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MOVING BEYOND TEACHING METHODS IN SCHOOL SCIENCE - EPISTEMOLOGICAL AND SOCIOCULTURAL VIEWPOINTS

Abstract. *The question of how to implement teaching methods in school science finally emerges, when new science curricula are introduced and taken in use. Fundamentally new orientations in curricula might however, be in conflict with the situation which is predominant at schools with more traditional views of school science. We start our article by exemplifying the Finnish situation in relation to the science curriculum renovation, taking into consideration tensions at a more general level. Our aim is to bring into discussion both epistemological questions and communicational aspects of science teaching and learning. We conclude that moving beyond the traditional focus on facts and the laws of science; we could teach students to use the knowledge and expertise of others, raising questions, living with uncertainty, articulating ideas in public forums, using evidence, reaching consensus, and making group decisions.*

Key words: *teaching methods, science education, lower and upper secondary school.*

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Introduction

There are several important aspects to be taken into account when a teacher plans, implements, and evaluates teaching methods to be used in science education. In this article we mainly concentrate on the guidelines that the national science curriculum gives to teaching and learning in science classrooms. From time to time science curricula are revised in every country. In Finland, for instance, the revision process resulted in the forms of the National Core Curriculum for Basic Education (NBE, 2004a) and the National Core Curriculum for Upper Secondary School (NBE, 2004b). Although there may be a shift in emphasis in the national curricula, this perhaps might be enough. We need to introduce and open up contemporary ideas of science learning and teaching, i.e., raising research-based suggestions and even developing teaching sequences for teachers, through the means of pre- or in-service teacher education. Mastering of content matters and basic pedagogical skills is not sufficient for teaching science; it is necessary to know the complex and contextual factors that influence the implementation of instructional approaches.

Our intention is to bring into discussion both the epistemological questions (the nature of science, role of experimentation, modelling, different information sources etc.) and the communicational aspects (discussion, arguing, and writing about science) of science teaching and learning. Communication will be discussed in the frame of the sociocultural aspects that are emphasised, e.g., in the general part of the Finnish National Curriculum for Basic Education:

> "The national core curriculum has been formulated on the basis of a conception of learning as an individual and communal process of building knowledge and skills. Through this process, cultural involvement is created. Learning takes place as purposeful study in a variety of situations: independently, under a teacher's guidance, and in interaction with the teacher and peer group. In addition to new knowledge and skills, both learning and work habits are to be learned that will serve as tools of lifelong learning." (NBE, 2004a, p. 16.)

The excerpt above, taken from the National Core Curriculum for Basic Education, shows it is possible to get the impression of a shift towards more socio-cultural aspects of education. However, the traditional views, e.g., transforming knowledge into pupils' heads still quite strongly affect science teaching, especially at the upper secondary level. However, there has been a change of views at the lower level.

Our aim is to open up questions related both to the epistemological and to the socio-cultural views of science education by exemplifying with the so called modelling approach. This combines the epistemological and conceptual nature of science to science teaching, by the means of bringing forth the necessary forms of social language in the science classroom. Our viewpoint here is the implementing of teaching methods, or instructional approaches as we prefer to say, into science education. However we are not dealing so much with the results or theories of science learning, because they do not necessarily have inevitable consequences for science teaching (cf. Millar, 1989). More emphasis should be put on the relationship between actual teaching and the learning that it promotes (cf. Leach and Scott, 2003, p. 95). Creating more authentic scientific experiences in classrooms requires changes in teaching practices, e.g., orchestrating student discussions, considering issues of equity in small groups (social status, dominating members) and balancing the tensions between students' ideas and disciplinary knowledge (Crawford, Chen & Kelly, 1997). The intention of this paper is to concentrate on the discursive nature of school science, taking into account the language used as well as epistemology referred to both tacitly or explicitly.

Tensions in school science

Typical science instruction teaches "final form science" (Duschl, 1990) where theoretical ideas are presented as incontrovertible facts, stripped of the history of their development. Such an approach effectively removes students from the role of producing scientific knowledge, locating authority for the thematic content of science and appropriate argumentation with teachers (Lemke, 1990) and textbooks. Typical science instruction leads students to develop an undesirable naļve view of science as an unproblematic accumulation of facts that describe the world. Students presume that the best way to learn such facts is to pursue shallow learning strategies, the memorisation and rote application of procedures and formulas that do not however promote deep learning. Very few students develop epistemological views of science as a process of building and revisiting models and theories, but consider it necessary only to discover about the world rather than the discovery of facts in the world]. (Sandoval & Reiser, 2004, p. 346.) Teachers are professionally committed to teaching the science of today "that how it is". Obviously, this is not 'doing science', but 'teaching science', and the justification for this practise is to be found in the "didactics" of science and not solely in science itself. Scientists propose theories and methods in order to achieve their own explanatory aims, but this is not entirely possible for students at school (Izquierdo-Aymerich & Adúriz-Bravo, 2003, p. 35).

In general the learning of school science requires students to incorporate prediction, observation, analysis, summarisation, and presentation into their science reading, writing, and oral language practices (cf. Lee & Fradd, 1998). At the secondary level in particular, young people are expected to apply the previously learned basic language, literacy, and technology skills to the comprehension, interpretation, and application of disciplinary knowledge, e.g. science (Moje, Collazo, Carrillo & Marx, 2001, pp. 471–472). At school, science has a normative component

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that should, as far as possible, be made compatible with students' autonomy, provided there is no distortion of the component. But compatibility requires new instructional and epistemological approaches.

For students, science is to some extent compulsory; school science being immersed in rhetoric of authority, demands the teacher's role to be convincing. This aspect has direct influence on the activities relating to science at school, and strongly differentiates school science from that of scientists': scientists choose the problems that interest them, they create their own theoretical models and their own language. This is not totally possible in school science. The value of school science might be that students have goals which they may call their own, which may conform to their expectations and beliefs about school and about the 'real world', while still being coherent with the science curriculum. However, school science is different from that of scientists, because when achieving their goals, students are at their best, able to explain the world (its facts and phenomena) through existing scientific theories. Hence, the teacher as an expert has to carefully plan school science so that it may become something intelligible in itself which is not only imposed from the outside (Izquierdo-Aymerich & Adúriz-Bravo, 2003, p. 34)

Hanrahan (2005, p. 3) believes that the language practices of school science are largely responsive for alienating and de-motivating students who have to accommodate to a new and a different discourse from their primary discourse. At the same time the language practices are providing some of the "wind beneath the wings" of more privileged students who share similarities with their existing discourse. School science sometimes imposes void scientific theories with no relationship to textbook phenomena and comprises of over-precise scientific language which has to be learnt by route (Izquierdo-Aymerich & Adúriz-Bravo, 2003, p. 41).

