

Teachers' focus on pupil's prior conceptions in Inquiry-Based Teaching

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ABSTRACT

An important component of inquiry-based instruction is identifying pupils' previous experience and knowledge about phenomena under study and reflecting on it during the investigation. This paper focuses on teachers' ways to identify and use the existing ideas and previous experience of pupils concerning the subject. We monitored to what extent teachers take pupils' ideas - once these are revealed - into account, how they reflect on them in the initial phases of forming predictions and hypotheses and how they incorporate them into their teaching. We gathered our data by observing in-service teachers implementing inquiry-based science education (IBSE) in their classes. These teachers, who were also interviewed, were taking part in an IBSE-training project and were teaching at junior high level of a grade school (ISCED 2). Results of the performed qualitative analysis show teachers' difficulties in revealing children's previous knowledge, uncertainty how to deal with it once revealed and lack of flexibility.

KEY WORDS

Inquiry-based science education, previous experience, previous knowledge

RÉSUMÉ

Un composant important dans la pédagogie d'investigation dans l'enseignement est l'identification de l'expérience antérieure de l'élève et des connaissances de l'enfant sur le phénomène étudié. L'expérience antérieure personnelle et l'interprétation personnelle de ce phénomène se développe constamment au cours de l'apprentissage de l'élève par l'investigation. Notre recherche présente la manière dont les

professeurs identifient l'expérience antérieure de l'élève avec le phénomène étudié et comment ils travaillent avec cette expérience. Nous sommes concentrés surtout à la phase de la formulation des suppositions et des hypothèses. L'échantillon de notre recherche était composé des enseignants de l'enseignement secondaire - premier cycle (CITE – Niveau 2) qui ont participé à la formation concernant la pédagogie d'investigation dans l'enseignement scientifique et de leurs élèves. Nous avons observé les cours de l'enseignement scientifique, analysé les fiches de travail des élèves et nous avons réalisé des entretiens avec les enseignants. Les résultats de l'analyse qualitative démontrent que les enseignants n'attribuent pas beaucoup d'importance à l'expérience antérieure de l'élève avec le phénomène étudié, ils ont des problèmes avec son identification et après avoir détecté les préconceptions et les misconceptions des élèves, ils ne savent pas comment les remédier. Elles n'influencent peu ou pas du tout la conduite du travail de l'élève par l'enseignant.

MOTS-CLÉS

Pédagogie d'investigation dans l'enseignement scientifique, expérience antérieure, connaissances antérieures

INTRODUCTION

Pupils come to science classes with pre-existing ideas about daily phenomena. They form ideas and interpret phenomena on the basis of everyday experience, talks, being influenced by the media, etc., in an attempt to give sense to the world around them. These ideas are mostly incoherent but still very persistent, even in the case a teacher prepares a stimulating situation or designs an experiment with outcomes that contradict them. Children seem to be certain about the validity of their ideas or explanations, and this significantly influences what they notice, what they take into account and how they interpret the new phenomena they encounter.

The experience reflected in a person's arguments or ways of acting does not allow the recognition and distinction of the objective components of the phenomenon (proof, evidence) from the subjective ones which lack verification (Kuhn, 1989). Personal beliefs significantly affect the abilities to remember, reason, solve problems and acquire new scientific knowledge. For instance, they are reflected in the process of identifying the variables of a phenomenon and formulating hypotheses about it. Even if a student is not familiar with the theoretical background of the observed phenomenon, they can argue by using their personal experience and previous knowledge (Mulder, Lazonder & De Jong, 2010; Glynn, Yeanny & Britton, 1991; Driver, Guesne & Tiberghien, 1985).

According to cognitive psychology, understanding and learning is connected with a person's prior knowledge and beliefs. Since pupils' prior conceptions interfere with

school learning, teachers need to be aware of the ways in which pupils' background knowledge might influence it. This may help them to anticipate children's confusion and recognize why they have problems with certain concepts. According to the constructivist view, new knowledge is constructed based on existing one (Monk & Osborne, 2000; Fensham, Gunstone & White, 1994). Therefore, it is essential for meaningful learning that teachers pay attention to prior understandings and beliefs that children have and bring into the classroom. Teachers need to build on these ideas in ways that help each student achieve more mature understanding. If pupils' initial ideas and beliefs are ignored, they may develop very different notions than those expected by the teacher.

