 'something' is 'colour'. Given the common tendency to interpret a bright area on a screen in terms of an impact of light, the situation is expected to facilitate introducing the concept of diffuse coloured light. A previous experiment with student teachers (Kaminski 1991) supports this hypothesis. Note that this strategy, which uses a commonsense idea as an intermediate step, does not call on an elaborate epistemological register. It is of the 'see and understand' variety, i.e. it uses a process of simple induction (table 1, box 2). A conscious choice was made not to banish such an inductive approach. It may give a wrong or at least incomplete idea of how knowledge is constructed, but teaching episodes with a different epistemological status (see below and table 1, box 3) are planned to balance this possibly negative effect. Moreover, there is no reason why pupils should reach a complete view on epistemological questions at the very beginning of a course in physics as such.

Light and vision

By contrast, consider now the episode focusing on the fact that *light has to enter the eye to produce a visual effect*. The proposed strategy is to raise a cognitive conflict. The same experimental set-up described above (a bulb, two screens with holes) is now used in the classroom. After having predicted, observed and interpreted the spot on the second screen (the holes being covered), on the basis of rectilinear propagation, pupils are asked to predict what will be visible when one looks through each of the three holes in the second screen which are now uncovered. As already explained, most people predict that the hole in the first screen will appear bright when observed through hole 3, even though this latter hole is not on the path of the light emitted by the bulb. The planned teaching strategy is to get pupils to discuss, observe and discuss again, under the guidance of the teacher, until the experimental facts are brought into line with the conceptual elements previously introduced: rectilinear propagation, the role of the eye, and consistent consideration of physical law.

It is not claimed that the cognitive conflicts that are likely to occur will be miraculously resolved, or lead to a definitive understanding. The only claim is that such an experimental set-up and the corresponding teaching strategy are likely to push thinking in the direction of consistency, or in other words, the idea that a law is a law. In this case, the 'laws' – light travels in straight lines from primary sources or diffusing objects, and it has to enter the eye to cause vision – can be expressed in simple words and, it would seem, without a further model. In particular, teachers are advised to avoid inappropriate images of what a light ray is, such as lines of luminous points on a sheet of paper which does not include the source (Kaminski 1991). A more sophisticated modelling process is sometimes necessary and has been suggested for other topics in this curriculum. But the goal remains the same: to see how a law applies in a range of situations, despite possible cognitive conflicts.

Mapping and discussing teaching strategies

The two dimensions that have been chosen to define the teaching episodes described in this paper (table 1, boxes 2 and 3) concern the epistemological status of teaching activities and the role of learners' common ideas. From the point of view of the links between research in science education and the design of innovation, these aspects seem to be especially relevant.

Turning to table 1, we can now consider the meaning of the empty boxes. One (box 1) represents a strategy of using ideas that are commonly shared and compatible with accepted physics, in order to initiate a search for consistency. But in this case, there is a risk that pupils may lack motivation, because common ideas often seem obvious. The second empty box in table 1 (box 4) represents the strategy of investigating a phenomenon which, on the one hand, contradicts common sense and may raise a cognitive conflict, and, on the other hand, is considered in itself, without any effort to integrate it into a unified comprehension of a conceptual domain. For the pupils, this would mean being convinced by experimental evidence despite a conceptual conflict. But it is now well known that in such cases, experimental evidence is not enough to solve the conflict (Driver 1989). Therefore the situation of cognitive conflict will not be useful to the learner unless it is accompanied by a desire for coherence, in other words the idea that a law is not randomly held. The means to be used to overcome the difficulties will depend on the particular situation, but feeling a need for coherence seems to be a minimum condition in any case. Therefore, it is suggested that the two boxes already investigated represent the only cases of real interest.

These two types of strategy make different demands on pupils, but they are probably both useful. As regards teaching activities focused on a search for consistency between facts and conceptual elements previously introduced, it is worth stressing that the goal actually goes beyond overcoming a particular conflict. It is also, if not mainly, to get acquainted with an essential feature of scientific method: consistency (Gil-Perez and Carrascosa 1985). The next section presents some elements of evaluation for a teaching sequence built on this principle.