Ritchie and Tobin (2001) provide evidence of the crucial role of the teacher; students' discussion may be dominated by statements that are reproduced **directly [information]** from textbooks or from the teacher. It is the teacher's task to ensure that students are engaged in a truly dialogical discussion – that is, building on the ideas generated during discussions amongst themselves and questioning or challenging ideas based on information gained from textbooks or through teaching. "Students need to be shown how to represent their knowledge in the form of evidence-based arguments. When students are able to challenge each other's arguments from an empirical position as well as one based on the authority of textbook propositions, small group discussion will move towards the discourse, characteristic of a scientific discourse community" (Ritchie & Tobin, 2001, p. 297.) Clive Sutton (1996) refers to science learning as' learning to talk in new ways' and sees science lessons as offering 'access to new conversation'. He also suggests that part of the job of the science teacher is 'to persuade pupils of the value and reasonableness of those new ways' (Sutton, 1996, p. 147). When introducing the scientific point of view, the teacher is offering students a new way of thinking about the world. If this new way of thinking is quite different from the everyday way of thinking, it is quite likely that the teacher will need to persuade pupils of the plausibility and usefulness of this scientific point of view. Thus, the teacher has a key role to elaborate interaction that supports this objective (Leach & Scott, 2003, p. 105).

The pressures of getting the correct answer through experimentation in school science might push teachers toward oversimplification and students toward fraudulent presentations of results. Students are faced with the dual roles of learning science and doing science. Due to the lack of experience when conducting research, students are often left without cultural resources (e.g., knowing how to research with integrity, how to persuade peers, how to understand the roles of uncertainty and error in experimentation) necessary to make scientific decisions and direct their learning (Fairbrother, Hackling & Cowan, 1997) Students might also abandon experiments when the results are not as anticipated, which reflects the students' belief that the correct answer can only be achieved through linear algorithms. In studying science, students must learn to work with conceptual tools, epistemological framing, ontological perspectives and forms of reasoning of the scientific community (Leach & Scott, 2003, p. 103).

Epistemological features of school science

We agree on the difference between the epistemological nature of school science and that of 'real' science with recent suggestions (by, e.g., Izquierdo-Aymerich & Adúriz-Bravo, 2003), which adequate to the objectives they pursue; and this is also true in school science (Izquierdo-Aymerich & Adúriz-Bravo, 2003, p. 38). An argument is formed on a set of reasons that convey a statement and reach a conclusion. Scientific arguments are hardly ever strictly formal (logical or mathematical); they are generally analogical, causal, hypothetico-deductive, probabilistic, abductive, inductive etc. Causal reasoning is in fact responsible for almost all the arguments constructed in science classrooms; we then realise that it is necessary to promote oral and written discourse in the classroom that enhances the use of reasoning (Izquierdo-Aymerich & Adúriz-Bravo, 2003, p. 38.)

Science education should promote a new way of theoretical thinking and reasoning, that is, it should have an important epistemological component. Scientific content should be reasonable and reasoned, and should be composed of a system of ideas and actions that is coherent, valid, and available to students (Izquierdo-Aymerich & Adúriz-Bravo, 2003, p. 27) There are at least two reasons why an understanding of scientific epistemology is of importance in science education, particularly in inquiry-based instruction. The first reason is instrumental: an understanding of the epistemological frame of inquiry will help students to perform better. The second, more fundamental, is the desire for students to develop sophisticated epistemologies of science. In contemporary democratic societies, lay citizens need to understand the nature of scientific knowledge and practice, in order to participate effectively in policy decisions, and to interpret the meaning of new scientific claims which affect their lives (Sandoval, 2005, p. 367) From a psychological perspective, people can have an epistemology, or potentially, more than one. Sandoval (2005, p. 636) defines students' formal epistemology as being a set of ideas about scientific knowledge and its production, that students appear to have about professional (formal) science. He uses the term practical epistemology to refer to the set of ideas that students have about their own knowledge production in school science.

Normally, people do not reflect explicitly on their epistemologies (Hammer & Elby, 2002) and epistemological beliefs are domain specific (Hofer, 2000). Therefore, epistemological ideas should be taken for explicit discussion in science classroom. Sandoval (2005) suggests the command of four broad epistemological themes in order for students to inquire effectively into scientific problems, to understand their inquiry into scientific problems, to understand their inquiry as science, and to be able to evaluate scientific claims in relation to socioscientific issues in their lives outside of (and beyond) school. Probably the most important epistemological notion for students to understand is that (1) *scientific knowledge is constructed by people*, and is not simply discovered in the world. Our observations of the natural world, including our interpretations of experimental manipulations of the world, are strongly guided by our prevailing theories. At the same time, these ideas must "be evaluated against the recalcitrance of the material world (Driver, Newton & Osborne, 2000, p. 293). The second epistemological theme is that to properly understand science and effectively conduct inquiry, students should understand that (2) *scientific methods are diverse* (Sandoval, 2005, p. 640). A part of the diversity in method stems from the differences amongst scientific disciplines when exploring different kinds of phenomena. Epistemologically, the goal is to help students develop standards for evaluating the fit between observations, the methods of obtaining them, and the knowledge claims advanced through them.

The third key epistemological goal is that students should understand that there are (3) *different forms of scientific knowledge*, varying in their explanatory or predictive power and in their relation to the observable world. For instance, besides theories, laws and hypotheses, models are an important form of scientific knowledge. There are also rhetorical forms, such as explanations, predictions, and arguments that rely on these other epistemological forms to advance specific claims (Sandoval, 2005, p. 640). Understanding forms of scientific knowledge seems to be an

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epistemological blind spot in standards documents and expert opinions that rather focus on scientific methods (McComas & Olson, 1998; Osborne et al., 2003). The fourth epistemological feature is that *scientific knowledge varies in certainty* – some claims are more tentative than others (Osborne et al., 2003). It has two consequences within science education: First, the removal of absolute certainty with respect to knowledge decentres authority from teacher toward students. Second, this decentring enables a more authentic consideration of claims in the locus of authority concerning their validity to satisfy epistemological criteria. An important instructional goal, therefore, is the recognition that current scientific ideas may change as new observations, or new competing ideas come to light. This changing nature of theories reflects the cultural, historical development of scientific theories. Sandoval (2005, p. 641) emphasises that the above-mentioned minimal set of epistemological themes that students should command clearly interrelate in multiple ways.