THEORETICAL BACKGROUND

The importance of revealing students' ideas

Taking for granted that all persons (teachers included) have the same understanding of basic concepts may be risky. When studying a new phenomenon, students may not be able to understand how the related concepts are linked to each other or they may have a different understanding of each of them. They may use proper expressions while they talk or write, but their words or formulas may actually have a different meaning for each of them. Obviously, such a scenario leads to a lot of misunderstandings, possibly to some new misconceptions or to a new parallel version of a concept in addition to the previously owned by a student. Being familiar with the pre-existing knowledge of students enables teachers to prepare a stimulating situation which challenges their understanding (Driver, Guesne & Tiberghien, 1985).

Inconsistency between the scientific knowledge and the student's personal theory or their personal understanding of certain concepts is not easy to reconcile. Students have to be convinced about the inadequacy of their existing personal theories. However, being aware of this inadequacy does not necessarily make them search for a better explanation. Pupils should face a situation in which they experience a dissatisfaction with their personal explanation, opening a door to a new alternative which has to be intelligible (reasonable), plausible and fruitful for them (Glynn, Yeanny & Britton, 1991). To meet all these prerequisites for conceptual change (or concept development) a teacher has to be aware of and get familiar with students' prior knowledge.

Prior knowledge in inquiry-based science education

Research evidence shows that when students encounter something new, they try to make sense of it using ideas formed through earlier experiences. These ideas become modified as pupils use them when trying to explain new experiences. In this process, an idea can be used to make a prediction and then, when the prediction is tested, to examine if the evidence from the new experience agrees with the prediction that

was made. Inquiry in the classroom starts when students try to explain observed phenomena by using existing personal theories. It is the moment when they find out if their theory can or cannot explain the situation. This is also a starting point for a teacher and his / her questions and guidance in order to start working with students' prior conceptions about phenomena in question. Students' theories may be wrong and teachers' questions must start challenging them as they can hamper learning. It is important to identify irrelevant factors and relationships in pupils' conceptions about the phenomenon under study and focus on rebutting them during an inquiry. Pupils' preconceptions can be also just incomplete and still relevant to a learning situation. These can be activated and used to develop and support better understanding.

One very important aspect of the inquiry-based teaching approach is to create a stimulating situation to initially ask for possible explanations of the phenomenon in question and consequently guide students' investigation so that they may test their own beliefs and explanations. Students use various justifications for their explanations and predictions. These are very important hints for the teacher, allowing him / her to have access to pupils' current understanding even if this is not necessarily expressed in an explicit way as a whole. Knowing the content of personal theories, teachers can draw students' attention to evidence which challenges them and thus help students to eliminate irrelevant factors and relationships from their view (Bransford, Brown & Cocking, 1999; Harlen, 2000).

Prior knowledge in students' predictions and hypotheses

Testing one's explanation requires formulating predictions relied on hypotheses. Making predictions based on previous empirical or theoretical reflection expresses students' view of the dynamics of the phenomenon, indicates what he/she thinks may happen in the future and calls for verification (confirmation or rejection). Hypotheses that lead to predictions state why something happens or does not happen by relating dependent and independent variables. So, they offer an explanation of the phenomenon in terms of cause and effect (De Jong & Van Joolingen, 1998; Baxter & Kurtz, 2001). Formulating the conclusion of the inquiry raises new questions and specifies further the concept under study. This pushes the investigation further.

Making predictions moves gradually from unfounded guesses to more informed statements based on a series of observations and finally to more precise hypotheses. Pupils at the primary level (ISCED 1) tend to explain the phenomenon under study only in the view of their past experience. Pupils at the interface of concrete and formal operations of cognitive development (ISCED 2) come up with predictions and hypotheses that tend to explain the phenomenon paying attention also to the specific aspects of the observed situation (Harlen, 2000; Etkina, Karelina & Villasenor, 2007). In addition, Lazondner, Wilhelm and Hagemans (2008) refers to two different experimental strate-

gies of pupils. If pupils do not have experience with the phenomenon, they prefer making observations and collecting data and then they go on with formulating hypotheses based on the collected data. On the contrary, if they have previous experience with the phenomenon or at least they are partially familiar with its theoretical background, they tend to formulate and test hypotheses more willingly.