Table 1. Two 'dimensions' for analysing teaching strategies: examples in elementary optics, at grade 8 in France.

		Epistemological framework	
		Search for consistency	*Simple induction*
Role of learners' common ideas:	→Bridge	Box 1	Box 2 Diffuse reflection
	→Cognitive conflict	Box 3 Light and vision	Box 4

Combining cognitive conflict and search for consistency: an evaluated sequence on colour

Unfortunately, although not surprisingly, there has been no systematic evaluation in France of the way the teaching strategies analysed above are implemented in schools. But an experiment was recently done on a very closely related topic – colour – with the same underlying principles as those presented above in connection with light and vision.

Colour is a perceptual response of the visual system to an impact of light on the retina. As such, it involves at least three domains: physics, the psychology of perception, and the technical bases of art. Different areas of expertise have developed in this connection, which may result in a certain lack of coordination in the ideas of an individual engaging with the subject. One of us (Chauvet 1994a, b, 1996) has designed, implemented in a school, and evaluated, a teaching sequence aimed at providing art students (aged about 19) with a unified view on colour phenomena. In particular, she introduced a conceptual tool in order to help students interpret various types of situation in a single frame: a 'chain' of successive transformations of information on colour from the source of light to the visual system (figure 3). The underlying hypothesis is that this tool would help students avoid limited and very common views on colour, such as 'colour as wavelength' or 'colour as matter', and facilitate a unified comprehension of the subject.

The very first session in Chauvet's sequence consists of raising a conceptual conflict by superimposing two beams of light on a white screen, one red, one green, each made up of one third of the spectrum of white light, and this in a dark room. The following dialogue between two students shows the destabilising effect of such a situation:

Alain: It's close to ochre . . . No, but it's close to brown. In the mixing of paints, in theory, red and green mixed together usually become brown.

Elodie: In practice . . . I can see yellow.

Alain: Yellow? . . . From above, we can't see yellow, I see it as brown. Maybe we've got a problem . . . The problem is that there are two superimposed colours.

Elodie: Face the object.

Alain: From above I can't see yellow . . . Facing the object . . . I see it as yellow.

Alain is clearly expecting to see a brown, as if the superimposed lights were mixed paints. So did more than half of the students ($N \cong 20$) before teaching, in each of the four years covered by this study. This confirms, if confirmation were still needed, that seeing does not mean that one is convinced. When the yellow

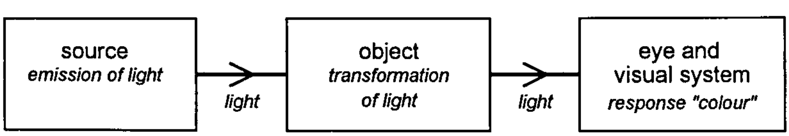

Figure 3. 'Chain': analysing successive changes in information about colour carried by light from the source to the visual system.

colour is agreed on, much work still remains to be done before real progress is obtained. The students are then asked the following questions:

What light is being received?
Where is this (yellow) colour created: in the space where lights meet? On the screen? In the observer's eye (on the retina)? In the observer's brain?

They are invited to debate and to illustrate what they think in a drawing. Two of these drawings (figures 4 and 5) show how successful this activity may be in revealing differences in students' understanding of colour as a perceptual response to light. Chauvet's fine-grained evaluation shows that this whole process is very effective in fostering constructive discussion among students and convincing them to accept the 'chain' as the most appropriate model to explain colour phenomena.

The whole sequence (15 hours in all) is built on such activities, experimental settings being used as the focus of prediction, guided observation and debate, with the support of conceptual tools, mainly the 'chain' presented above.