Science teaching and the learning of science as sociocultural processes

Our main interest lies in the so called sociocultural views on learning, but we also discuss some features of individual views (cf. Leach & Scott, 2003). According to the sociocultural view, individuals' "*inner speech*" has a decisive role in the formation of mental processes. Inner speech is a part of a dialogue one carries on; this kind of language provides the very tools through which thoughts are first rehearsed by the learner (or, on so called intermental plane) and then processed and used on the intramental (i.e., social) plane (Howe, 1996, p. 41). The process of *internalisation*, introduced by Vygotsky (1978), is one in which individuals appropriate themselves and are able to use (on the intramental plane) conceptual tools first encountered on the social plane (Leach & Scott, 2003, p. 99) The process of internalisation does not simply involve direct transfer of 'ways of talking' form the intermental to the personal plane. There must be a step of personal interpretation, where the individual comes to a personal understanding of the ideas encountered on the social plane. Learners must reorganise and reconstruct the talk and activities of the social plane (Leach & Scott, 2003, pp. 101-102)

Cultural features in learning

According to the sociocultural view, learning and meaning-making are portrayed as originating in social interactions between individuals, or as individuals interact with cultural products that are made available to them in books or other sources. The intended products of learning (i.e. science concepts) are cultural in their nature, because they cannot generally be perceived by individuals. They are validated through complex empirical and social processes, and they are used within certain communities for particular purposes. Thus, knowledge can only be learned through some process of *social transmission* (Leach & Scott, 2003, pp. 93-94) This social transmission is also described in the contemporary Finnish Core Curriculum for Basic Education:

> "The learning environment must also support interaction between teacher and pupil, and among the pupils. It must promote dialogue and guide the pupils in working members of a group. The objective is an open, encouraging, unhurried, positive atmosphere, for whose maintenance the teacher and the pupils share responsibility." (NBE, 2004a, p. 17)

Sociocultural views of learning endorse the view that knowledge is socially constructed and context dependent, and that human mental processes are situated within their historical, cultural and institutional setting (Wertsch, 1991). It is necessary to provide an account of how students come to personal understandings of ideas and information that already exit in the culture, from their interactions with teachers, textbooks and peers (Leach & Scott, 2003, p. 94). From our perspective we see that cognition is mediated by social interaction and cultural practice and that language, literacy, and discourse are both tools and products of cognitive, social, and cultural practice (Vygotsky, 1978; Moje et al., 2001, p. 470). Incorporation of this perspective has an impact on our view of the *role of language* in science instruction. A sociocultural approach to instruction relies on language as a tool to support and promote thinking, using it as a means to stimulate students to reflect and explain, in order to understand how their experiences and their context-bound knowledge fit into a larger system. Students should be allowed to use their own language as a tool for thought and communication as they gradually learn to use the special language of science. Following Vygotskian arguments, the central and essential role of this enculturation is assigned to the teacher (cf. Howe, 1996, pp. 47-46)

From a sociocultural perspective, learning means changing from one sociocultural context to another as a process of enculturation by participation in shared activities (Lave & Wenger, 1991). Typically, such a sociocultural view of learning, e.g. in science, promote the community aspect of the classroom and the role of peer discussion in assisting students to learn science. From this viewpoint, discussion amongst peers has the potential to provide students with alternative models of scientific phenomena, and to introduce criteria as well as evidence, to help learners to distinguish between the scientific models. (Coll, France & Taylor, 2005, p. 190) The National Core Curriculum for the Upper Secondary School describes the nature of physics education as follows:

> "Students will learn to plan experiments in groups and to discuss information or material acquired through experimentation, its processing and modelling and the assessment of its reliability. The group will learn to share new information." (NBE, 2004b, p. 148.)
> The objectives of instruction in physics are for students to, e.g., "acquire and process information together with other students in the same way as expert communities; ... make use of various sources to acquire information and be capable of presenting and publishing information in a diverse manner..." (NBE, 2004b, p. 148.)

According to the sociocultural view, teaching comprises of activities associated with enabling the learner to participate effectively in the activities of the more expert nature, and learning is seen as *enculturation* via guided and modelled participation. (Hodson & Hodson, 1998a, p. 37) Students need the opportunity to work alongside and to gain assistance, encouragement and support from someone who has already been successfully enculturated; within science education that person is usually the science teacher (Hodson & Hodson, 1998b, p. 17)

"*Discourse*" is regarded as a sociocultural and political entity that subsumes ways of saying, writing, doing, being, valuing and believing. Discourse facilitates communication and establishes social identity within a community. The teaching and learning of science are considered to occur in evolving communities of practice in which the participants' discursive practices (e.g. talk, writing, cognition, argumentation and representation) are constantly varying. The catalysts for change are social interactions between participants and social structures such as conventions and norms (Bleicher, Tobin & McRobbi,e 2003; Moje et al., 2001) Given the appropriate conditions in which particular interests in a group are supported, learning about science can lead students to develop an increasingly science-like discourse (Bleicher, Tobin & McRobbie, 2003, p. 320).

The role of preknowledge

Although young people have ample funds of knowledge about the natural world available to them in their everyday interactions, understanding and communication through discourse is often distinctly different from that valued in science and science classrooms. In addition, their teachers are often unaware of, or sometimes dismiss, these funds. As a result, students' funds of knowledge about scientific phenomena are rarely articulated to scientific funds of knowledge and scientific discourse. This lack of articulation concerning various types of knowledge, and ways of knowing and talking about that knowledge, can hinder deep conceptual learning in science. Students and teachers use the same words but mean very different things. Thus, discursive scaffolding should be woven into science instruction (Moje, Collazo, Carrillo & Marx, 2001, p. 474). From a sociocultural view, e.g., students' 'misconceptions' simply present ways of communicating in everyday social

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language. This is the mode of communication that prevails in day-to-day living, and represents ways of communicating that are 'viable' in that they are widely understood. In these terms, it is science that offers an alternative view of the world. 'Alternative conceptions' do not represent fixed items in students' 'mental structures', but rather have the status of ways of thinking and talking, which are used by students in particular situations. The goal of teaching is to introduce new ways of thinking and talking to students, illustrating and modelling as to how these ideas could be appropriately used in particular situations.

Students' knowledge, skills, and language have a *social history* and students "carry with them both cargo of sociocultural meaning ... [a]nd a potential for further development. In that sense, knowledge is not merely handed on, nor is it discovered or constructed solely by the individual learner. Rather, it is co-constructed through social instruction." (Hodson & Hodson, 1998a, p. 37) These elements are also described in the contemporary Core Curriculum for Basic Education:

> "Learning results from the pupils' active and purposeful activity, in which they process and interpret the material to be learned on the basis of their existing structure of knowledge. ... [L]earning depends on the learner's previously constructed knowledge, motivation, and learning and work habits. Learning that occurs through interactive cooperation aids individual learning. In its all forms, learning is an active and goal-oriented process that includes independent or collective problem-solving. Learning is situational, so special attention must be given to the diversity of the learning environment. In learning, new possibilities open up for understanding culture and the meanings that culture contains, and for participating in social activity." (NBE 2004a, p. 16.)

Role of discursive practices

By strategic use of particular discourse processes teachers can teach about science as a process, and model ways for students to effectively "talk" and practice science (Crawford, Kelly & Brown, 2000, p. 253). Sociocultural views of learning draw attention to scientific knowledge which is 'talked into existence' on the social plane of the classroom (Leach & Scott, 2003, p. 103). The ability to guide the classroom discourse exploring ideas and introducing explanations, is central to the science teacher's skill, and is critical in influencing students' learning. This argument should not be mistaken as a stance against practical work; rather, Leach and Scott (2003, p. 104) argue that in most cases practical work should be conducted in such a way that the main purpose is for students' interaction with ideas, as much as the phenomena in question.