Most of the studies about students' ideas focus mainly on the ways teachers identify them as preconceptions or misconceptions about particular phenomena and introduce strategies which may lead to conceptual change (Larkin, 2012; Gooding & Metz, 2011; Lucariello, 2013; Driver, Guesne & Tiberghien, 1985). Nevertheless, there is not an agreement on whether students' ideas are obstacles or resources for students' learning. Larkin (2012) describes five different views on students' prior conceptions. They are perceived as (a) evidence of content coverage, (b) obstacles to understanding, (c) tools to prime students thinking, interest and activity, (d) elements of a positive classroom environment, and finally (e) raw material of learning. Knowing the conceptual source of errors which students make might inform the design of didactic interventions likely to fit and extend each student's conceptual understanding (Xiaobao & Yeping, 2008; Bischoff, 2006). Still, previous studies show that teachers are not really aware of students' misconceptions, their individualistic character and their impact on instruction (Gomez-Zwiep, 2008; Morrison & Lederman, 2003). In fact, they tend to believe in uniform instruction by often assuming that students hold the same preconceptions and experiences since they are exposed to the same content in different classes.

The purpose of this study was to highlight the actual practices of teachers concerning students' prior conceptions during inquiry-based science teaching, namely the practices they actually use not only to trace these preconceptions but also to deal with them in their didactic sequences.

METHODS

The overview of the study: goal and method

The main goal of this study was to analyze the ways teachers elicit students' prior knowledge, to identify what importance they assign to it and how they handle it so that their instruction can lead students to meaningful learning. The research follows the qualitative phenomenological trend, attempting to "*understand and interpret the world in terms of its actors*" (Cohen, Manion & Morrison 2007, p. 181). In other words, it tries to reveal teachers' practices in the classroom, as well as their own view about them. In fact, we analyze observed teaching sequences, give examples of teachers' practices in real classrooms, and try to identify the effect of the latter (Marton, 1981; Cohen, Manion & Morrison, 2007).

More specifically, we observed 30 teaching units of chemistry, biology and physics,

analyzed 150 student worksheets and interviewed 13 teachers. All of them were teaching at the junior high level of a grade school (ISCED 2) and were still novices with regard to the inductive teaching of science since they just were at their second year of using the inquiry-based approach.

Data collection

The data were derived from the analysis of (1) observation recordings of the science lessons, (2) students' worksheets used in these lessons and (3) teachers' interviews in order to clarify certain moments during the lesson or the misunderstandings in pupils' worksheets. A general statement about identified actions in the classroom was made only after clarifying their meaning with the teacher.

Students' personal theories are revealed in the initial point of an inquiry when students are confronted with new aspects of a phenomenon through a stimulating situation. Their beliefs are also becoming obvious when they predict or hypothesize, as well as in the process of designing the investigation. So, during our classroom observation we focused particularly on these phases. More specifically, we followed the strategies that teachers used in order to support students in creating predictions and hypotheses and we analyzed students' worksheets. Identified linkages between teachers' practices and their consequences on the learning process were further clarified in the interviews with the teachers (3).

Analysis of teachers' practices in the classroom

The observation of teachers' strategies regarding students' pre-conceptions was guided by the following set of actions that we considered as expected in the context of IBSE. More specifically, the observer had to identify whether teachers:

- Used tools (e.g. pretests, discussion, drawings) to identify pupils' prior knowledge
- Used a stimulating situation (unexpected, familiar) to elicit pupils' prior knowledge
- Asked open questions that required more than a one-word answer
- Asked about pupils' experience
- Analyzed the revealed preconceptions through discussion by asking pupils to give further explanations or clarifications
- Asked pupils to formulate predictions and hypotheses
- Put the revealed preconceptions in test through investigation
- Gave pupils the opportunity to compare the results of the investigation with their preconceptions
- Responded on pupils' prior knowledge and how (verbal clarification, obvious change of instruction, other) or they didn't respond at all.

Analysis of student worksheets

Students' worksheets were analyzed in order to highlight whether students:

- State clearly the problem or question of inquiry
- Indicate relations between aspects of the phenomenon in their drawings
- Make predictions or hypotheses that reveal preconceptions or misconceptions about the phenomenon in question
- Reveal preconceptions or misconceptions in other tasks like for instance when they were required to agree / disagree with a statement or make a concept map or drawing.