An evaluation carried out one year after the end of the sequence using written questions of various types (Chauvet 1996, Viennot 1995) showed that a coherent and lasting comprehension has been achieved by a third of the students in the test

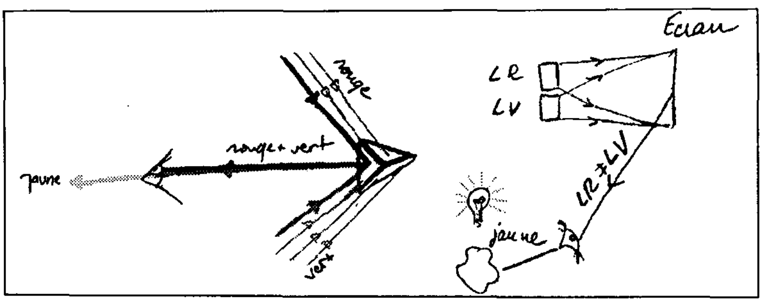

Figure 4. Students' semi-figurative explanation of the situation: red ('rouge') and green ('vert') lights superimposed on a white screen ('écran'): with diffused light and visual response (yellow: 'jaune').

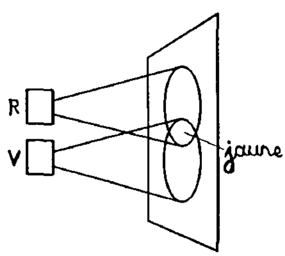

Figure 5. Students' semi-figurative explanation of the situation red ('rouge') and green ('vert') lights superimposed on a white screen ('écran'): without diffused light or visual response (yellow: 'jaune').

group ($N = 18$), whilst each of the two control groups showed a narrower type of understanding, one being dominated by physics and perception, the other by the technical aspects. In both control groups ($N = 31$ in both) not more than 5% of the students achieved conceptual mastery of the complete 'chain' of transformation of information on colour from the source to the visual system.

This experiment is described in greater detail in Chauvet (1994a, b, 1996). It is cited here as an example to show that prediction and observation, even if they produce considerable surprises, are just a first step towards understanding. Only a search for consistency, supported in this case by a structuring conceptual tool, is shown to foster a real conceptual achievement.

Concluding remarks and research questions

In this paper, we have presented an evaluation of one teaching strategy (box 3 in table 1), but not of the other type of strategy that we consider potentially useful (box 2 in table 1). This consists of using a common view compatible with accepted knowledge as an aid to constructing a given concept. In such a strategy, the first question is to evaluate the extent to which learners are convinced of what the teacher sought to convey. For instance, using the example described above: something red is 'sent' from a red screen to a 'normally' white one (figure 1) when the first screen is lit with white light. Such an idea is compatible with accepted theory but highly superficial in terms of this theory. Much work remains to be done to understand diffuse reflection and vision. The whole question is how far such an 'easy-but-limited' idea is or is not an obstacle to further conceptual development. In the example presented above, there is not yet any experimental evidence that the partial understanding of diffusion fostered by this experiment would block further conceptual achievement. In other cases, such as the very common way of demonstrating the existence of a force by the movement of a body in the same direction, the risks of repeatedly using such strategies are obvious. The assessment of this type of risk is a very complex problem, highly dependent on the particular taught content.

We may agree that a given teaching strategy (of box 2 or box 3 types) is likely to be suitable for a given population in a given teaching context, but we may still wonder how it will work when it is suggested to a particular population of teachers, which may be large as it is in France following recent changes in the educational system. The authors' research team (L.D.P.E.S.) is looking into this point on a small scale. Our hypothesis is that it is not enough to investigate students' conceptual achievement before and after an innovation or a new curriculum is implemented. Teachers play a critical role, as they may or may not understand and accept the proposed strategy (Hirn 1995, Couchouron *et al.* 1996). In that respect, the centralized French system provides an opportunity to investigate the role of teachers as curriculum transformers, in relation to their former practice, their conceptual difficulties and their views on the teaching-learning process. This line of research probably deserves great attention. Previous research has concentrated on pupils' own ideas and ways of reasoning in order to guide the design of teaching strategies. There is now a need to do the same thing for teachers and teacher training.

References

ANDERSSON, B. and KARRQVIST, C. (1982) How Swedish pupils, aged 12–15 years, understand light and its properties. *European Journal of Science Education*, 4, 387–402.

BARNEJEE, A. C. (1991) Misconceptions of students and teachers on chemical equilibrium. *International Journal of Science Education*, 13 (4), 487–94.