Leach and Scott (2003, p. 100) suggest that a mature understanding of science can be demonstrated in terms of the ability to adapt to ways of talking and thinking about phenomena according to the context, recognising the appropriateness, power and limitations of each. Teacher talk, whether in the mode of a more formal lecture or in informal exchanges with individuals and groups during other activities, plays a key role. By alternating between scientific and everyday language, and through the use of everyday exemplars, similes and analogies, anecdotes and jokes, teachers can make science more meaningful, exiting, humane and accessible for students. A teacher talk is a way of introducing new ideas and new terminology carefully, systematically and sensitively (Hodson & Hodson, 1998b, p. 22)

Leach and Scott (2003, p. 103) have developed the view of science learning unites the social-interactive and personal-sense-making parts of the learning process, and identifies language as the central form of mediational means on both intermental and intramental planes. It draws upon sociocultural approaches in conceptualising learning in terms of developing a new *social language*, and in identifying epistemological differences between social languages. The classroom discourse should be guided by the teacher through different kinds of pedagogical intervention that might include

- developing key ideas relating to the new concepts being introduced;
- introducing points relating to epistemological features of the new way of knowing;
- promoting shared meaning amongst all of the students in the class, making key ideas available to all;

- checking student understanding of newly introduced concepts.

Taken together, these different kinds of teacher intervention and the ongoing interactions between teacher and students constitute a teaching and learning 'performance' on the social plane of the classroom (Leach & Scott, 2003, p. 105)

Discursive practices involve text production, reproduction, and consumption, where text is broadly defined as any written of spoken product. If students are to learn science as a form of discourse, it is necessary for them to adapt their language resources while practising science in settings in which there is competent guidance (Tobin, McRobbie & Anderson, 1997, p. 493); the shared language must be negotiated in the classroom community. Talking and writing in the science classroom offers opportunities for students to use scientific terminology and genres, and to participate in social practices associated with science. To "talk" or "write" science is not an easy task, and must be learned through participation with those who more knowledgeable. Talking and writing requires time and opportunities for both success and failure (Kelly & Chen, 1999, p. 909)

Applying sociocultural approach into school science

In 1960s and 1970s Piaget's ideas of learning had a major influence on science education. In this framework students were encouraged to "test", "find out things", "be creative", and with the aid of equipment to "see what happened". The learning philosophy was inductive in its nature and learning was considered to follow from observation and activity, generated by the students' own interests and spontaneous questions. As a result, researchers were interested in individual students' understanding of specific phenomena, their discussions and interaction. However, personal knowledge construction in science is not so easy, since most of the knowledge is very abstract. Abstract scientific knowledge cannot be constructed or learnt by the student on his own. Students need the teacher's help in knowledge construction.

The teacher's central role in guiding students' learning is stressed in the socio-cultural perspective of learning. Contrary to Piagetian ideas, the socio-cultural perspective of learning considers the teacher, or some other knowledgeable figure, to have a key role in mediating existing scientific knowledge to students (cf. Edwards & Mercer, 1987). In this framework science education is an enculturation process and learning can be described as guided participation in which the role of the competent member, the teacher, is critical in order for learning to occur (Säljö & Berqvist, 1997, p. 394). Mortimer and Scott (2003, p. 12) characterise socio-cultural framework by describing that teaching science involves introducing the learner to the social language of school science. Firstly, the teacher makes the scientific ideas available to the social plane of the classroom. Secondly, she needs to assist students in making sense of, and internalising, those ideas. Thirdly, the teacher needs to support students in applying the scientific ideas, while at the same time gradual transfer of responsibility for the use of them is given to the students.

Mortimer and Scott (2003) emphasise the role of language by stating further that the teacher introduces and develops the scientific story to the students. It is important to see that the scientific story includes both the conceptual and the epistemic line. This point was already made by Scott (1998, p. 57) by pointing out that "learning the science way of knowing involves not only learning how to use the conceptual tools of science but also coming to appreciate the epistemological framing of those tools". Although the teacher has to introduce the scientific story to the students, all students have to reconstruct the story in their own mind. "The process of learning and development is not one, which involves ideas being transferred directly from teacher to student, parent to child, or friend to friend. What is involved, for each participant, is an ongoing process of comparing and checking their own understanding with the ideas, which are being rehearsed on the social plane (cf. Mortimer & Scott, 2003) Science learning is both personal and socio-cultural.

In the sociocultural framework, students' understanding is not seen as shaped only through adaptive encounters with the physical world. On the contrary, understanding develops through interaction between people in relation to that world. It is not only physical and comprehended by

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the senses, but cultural, meaningful and significant, and made so principally by language (cf. Edwards & Mercer, 1987) It has also been argued that the structure of discourse and the language used in classrooms directs the attention of participants and thus influences their thinking (Edwards and Mercer, 1987; Mercer, 1995). The way in which the teacher talks around the activity is at least as important as the activity itself. As Mortimer and Scott (2003) see it, talk is the central mode of communication in the science classroom.

Learning demand as a challenge

In a socio-cultural framework, science learning involves learning to talk science (Sutton, 1996; Ogborn Kress & McGillicuddy, 1996). Bakhtin (1981) refers to different social languages used by specific communities of people for particular purposes. In the context of science teaching a distinction can be drawn between the everyday social language and the social language of school science. Teachers and students alike, bring many different language and literacy practices to their classroom work. These practices are embedded in various discourses, or ways of knowing, doing, talking, reading, and writing, which are constructed and reproduced in social and cultural practice and interaction (Moje et al., 2001, p. 470) Learning science involves internalising the social language of science and the ability to use it appropriately in various situations. Students should learn the language of science. The important issue of teaching is to find ways of helping students to recognise the context, in which it is appropriate to think, act and talk in particular ways.

Science teaching can be conceptualised in terms of introducing the learner to one form of the social language of science. A distinction can be drawn between the everyday social language and the scientific social language. There are also differences between 'real' science and school science. The science, which is taught in school, is a simplification of real science and for example takes into consideration the age of the students. The concept of *learning demand* (Leach & Scott, 2000) describes the differences between the social language of school science and the social language, which the student brings to the classroom. This difference is the learning demand for the student. The difference between the teachers' interpretation of school science and the social language of real science) is the learning demand for the teacher (Viiri & Saari, 2002, p. 140).