Teachers' interviews

The interview included first questions to clarify certain moments during the observed lesson, and then questions to highlight teachers' own views about their practices. More specifically:

- How important is it for you to find out what pupils know about the phenomenon they are going to study?
- When you find out what pupils think / know about this phenomenon does it affect your teaching strategy? Do you alter your instruction?

RESULTS

Teachers' ways of gathering evidence about students' pre-conceptions

The most common and frequent way teachers used to gather evidence about students' pre-conceptions in the classrooms we observed was through discussion, either in small groups of students or in the whole class with the teacher. A group discussion can remove possible stress from the teacher-authority and help students clarify better their understanding with their peers. The teacher's question was discussed in groups where students tried to find plausible and convincing explanations. After a group discussion, ideas and arguments were expressed easier and clearer. Teachers did not take any notes of students' initial ideas.

The most frequent types of questions teachers asked were the following:

- Open questions that eliminated conviction that there is a wrong and a right answer: "What do you notice about...?", "What do you know about...?"
- Person-centered questions: "Why do you think that?"
- Problem-posing questions that required from students to use their experience or apply their knowledge: "Can you find a way to ...?"

Another way of revealing students' pre-conceptions about the phenomenon in question was *student's drawings and writings* (Figure 1, Table 1). These enabled teachers to identify

the main factor of the phenomenon as perceived by the pupils and get a permanent record of pupils' previous understanding to which both teachers and pupils could actually refer after the investigation. It was important to carefully frame the drawing task so that it wouldn't be too vague and thus inappropriate for revealing children's conceptualization of the critical features of the phenomenon in question. As inquiry proceeded further, going back to the drawings gave a clear feedback to both teachers and - more importantly - students about how their initial ideas were consistent with what they found out in their investigation or they were altered.

FIGURE 1

Drawings revealing prior ideas before studying leaf nervation (tulip and lilac leaves)

In addition, teachers consider students' writings as another important way of getting familiar with their prior knowledge (Table 1).

TABLE 1

Recording sheet for writing predictions and observations

	prediction	observation
What happens with a drop of crude oil in water?		
What happens with a drop of crude oil in water after 10 minutes?		

Analysis of classroom discussions as a way of gathering evidence about students' pre- conceptions

We analyzed teachers' ways of gathering evidence about students' prior knowledge during initial phases of the lesson and we identified certain patterns, which are discussed further. After having observed the lesson and its phases, analyzed students' worksheets and interviewed the teacher, we could also define the implications of certain teaching practices.

Pupils' response to teachers' questions

Pupils' response to the teachers' questions within stimulating situations was classified into 4 categories. These are summarized in Table 2.

TABLE 2

Pupils' response to teachers' questions		
	Pupils' response	Example
(a)	They don't give the correct answer	Q.: "What seeds need in order to sprout?" A.: "Seeds need light in order to sprout."
(b)	They don't explain and thus don't reveal any pre-conceptions	Q.: "Why is an acid rain harmful?" A.: "A low amount of pH"; "Energy causes the change"; "Water moves because of gravitation, pressure and wind."
(c)	They use an explanation they cannot actually understand	Q.: "Why there is soft water and hard water?" A.: "Water is soft because they boil it and that's the way how you can get rid of hardness. It disappears."(grade 5, no chemistry lessons)
(d)	They use a cliché	Q.: "Why cannot we eat spoiled food?" A.: "Because there are harmful things."

Concerning the first type of pupils' response, we note the following. Pupils answered incorrectly and formulated wrong predictions when they had no prior experience of the phenomenon in question and/or when this phenomenon concerned a partially concrete or a non-concrete system that contains invisible features causing observable changes.

Going on with the second type of response, it should be noted that pupils express their experience of the phenomenon by using intuitively certain expressions. They had learnt about many of these topics, but remembered only definitions or certain characteristics. Prior knowledge expressed in this form was not clear and therefore it was not useable for any meaningful intervention by the teacher.

The third type of pupils' response has to do with providing explanations they cannot really understand. We suppose they thought that the teacher expected them to give a certain answer. Pupils' assumption concerning the phenomenon was implicitly confirmed, since the teacher did not ask for more.