CHAUVET, F. (1990) Lumière et vision vues par des étudiants d'arts appliqués, DEA de Didactique Université Paris 7. Unpublished document, on request from L.D.P.E.S.

CHAUVET, F. (1994a) Construction d'une compréhension de la couleur intégrant sciences, techniques et perception: principes d'élaboration et évaluation d'une séquence d'enseignement. Unpublished thesis, Université Paris 7.

CHAUVET, F. (1994b) Un instrument pour évaluer un état conceptuel: exemple du concept de couleur. *Didaskalia*, 8, 61–79.

CHAUVET, F. (1996) Teaching colour: design and evaluation of a sequence. *European Journal of Teacher Education*, 19 (2), 119–34.

COUCHOURON, M., VIENNOT, L. and COURDILLE, J. M. (1996) Les habitudes des enseignants et les intentions didactiques des nouveaux programmes d'électricité en classe de quatrième. *Didaskalia*, 8, 83–99.

DRIVER, R. (1989) Students' conceptions and the learning of science. *International Journal of Science Education*, 11 (5), 481–90.

DRIVER, R., ASOKO, H., LEACH, J., MORTIMER, E. and SCOTT, P. (1994) Constructing scientific knowledge in the classroom. *Educational Researcher*, 23 (7), 5–12.

DRIVER, R. and OLDHAM, A. (1986) Constructivist approach to curriculum development in science. *Studies in Science Foundation*, 13, 105–22.

FENSHAM, P., GUNSTONE, R. and WHITE, R. (1994) *The Content of Science* (London: Falmer).

GIL-PEREZ, D. and CARRASCOSA, J. (1985) Science learning as a conceptual and methodological change. *European Journal of Science Education*, 7 (4), 431–43.

GUESNE, E. (1984) Children's ideas about light. *New Trends in Physics Teaching*, vol. 4 (UNESCO: Paris), 179–92.

GROUPES TECHNIQUES DISCIPLINAIRES DE PHYSIQUE ET DE CHIMIE (1992) Avant-projets des programmes de physique et de chimie. *Bulletin de l'Union des Physiciens*, 740, supplément, 1–52.

HIRN, C. (1995) Comment les enseignants de Sciences Physiques lisent-ils les intentions didactiques des nouveaux programmes de quatrième? Didaskalia, 6, 39–54.

KAMINSKI, W. (1989) Conceptions des enfants (et des autres) sur la lumière. *Bulletin de l'Union des Physiciens*, 716, 973–96.

KAMINSKI, W. (1991) Optique élémentaire en classe de quatrième: raisons et impact d'une séquence d'enseignement. Doctoral thesis, Université Paris 7.

KOULAIDIS, V. and OGBORN, J. (1995) Science teachers' philosophical assumptions: how well do we understand them? *International Journal of Science Education*, 17 (3), 273–83.

LIJNSE, P. L. (1994) La recherche developpement: une voie vers une 'structure didactique' de la physique empiriquement fondée. *Didaskalia*, 3, 93–108.

MILLAR, R. (ed.) (1988) *Doing Science. Images of Science in Science Education* (London: Falmer).

MILLAR, R. (1989) Constructive criticism. *International Journal of Science Eduction*, 11 (5), 587–96.

MINISTERE DE L'EDUCATION NATIONALE (1992a) Programme des classes de quatrième et de quatrième technologique. *Bulletin Officiel*, 31, Paris, 2086–112.

MINISTERE DE L'EDUCATION NATIONALE (1992b) Groupe technique disciplinaire de physique. Document d'accompagnement pour la classe de quatrième, Paris.

VIENNOT, L. (1994) Recherche en didactique et nouveaux programmes d'enseignement: convergences. *Didaskalia*, 3, 119–28.

VIENNOT, L. (1995) A multidimensional approach to characterise a conceptual 'state' in students: the role played by questions. In D. Psillos (ed.), *European Research in Science Education II*, proceedings of the second PhD Summer School, Leptokaria (1994), 178–87.

VIENNOT, L. and KAMINSKI, W. (1991) Participation des maîtres aux modes de raisonnement de leurs élèves. *Ensenanza de las Ciencias*, 9 (1), 3–9.