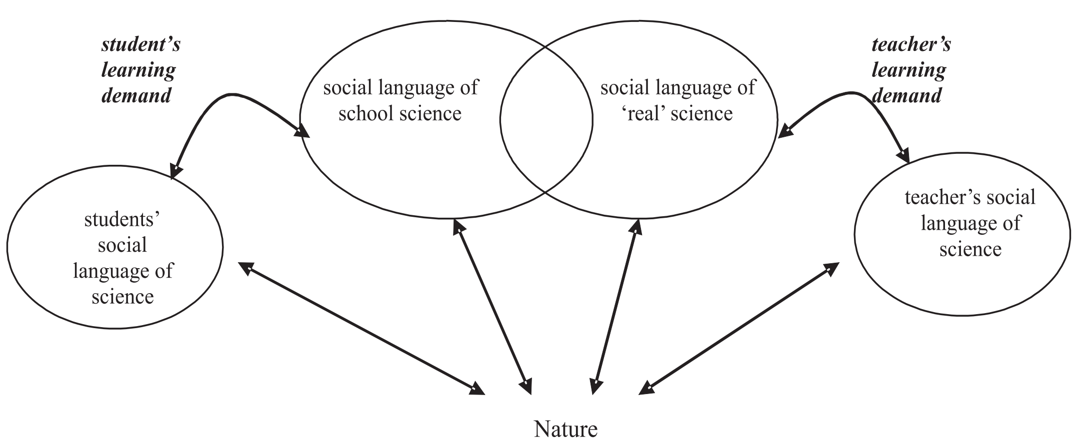

Figure1. Learning demands in a science classroom.

Students' learning demand is important when we are planning a teaching sequence. As learning is personal and socio-cultural, we have to know what the student has to construct personally and what the difference is between the students' ideas and the cultural knowledge of science. In

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order to implement a teaching sequence in a real school context we must know how the teacher has to be advised to be able to guide, stage, enculture, and use semiotic tools in classroom settings. The learning demand approach on a general level might involve, e.g., using different concepts from those used in everyday explanations, explaining in terms of different ontology, and recognising that key epistemological features of scientific explanations include generalisability and empirical consistency (Leach & Scott, 2003, p. 102).

Epistemological demand as a challenge

Beside the differences related to various languages used in the science classroom (the learning demands), there are also differences in epistemological features that should be explicated. In order to examine this challenge, here we introduce the concept of 'epistemological demand' derived from Sormunen's (2003, pp. 108–109) 'epistemic demand'. The above introduced concept 'learning demand' (Leach & Scott, 2000, Viiri & Saari, 2002) was used as an analogical premise for epistemic demand, which referred to the different understandings of the nature of knowledge and knowing. Sormunen (2003) used the word "epistemic" in order to avoid comparing young people's views against well-defined intellectual positions or epistemological theories, e.g. relativism or realism (cf. Donnelly, 1999). Here we return to the term "epistemological", because we found Sandoval's (2005) division of students' epistemologies to formal and practical ones very suitable for describing the epistemological tensions in science classrooms.

We define *epistemological demand* as the difference between individuals' formal and practical epistemologies. Formal epistemology is a set of ideas about scientific knowledge and its production that an individual appears to have about professional science, and practical epistemology refers to ideas about one's own knowledge production related to science. Our definition of epistemological demand follows our conceptualisation of learning demand, by expanding Sandoval's (2005) idea of students' two-fold personal epistemologies which also concern the teacher in the science classroom (Figure 2). The student's epistemological demand sets a challenge for science education to complement the difference between her epistemologies of 'real' science and school science; the difference might only be narrowed by meaningful and epistemologically reasoned science education. Another challenge is portrayed in the consistence between the teacher's epistemologies concerning both formal science and school science; i.e. the teacher's epistemological demand.

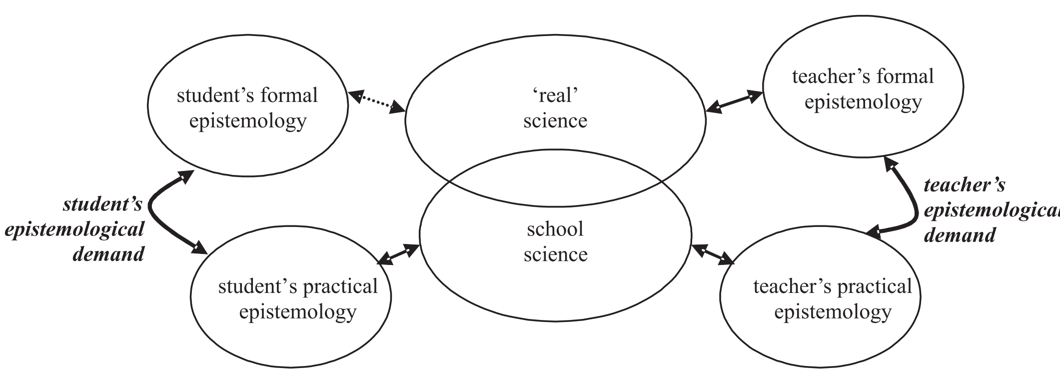

Figure 2. Epistemological demands in a science classroom.

For students the epistemological demand cannot be totally fulfilled: their formal epistemologies will always be restricted, because having inherent ideas about professional science requires a long apprenticeship in the scientific field. School science, if properly organised, could, however, help to fulfil this demand. One of the crucial factors affecting this is the epistemological demand of the teacher: if she has studied, e.g., physics, participating in a research group at

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university the teacher's formal epistemology may be well-informed about the features of professional science. This might be possible in Finland, because subject teachers have Master Level studies in their major subject. The challenge for the teacher is to plan, implement and evaluate science teaching sequences in the way that reflects the epistemological features of real science.

Scientific inquiry in school science

Scientific inquiry generally refers to a process of asking questions and generating and pursuing strategies to investigate them. Also by generating data, analysing, and interpreting the data, drawing conclusions from it, communicating the conclusions, applying conclusions back to the original question, and perhaps following up on new questions that arise. (cf. Krajcik, Blumenfeld, Marx, Bass & Fredricks, 1998; White & Fredricksen, 1998.) Many scientific inquiry tasks given to students in schools, do not however reflect the core attributes of authentic scientific reasoning. Most of the inquiry tasks represented in many school textbooks, can be classified as simple inquiry tasks (Chinn & Malhotra, 2002, p. 179), i.e., simple experiments (students conduct a straightforward experiment controlling only one variable), simple observations (students only carefully observe and describe the objects) or simple illustrations (students follow a specified procedure and observe the outcome). It must be emphasised here, that inquiry-based learning is not discovery learning, which is designed to lead students towards a predetermined view (Hodson & Hodson, 1998a, p. 40). It has been widely suggested that discovery learning approaches neglect social, cultural and affective dimensions of science and they are only partially suited to the complex and diverse context of school classrooms where these dimensions play an important role (Coll, France & Taylor, 2005, p. 190).

From an epistemological perspective, inquiry is simply the process of doing science, and from an instructional perspective, inquiry is a way of organising activities in the classroom. Complex inquiry tasks will take a substantial amount of classroom time; there is no way to condense authentic scientific reasoning into a single 45-min science lesson. Even if ample time is allotted to authentic reasoning tasks, there are still serious instructional challenges, e.g., how to foster complex reasoning when it is already difficult for students to learn to control variables in simple situations (Chinn & Malhotra, 2002, p. 213). However, we have taken into account Sandoval's (2005, p. 637) broad definition for so called *guided inquiry*: it refers to "approaches to supporting students' inquiry by guiding one or more of the steps mentioned above". His view reflects that within and across scientific disciplines there are many ways to investigate particular questions, from simple observations to controlled experimentation.