Finally, according to the forth type of response, when being unable to explain the phenomenon, students appeal to a cliché which cannot actually serve to the teacher.

Implications concerning teachers

As shown above, teachers try to elicit pupils' personal understanding about the phenomenon in question, but they are not always successful. It is important - especially

in case (a) and (b) - to keep asking various questions and search for pupils' personal experience in order to find out the source of their beliefs and eliminate guessing. Teachers need to keep asking in order to clarify or find the limit of pupils' knowledge. Not asking further questions possibly signifies that teachers do not feel as real experts in a field, or they haven't been well-prepared for the lesson and they are not certain about the principles of the phenomenon they introduce in their classroom. Therefore, they do not communicate sufficiently with the pupils and do not ask them for clarifications. They do not realize that every word a pupil says matters. Teachers suppose that pupils know what they should know and they are not attentive and sensitive enough to what their students really keep saying.

Perhaps it is difficult for pupils at a certain level to fully understand all the expressions used in their explanations, but teachers should be sensitive to reveal this (see c in Table 2). Once teachers identify things that are beyond pupils' understanding, they should keep asking further questions in order to clarify students' explanations. In case of not doing so, teachers may be engaged in building on a problematic background leading students to even worse misunderstandings.

Teachers' strategies: delivering questions & handling responses

In analyzing teachers' work with pupils' prior knowledge we identified categories about the ways teachers asked questions when dealing with a stimulating situation (Table 3).

TABLE 3

Teachers' practices in delivering questions		
	Teachers' practices in delivering questions	Example
(e)	They state a research question They ask students to make a prediction/hypothesis	<i>"What does buoyancy depend on?" "Read the description of the situation and predict what will happen."</i>
(f)	They ask questions which are not directly relevant to the investigation that follows	<i>"What kind of change do you notice around?" (Students have to make a distinction between physical and chemical changes)</i>
(g)	They ask suggestive questions	<i>"Is water (oxygen, warmth) an essential factor for living?"</i>
(h)	They do not ask further questions after pupils' response	<i>To pupils replies: – "A seed gets smaller in a soil" – "Water is chemically cleaned in a water treatment plant". The teacher does not ask questions that would clarify further answers like the above.</i>

Posing a research question or asking pupils to formulate predictions, revealed their ideas about the phenomenon in question (e). Students also justified their predictions. The investigation that followed gave a clear answer (or a part of the answer), which confirmed or rejected pupils' predictions and justifications.

By asking too general questions, teachers lost the chance to guide students through identifying properly the essential factors of the phenomenon. This was probably caused by a rather poor preparation for the lesson, resulting in confusing questions and situations (f). Pupils were not able to follow the research question.

Teachers wanted students to recall certain knowledge in order to carry on the inquiry (g). The answers did not necessarily correspond with pupils' preconceptions and students did not actually have the chance to express them since teachers asked suggestive questions.

Since teachers had time restrictions and were also following their own lesson plan, they did not ask further questions in order to clarify pupils' preconceptions (h). In order to expose pupils' preconceptions, more questions needed to be asked. Pupils' responses did not contribute to the class discussion and it was also not obvious if pupils themselves could explain why they thought so. This kind of practice on behalf of the teacher had no or little contribution in clarifying pupils' preconceptions for both teachers and the rest of the class.

Analyzing teachers' work with pupils' prior knowledge, we also identified categories about the ways teachers handled pupils' response. These are shown in Table 4.

TABLE 4

Teachers' practices in handling pupils' responses	
	Teachers' practices in handling pupils' responses
	Example
(i)	Teachers clarify and unify the meaning of the used expressions <i>"Let's agree that we all call them minerals." Pupils used words mineral or vitamin when they talked about mineral water and infer to cations.</i>
(j)	Teachers have a pre-determined way of inquiry which they impose on pupils <i>"What procedure would you suggest to prove your idea?" Despite pupil's suggestions the class follows procedure suggested by a teacher.</i>
(k)	Teachers do not take pupils' responses into account and do not handle them at all <i>Pupil's claim: "Microorganisms are visible only under a microscope." Students cultivated mold on a Petri dish. Colonies were visible with naked eye after a couple of days. Nevertheless, the teacher did not appeal to pupils' initial claim.</i>

Pupils used different expressions for the same content in an initial discussion. Unifying the terminology (i), teachers helped all participants to understand the meaning of the

words in a shared way. This clarification decreased confusion and intuitive usage of certain expressions.