We are following the steps of scientific inquiry quite broadly, using it as a referent to our implementation to model the states of matter in 7th grade science classroom. Our modelling sequence includes several forms or steps of inquiry in a broad sense. Our point here is that according to Sandoval (2005, p. 637), it is clear that the way in which inquiry is implemented in particular classrooms has direct consequences upon the epistemological ideas that students may bring to bear on their work, and the potential effect of that work.

Modelling as an example of instructional approaches

We have chosen modelling as our example for the implementation of instructional approaches in science education, because it combines both epistemological and sociocultural aspects that are related to epistemological and learning demands described in the earlier section. Our aim here is not to give a thorough description of various models that can be used in science classrooms; instead when we describe our instructional sequence on the modelling of the states of matter in middle school science we are referring to recent reviews on the use (e.g., Gilbert & Boulter, 2000), typology (Harrison & Treagust, 2000), and role of models (Coll, France & Taylor,

2005) in science education. The Finnish national core curriculum for basic chemistry education describes instruction as follows:

> "The instruction relies on an experimental approach in which the starting point is the observation and investigation of substances and phenomena associated with the living environment. The pupil progresses from that point to the interpretation, explanation, and description of phenomena, and to modelling both the structure of matter and chemical reactions with the symbolic language of chemistry. The experimental orientation must help the pupil to grasp the nature of science and to adopt new scientific concepts, principles, and models; it must develop manual skills and abilities for experimental work and cooperation and stimulate the pupil to study chemistry." (NBE, 2004a, p. 192.)
>
> "Chemistry instruction [on upper secondary level] is characterised by observation and experimental study of the properties of chemical phenomena and substances, the interpretation and explanation of phenomena by means of models and structures, description of phenomena using chemical notation and by modelling and mathematical processing of phenomena." (NBE, 2004b, p. 156.)

Models are an important part of physics and chemistry; in order to understand science, students must know how scientific models are constructed and validated (Hestenes, 1992, p. 732). Consequently, the use of models and analogies in the teaching of physics has already been studied to a considerable extent (see, e.g., Gilbert and Boulter, 1998; Gilbert and Boulter, 2000). To teach models and modelling, we should not only know the nature of the knowledge students have about modelling in a particular scientific topic but we should also know what kind of conceptions students have of models in general. It appears that students, like the general public, have limited understanding of the nature of science and how scientists conduct their 'business'. As soon as scientists attempt to explain macroscopic nature (e.g., physical and chemical properties of substances, chemical behaviour) they inevitably resort to use of models (Coll, France & Taylor, 2005, p. 183) Thus, models and modelling are key features of science and consequently of science education, when there is an attempt to make scientists' understanding accessible and to provide some insight into their business. It is considered that to understand science is to understand the models used by scientists (Harrison & Treagust, 1996).

The use of analogies and models within the pedagogy of science education may provide a route for students to gain some understandings of the nature of science and scientific enterprise. In addition, some pedagogical approaches to model use can enable students to develop a metacognitive awareness (cf. Lehtelä, 2001) as well as providing tools with which to reflect on their own scientific understanding (Coll, France & Taylor, 2005, p. 184). We suppose that model-based inquiry sequences could construct a "process of mediating the nature of academic content with students' language and cultural experiences in order to make such content (e.g. science) accessible, meaningful, and relevant" (Lee & Fradd, 1998, p. 12).

Model-based teaching and learning strategies provide opportunities for school science to go beyond the narrow focus of conceptual change to an examination of the wider social aspects involved in learning science; learning about science could be regarded as important as the development of conceptual and procedural knowledge (cf. Coll, France & Taylor, 2005, p. 189). Our idea of presenting a teaching sequence of modelling to states of matter in school science is analogical, or at least in a broad sense, to scientific inquiry implemented in science. This approach allows us to discuss the various aspects related both to the epistemological and to the sociocultural aspects presented.

Students' ideas about natural phenomena provide us with the first anchoring models that can be considered in the classroom (Clement 1993). But, it is necessary to relate the new scientific knowledge – formulated through other kinds of models – to the students' own ideas about knowledge (Izquierdo-Aymerich & Adúriz-Bravo, 2003, p. 35). Students reason according to their initial models, which generally have an iconic relationship with phenomena; a simple image may function as a model for students. Experimentation and its written reconstruction bring students to a new epistemic level, in which non-iconic (i.e., symbolic) signs are much more relevant

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(Izquierdo-Aymerich & Adúriz-Bravo, 2003, p. 38)

When students learn science, the aim is for them to come to understand and be able to use scientific ideas that already exist through their use within particular communities. Scientific knowledge presented to students may, however, be a gross simplification of, or in conflict with, the best knowledge available to the scientific community – simplified models are introduced in the science curriculum (e.g., a model of matter consisting of particles which are hard, invisible balls) because they have explanatory power in themselves, and because they can be built upon in future teaching (Leach & Scott, 2003, 107, p. 110)

Izquierdo-Aymerich and Adúriz-Bravo (2003, p. 39) have generated a sequence of questions and answers that can contribute to the construction of applicable knowledge:

1. What we already know and what we are looking for.
2. The theoretical model, which is a representation of the phenomenon and of our actions upon it.
3. The analogical relationship with other empirical situations that are known and which correspond to the same conceptual and procedural structure, and contribute to the robustness of the model.
4. The arguments that associate facts, procedures, symbols and ideas through reasoning and discourse.

Izquierdo-Aymerich & Adúriz-Bravo (2003, p. 40) believe that thinking through models is the most important feature of science and therefore it is emphasised in their teaching proposal. Referring to aspects dealt with here, we move now to describe our implemented teaching sequence.

Implemented teaching unit on states of matter in 7th grade physics and chemistry

The following presents an example of inquiry-based approaches demonstrating how we constructed a teaching unit for teaching the modelling idea for secondary school students (see it in details in Saari & Viiri 2003). The teaching unit of eight hours, which was based on an earlier study (Saari, 1997), was designed for 13 year-old physics students in the 7th grade. Our aim was to teach students the general ideas of modelling, by teaching them how to use models in learning the states of matter (gas, liquid, solid). We used curricular models, i.e. particle model and continuous model, to portray the most important aspects of matter to the students. The intention was for students to develop their general idea of modelling with these "concrete" examples of modelling and with the teacher's general comments about modelling in connection with these models. In our teaching unit, we tried to discuss the nature of the models and students actively constructed them. Of course, whenever possible the models were tested experimentally. We tried to explain to the students the process of constructing a scientific model: the methods, representations, concepts, and reasons which scientists also use when they construct models. The purpose of the teaching was to influence the student's idea of modelling.

In literature, we can find many definitions of models and their use in science (e.g. Bunge, 1998; Justi & Gilbert, 2002); these aspects represent the particular epistemological ideas of formal science. There have also been some studies dealing with students' and teachers' ideas of models and modelling, which are in turn practical epistemologies of classroom members. From this literature, we collected the ideas that we thought to be the aim of teaching: the school science idea of modelling and students' typical ideas of models (Table 1). The difference between the school science idea of modelling and the students' ideas of modelling was used in the planning of the teaching unit in this study.

Table 1. Differences of school science and students' typical everyday views concerning models (Saari & Viiri, 2003).

Aspects of school science to be addressed	Students' typical everyday views
A scientific model represents a target that is known or unknown.	A model is a thing or an act.
The purpose of the model is to give an idea of a target and help in conceptualising it.	The purpose of the model is one of copying.
The model also provides the vocabulary to represent the target.	
The model's fitting depends on its use.	The model's fitting depends on who is making the model but the model has to be as accurate as possible.
The changing of a model is based on research.	Model is changed if there are mistakes in it or if the maker wishes to do so.

By comparing the different views set out in Table 1, the "learning demand" (Leach & Scott, 2002) is seen to involve the student in coming to recognise the following:

1. Models can be concrete or abstract rather than just artefacts.
2. Models are used to represent a target (its structure and processes) rather than copy a target.
3. A model simplifies its target rather than being an accurate copy of it.
4. A model can be used to predict and explain the behaviour of its target.
5. Models can be applied generally to a wide range of contexts rather than just in the situation relevant.

The planning of the teaching unit was based on these five ideas.

The learning demand may be divided into conceptual, epistemological and ontological parts (Leach & Scott, 2002). In the case of the general modelling idea, there are not so many differences on the conceptual level. Of course, when we model a specific phenomenon, e.g. kinematics, differences related to concepts will arise. The students' main problems are perhaps related to the epistemological and ontological aspects of modelling. They think that a model must be a true description of Nature and that the entities related to the concepts used in the model really exist. This epistemological point is also reflected in the five aims presented above. All of them could be categorised as epistemological demands.

Because modelling, at least in the case of teaching the constitution of matter, deals with un-observable phenomena and is an abstract issue, students cannot discover it by themselves. This is why the teacher has a key role to play in mediating the existing public knowledge. The meanings of modelling have to be introduced, rehearsed, and checked on the social plane in such a way that students, and the teacher in the classroom, develop shared "common knowledge" of the modelling event.

The teaching unit started with a "black box" experiment where the students, without opening it had to make models of what was inside the box. The black box was a little box made of cardboard. The box could for example contain a coin or an eraser. The box was tightly closed with adhesive tape so that students could not open it. The teacher gave one box to each pair of students. They made experiments to find out what was inside the box. For example, they shook the box and listened to the sound made by the object inside. Some pairs used magnets to find out if there was iron inside the box. Finally the students wrote a description of what they thought was

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inside the box. They noted that each pair had described the unknown object inside the box with the help of familiar objects, such as coins, toy cars etc. Discussion followed to show how this simple experiment portrayed the idea of scientific modelling. After the experiment, and even after the conclusion of the whole teaching unit, the teacher did not tell the students what was inside the box. We used this experiment because we wanted to simulate Nature, since Nature does not reveal its secrets to the researcher, either.

The students were subsequently required to classify things according to their state of matter. The aim of this was to the students to notice the different macroscopic properties of different states of matter. The students were told that the bulk properties of matter could be portrayed by means of different models of the structure of matter. The model of continuous matter and the particle model of matter were introduced. Both of these models are scientifically valid and which one of the models is used depends on the situation and problem in question.

Each state of matter (gas, liquid, and solid) was studied through approximately the same phases. The macro properties of the different states of matter are different. We need different micro models to explain these properties, although we use particle models in every case. The first state of matter to be examined was the gaseous state, and in the following we describe in more detail the content of this cycle. The structure of the teaching unit:

- The students collected macro-properties of a gaseous substance. They claimed, for example, that although you can walk through gas, it must be a substance because you can feel the wind. You can also compress it into a smaller volume such as in a bicycle pump;
- Secondly, we used a demonstration of perfume spreading in the classroom;
- The teacher explained that the particle model could be used to give an explanation of what was observed;
- Students modelled the experiment using role-play in which individual students played the role of gas particles. Half of the class observed the role-play and gave advice to the pupils taking part. After this there was a teacher-led discussion of how the role-play, showing the micro-properties of gas, explained the macro-properties of the substance;
- The limitations of the model were highlighted using an applied TWA (teaching with analogies) - analysis (Glynn, Duit & Thiele, 1995). The students made this analysis individually on a paper sheet;
- The teacher showed a computer model of the gaseous state of matter (de Podesta, 1996). Students compared their role-play model to this new model. They noticed the interaction of the particles when colliding with each other and the rectilinear motion of the particles. The properties of the particle model were written up on the black board;
- After the modelling session, the teacher gave a demonstration in which a glass bottle that had a balloon on its neck was warmed with a Bunsen burner. Students noticed that the volume of the balloon increased. They tried to explain this phenomenon with their particle model. Role-play was used to help them find out the effect of warming up the gas;
- At first the students could not explain the balloon's expansion through their micro model. The teacher gave the students a thick rope and asked them to use it as a "balloon". The students modified their role-play model so that the students colliding with the rope made the "rope balloon" expand. Discussion followed about the collision of the gas particles and the balloon particles being the possible reason for expansion;
- After the teaching phase of the gaseous state of matter, the students were tested individually.

After step 9, the teaching unit goes back to step 1 and restarts with the liquid state of matter followed by the solid state.

The learning demand analysis was effective in planning the aims and the structure of the teaching unit. Students need to be taught the culture of model based reasoning with modelling taken into practice. The teacher gives the vocabulary and language of modelling which enables the students to use and practice the new language themselves or with the teacher. The idea of modelling in physics and chemistry is not easy to adopt (Stephens, McRobbie & Lucas, 1999). For this reason we decided to use certain methods in our teaching unit. Some parts were teacher directed and some central to the student. We tried to find a balance in the teaching unit between information presented by the teacher, and students exploring their own ideas. Epistemological ideas of modelling are especially difficult to grasp without the help of a teacher. For example, the idea that models are used both to represent and simplify a target and also to predict and explain the behaviour of the target, are instrumental in understanding the idea of modelling. It takes time to learn the idea of modelling (Harrison & Treagust, 1996; 2000); the process of internalisation requires using models and the practising of modelling. That is where we need student centred discourse. This appropriate balance of teacher presentation and student discussion should be planned carefully to give the rhythm of the talk.

Modelling was practised while learning the properties of matter and changes of the states of matter. In order to describe these phenomena we needed many different models. The advantages and limitations of the generated models were discussed in small groups. The role of the teacher was to ask questions that helped students to focus on the main aspects. New challenges were given in demonstrations. This idea was based on the result of research that argues that understanding is enhanced when students appreciate the strengths and the limitations of models (Harrison& Treagust, 1996). It has also been found (Harrison & Treagust, 2000) that in order to learn the idea of modelling, it is necessary to use different kinds of models at the same time. This helps students to understand that no one model is complete or ‘right’.