Obviously, the easier way for the teachers, was to give pupils their own, pre-determined procedure of testing the stated predictions or hypotheses and not take into account the one suggested by the pupils (j). But if the teacher's pre-determined procedure does not correspond to pupils' suggestions, they may not be able to adapt it or even see the point in following it, especially if the teacher does not explain its steps.

As illustrated in (k), teachers may lack flexibility, not being sensitive to pupils' replies or lack expertise on the topic. Pupils' prior understanding may not be taken into account. In the corresponding example given in Table 4, it is not clear if students' preconceptions got affected by the inquiry that was carried out. Singular cells are visible only under microscope but one can also see them with naked eye after cultivating them on a proper substrate as did the pupils in that particular class.

Implications concerning teachers

Stating the research question, teachers can get valuable responses from the pupils that may include explanations and arguments in favour of them and thus avoid unfounded guessing (e). These explanations provided by the pupils represent their pre-conceptions and thus they are what teachers must work with.

Not supporting pupils in identifying properly the essential factors of the phenomenon (f), leads to confusion and misunderstanding concerning the inquiry that is carried out. Sufficient attention has to be paid by the teachers to a preparation of a logical sequence of questions that are relevant and proper for the phenomenon under study.

A suggestive question (g) is one which implies in advance which is the expected answer. Such questions make pupils answer in a specific way that may or may not be true or consistent with their actual understanding of the phenomenon. In the process of uncovering pupils' preconceptions, open questions which require more complete responses may be more effective.

Identifying pupils' conceptions without asking for clarifications or without searching for their origin, does not give teacher sufficient information to react meaningfully to and it is not clear if the inquiry that follows can actually improve pupils' conceptions about the phenomenon they study (h).

It seems to be important and useful to clarify and unify expressions which students use in the class discussion (i). Sometimes a new unifying term has to be introduced. This strategy can lead to a more clear discussion.

Teachers do not really take into account pupils' suggestions about the testing procedure even if they may be good or worth trying in a structured guided inquiry (j). The design of the lesson seems to be strongly influenced by the deductive way of teaching. This may also indicate a lack of expertise on the topic and self-confidence on

behalf of the teachers. Teachers do not talk with the students over the given procedures, so they do not understand that perhaps their suggestions are either very similar to the ones of the teacher or that the teacher's suggestions may be better and thus followed.

One of the reasons teachers ask about students' preconceptions is that they need to return to them after having tested the stated predictions. The conclusions of the inquiry need to be discussed and confronted with pupils' prior explanations of the phenomenon. This cannot be possible if teachers do not record them, work with them and return to them at the end (k).

Analysis of students' drawings and writings as a way of gathering evidence about their pre- conceptions

The practices used by the teachers in order to elicit students' preconceptions through their drawings and writings are summarized in Table 5.

TABLE 5

Teachers' work with students' preconceptions in drawings and writings		
	Teachers' practices	Example
(l)	Pupils' prior ideas and knowledge are put on the board	<i>Fig. 1</i>
(m)	Recording predictions / hypotheses: pupils are asked to present statements about the phenomenon Pupils mark their agreement or disagreement with a given statement	<i>Tab. 1</i> "Seeds need light in order to sprout" "Yes / No"
(n)	Pupils are asked to represent their conception in drawings as an isolated task with no connection to the investigation that follows	<i>Pupils are asked to draw a model of any ecosystem they want and identify relationships in it Next, they are asked to analyze an artificial ecosystem that has been pre-designed by the teacher</i>

Pupils' prior ideas about the phenomenon in question were visibly recorded and could be discussed with the whole class and classified (l). This gave teachers and students the opportunity to return to them and make a comparison between what they initially thought and what they concluded at the end of the inquiry.

Another way of recording pupils' preconceptions in their personal worksheets is in form of predictions/hypotheses or answers in a pretest (m). Once more, teachers and students can return to them and rephrase them in the light of the findings of the inquiry.

Finding out pupils' preconceptions and not returning to dealing with them in any way during instruction, is absolutely pointless. This practice may indicate that teachers tend to elicit preconceptions simply as a required step in the inquiry process, but they do not actually realize its importance for students' learning (n).

Implications concerning teachers

Recording ideas on the board is very important as it enables students to re-examine, add, remove or alter them after the inquiry (l). The whole class can be involved in discussions over particular preconceptions.

Keeping records of pupils' predictions and explanations of the phenomenon seems to be very useful for developing their understanding. When pupils first work individually or in groups and then discuss differences between new findings and preconceptions in the group or with the whole class, it gives them time to formulate an explanation which may indicate change of / persistence on their preconceptions as stated at the beginning of the inquiry (m).

On the contrary, as identified in (k) & (n), recordings of pupils' prior ideas which are not used during and after inquiry, illustrate that the teachers do not consider them as important and thus they show no intention of working with them. Such recordings are purposeless.

Teachers' practices during the formulation of predictions and hypotheses

We additionally focused on evidence about teachers' practices concerning the process of formulating predictions and hypotheses. The teachers' practices that we observed correspond to the steps of the process and may be arranged into the following categories:

- practices that help students in starting to shape predictions/hypotheses (A)
- practices towards a more precise formulation of predictions/hypotheses (B)
- practices that lead to the experimental test of predictions/hypotheses in order to confirm or reject them (C)

Practices grouped as (A) included “*direct questions concerning pupils' previous knowledge*” that were recorded on the board or in the worksheets. Questioning pupils about their ideas is important not only for the teachers as mentioned above, but also for students themselves, since they are engaged in recalling knowledge related to the phenomenon they study. Another useful intervention by the teachers in (A) was the “*clarification of terms/meanings*” (see Table 4, (i)). In addition, teachers' “*use of stimulating situations*” they have prepared in advance and their “*support in identifying variables*” led students to recognize factors which might have caused the observed condition and also stimulated them to ask investigative questions. The following description of a classroom activity may serve as an instance for the above:

In the first session pupils observe the decaying process of some paper placed on soil in the classroom-set observation. They are asked to keep all conditions identical with the conditions affecting paper outside. They are to notice various factors which could be the cause of the observed change. Some of them are obvious (e.g. presence of soil, water) but some are harder to notice (e.g. temperature, light conditions, organisms in the soil, etc.). In the second part of the session (which takes place after concluding the first part

in two or three weeks) they are asked to change or eliminate one factor which they think as causing decay. Based on knowledge gained from their previous experience and current observations, pupils try to answer the question by formulating predictions and designing an experiment. Finally after two or three weeks they formulate conclusions. These may be reached only after the discussion of the results coming from all groups in the classroom, since each group works with a different independent variable. Pupils identify an independent variable and describe the relationship between this and the dependent one without explicitly formulating a hypothesis. The simple table helps them see clearly the relationship they are about to prove or disprove (see Table. 6).

TABLE 6

The relationship between variables as required in pupils' worksheets

<i>Which factor have you eliminated / changed?</i>	<i>What do you expect to happen?</i>	<i>Did you prove your expectation?</i>
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If a “stimulating situation” was not properly analyzed and the relevant variables of the observed system were not obvious, predictions or hypotheses could not be stated clearly. *If the teacher keeps asking about pupils' preconceptions of the phenomenon, pupils may elaborate their explanation and specify more precisely the predictions or hypotheses they shaped previously rather loosely.* For example, when a pupil was asked about what would happen with a drop of a crude oil in water, he answered that it would spread. The teacher asked him how fast he thinks it would spread on a certain surface and if it would cover the whole surface that was available in a given time period. The student had to recall much more he had learnt about crude oil, he took into consideration what he knew about oil spills and finally specified his prediction.

During the phase (B) that is actually the task of formulating predictions and hypotheses, the teacher guides students “*towards clarifying the relation between the identified variables*” and is “*asking about reasons and background of the shaped predictions*”. These practices enabled pupils to analyze their predictions and develop a critical thinking which eliminated guessing. Pupils were also asked to propose a procedure for the solution of a problem that was related to the phenomenon in question (e.g. cleaning the water from spilt oil). This practice of “*requiring pupils to propose a procedure*” helped them reveal their understanding of the relationship between the variables of the phenomenon. See for instance the following description of a classroom activity:

Students explored a crude oil spilt on water. They measured how fast it spreads, what happens when it is exposed to wind, when they try to mix it with water, etc. Based on their observation they need to suggest the way of cleaning it from water surface. They are asked to justify their proposal.