In striving to help students’ learning, it is important that the teachers understand the students’ ideas of modelling, and both the learning and epistemological demands made on the students. The idea of modelling can be adopted in this kind of teaching unit. An interesting and important aspect which is not discussed here is the teacher’s own epistemological and learning demands related to models and modelling concerning the differences between one’s own practical and formal epistemologies or the use of social language.

Conclusions

We have described here the socio-cultural approach in school practice and modelling as an example of scientific inquiry. These ideas have also been adapted for Finnish teacher education. We have, for example, special courses for science teachers, dealing with both socio-cultural aspects of teaching and learning and epistemological issues (see, e.g., Nivalainen, Sormunen & Hirvonen, 2006). We can also see the effect of research in science education in Finnish textbooks; for instance modelling is one of the key subjects in physics textbooks.

Teachers are ”in authority” in their role as classroom manager, and are seen as ”an authority” of science by their students. We see that the teacher’s authority should be explicated in the science classroom in the way that enables a meaningful and aim-based learning environment in order to highlight both epistemological and sociocultural aspects. Teachers can be scientific authorities when they provide evidential arguments for the claims they seek to establish, thus modelling the grammatical features of scientific discourse for students (Russell, 1983). A skilful teacher can successfully take up both roles, if she shares these roles with other members of the classroom community, i.e. students. A teacher can distribute scientific authority to outside experts and then redistribute talk in the classroom by inviting students to give their ideas and interpretations even after an initial answer has been given. By this way the teacher can model to students that, what they have worth to say is important and worth listening to and the contributions of others when making decisions, are viable scientific practices. Through this kind of process, students are encouraged to articulate their ideas, explain their reasoning, and respect the ideas of their peers (Crawford, Kelly & Brown, 2000, p. 253)

The key problem is how, at the same time, to respect the dynamic and constructive nature of learning and the normative nature of science; science teachers believe that the world functions in

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a certain way – which is what the students must learn – and not in another. This contradiction can be solved by increasing the autonomy of school science in such a way that school theoretical models are adapted to the students' world and therefore have a meaning for them, while still retaining, as a final target, the accepted scientific knowledge. Experiments and language in school science do not need to be strictly those of scientists for students to reach meaningful scientific knowledge. Science teachers should then be free to organise teaching aiming to imitate scientists' methods and objectives: the questions and answers considered in the classroom will be slightly different from those of scientists, but still profoundly connected to them (Izquierdo-Aymerich & Adúriz-Bravo, 2003, p. 41) It appears from the sociocultural learning perspective, that in group activities it is sometimes necessary lessen demands on students to construct understandings that are scientifically accurate (Coll, France & Taylor, 2005, p. 192). This view makes it important, at least initially, to allow them to experience what it is like to build original models, theories and explanations in the same way as that of scientists (cf. Hogan, 1999). Of course, we must take care that the experiments, language, and models used in the classroom are not in contradiction with those of 'real' science. On the contrary, they must be favourable when students continue their learning processes.

Teachers are professionally committed to connect scientific models to those used by the students themselves; resorting to the analogies and metaphors which would best help them to move from the latter to the former – i.e., filling the epistemological and learning demands. Throughout the school years, this should result in a process of selecting the relevant questions suggested by experiments and contexts in which these questions make sense to students. Although the answers to questions will not always be found in class, they can be discussed there: some of them bear a philosophical, historical or social reflection; other refers to non-scientific beliefs which may be compatible with science because they go beyond the problems that science addresses (Izquierdo-Aymerich & Adúriz-Bravo, 2003, pp. 35–36)

There is a model for the construction of science knowledge in the classrooms that emulates the way science knowledge is developed in scientific communities (Woodruff & Meyer, 1997). There are supposed to be two types of communities of scientists using two types of discourse: Within the scientists' laboratory, amongst peers, scientists discuss ideas that are not fully worked out without high risk to their ego or career. Scientists also participate in a wider, inter-laboratory community. This more public forum sets and applies standards and benchmarks to claims of scientific knowledge and supports the arbitration that allows the discipline to advance. Woodruff and Meyer (1997) speculate that classroom conditions can support these two forms of discourse when students build their knowledge through the combination of small-group and whole-class work. Small-group discourse supports students as they generate explanations and build on each other's ideas. Whole-group discourse places a high demand for clarity and explanatory power on the working products of the groups, and challenges the acceptability of the ideas students generate. If students were made aware of the differing purposes of these two types of discourse in a real scientist community, such deliberation could be used to develop students' learning about the nature of science outcomes. We must also remember that whole-class discussions can be valuable pedagogical tool with the potential of adding to the effectiveness of small group work (Crawford, Kelly & Brown, 2000, p. 254). At its best, this gives all students (even the silent ones) opportunities to hear the conversation and learn how to speak and listen to each other as members of a science community.

Although we do not advocate that all science teaching should be of the sort described here, by moving beyond the traditional focus on the facts and laws of science, students should be offered opportunities to use their knowledge in inquiry processes (e.g. posing questions, observing, offering interpretations) and associated social practices (e.g., group norms for speaking and listening, particular ways of formulating an explanation) to "talk science" (cf. Lemke, 1990; Crawford, Kelly & Brown, 2000). We hope that there will be inspiring situations in science classrooms where students engage in science; we must teach them that it requires using the knowledge and expertise of others, living with uncertainty, articulating ideas in public forums, using evidence, reaching consensus, and making group decisions. Inquiry processes co-constructed by a learning community offers a perspective on science that is typically available only after a long apprenticeship in a scientific field – ways of talking, thinking, acting and interacting.

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Резюме

ДАЛЬНЕЙШЕЕ ПРОДВИЖЕНИЕ МЕТОДОВ ШКОЛЬНОЙ НАУКИ - ЕПИСТЕМОЛОГИЧЕСКАЯ И СОЦИОКУЛЬТУРНАЯ ТОЧКА ЗРЕНИЯ

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Введение новых программ естественнонаучного образования всегда ставит вопрос о внедрении также соответствующих учебных методов. Принципиально новые ориентации в программах могут вступить в конфликт с уже существующими в школах традиционными взглядами. Статья начинается с рассмотрения примера реновации программ естественнонаучного образования в Финляндии, учитывая (инновационные) подходы на более высоких уровнях. Наша цель состоит в том, что предложить дискуссии по эпистемологическим вопросам и коммуникационным аспектам естественнонаучного образования. Мы приходим к выводу, что, продвигаясь дальше традиционной фокусировки обучаемых на научные факты и закономерности, мы должны учить учеников экспертизе и применению знаний, поднимая такие вопросы, которые характеризуются неопределённостью, формулируя идеи на публичных собраниях, употребляя доказательства, достигая согласия и принимая групповые решения.

Ключевые слова: методы обучения, естественнонаучное образование, основная школа, средняя школа.

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