The step that comes after formulating a prediction is its *verification through an experimental procedure* that needs to be proposed (C). In a guided inquiry like the one that concerns us here, the verification did not always have to do with predictions or hypotheses made by the students themselves. On the contrary, teachers often underestimate the importance of engaging students in testing their *own* predictions or hypotheses and suggest inquiry that does not correspond to students' predictions. What follows is another example from a classroom activity:

What is needed for seed germination? Students suggested soil, water, fertilizer, light, warmth, etc. The teacher chose only some of the suggestions and gave them a specific, common procedure and a chart in a worksheet. The rest of the suggestions were simply omitted.

Based on the conceptual change theory, it is essential to deal with questions which exhibit curiosity and uncover the background of pupils' knowledge. Students are to become dissatisfied with their own ideas; only then conceptual conflict begins to build and pupils become more open to changing them. If teachers avoid particular questions or explanations of the students, then students may not recognize the inadequacy of their conceptions.

DISCUSSION

The role of the teachers in revealing pupils' pre-conceptions is essential. Moreover, teachers can actually benefit from knowing how students think about the phenomenon, they intend to introduce to their class. Difficulties with identifying and using pupils' prior knowledge have a long history since they originate in the deductive way of teaching and the assumption that they don't interfere with students' ability to reach new knowledge. The inquiry-based approach to teaching science requires high erudition and flexibility on behalf of the teachers because they are not actually in charge of the learning process all the time. The lack of expertise on a particular domain of science may affect the whole process of the inquiry in a negative way by leading to a strictly guided inquiry with no or just a little reflection on pupils' previous knowledge. Confrontation of prior conceptions with new findings is an essential element in the process of learning. There is a concern that teachers underestimate the importance of uncovering students' prior ideas and working with them.

Observing and analyzing teachers' work during inquiry-based science lessons, showed their uncertainty about what to do with pupils' hypotheses that were different from the ones they expected. In general, both teachers and students prefer to pursue *one* teacher-proposed, "correct" way of hypothesis testing that is supposed to lead to the correct answer. This also confirms the reluctance of pupils to change or enrich their

own conceptions in the light of the findings of their own inquiry, even if the teacher had given them the freedom to suggest their own way of testing the hypothesis they formulated. There is also no or a very little interest on behalf of the teachers in finding out whether and how the pre-conceptions of individual students were changed; in other words, if they remained untouched or got elaborated or enriched. Teachers often do not return to the ideas that students appeared to hold before the inquiry. They mainly focus on the conclusions which actually introduce the new knowledge.

The focus of our research was set on the practices that teachers used with regard to their students' pre-conceptions, in *specific* phases of the inquiry. Nevertheless, it is necessary for them to consider these prior ideas throughout the whole process of inquiry. This is actually reflected in the "IBSE diagnostic tool" that has been recently developed in the context of the "Fibonacci project", a project funded by the European Union under FP7 (Tools for Enhancing Inquiry in Science Education, 2012). The tool suggests that "*Building on students' ideas*" - which requires specific teaching practices - is not expected only at the beginning of the inquiry process but also during the phases of "*Supporting pupils' own investigation*" and "*Guiding analysis and conclusions*". In sum, this tool or observation grid seems to be useful in analyzing teachers' and pupils' actions when working with the IBSE-model.

The importance of the inquiry-based approach to teaching and learning derives from its potential to enhance students' intellectual engagement and conceptual understanding by bringing the initial ideas they personally hold into play. If it aims at challenging pupils' preconceptions or elaborating them, class-inquiry should trigger personal engagement and invest on the natural curiosity of the children. Being aware of their students' previous knowledge, teachers can prepare stimulating situations with triggering questions that can actually engage students in an active way.

According to our findings, students' pre-conceptions may not be handled properly by the teachers. This may have to do with their view of learning, in the context of which the prior knowledge of students does not appear as an essential element. Continuing our work with science teachers, we have the chance to communicate to them some significant implications of the specific practices they tend to use regarding their students' pre-conceptions. This may be considered as an instance of the close relationship that educational research may have with the professional development of the teachers.

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