Designing Teacher Education and Professional Development Activities for Science Learning

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1 Introduction

Inquiry-based teaching is complex and includes many different aspects, from designing relevant problem-based activities to developing student autonomy and discursive argumentation between peers and in the whole classroom. This teaching orientation should encourage students to learn science: its content, its epistemology (Nature of Science), its value and its relevance for the study of societal questions.

This chapter is focused on some basic components of inquiry-based science teaching (IBST), designed to develop students' autonomy, in relation to some general aspects of learning science. The chapter particularly deals with what we call "students' intellectual autonomy" in a scientific domain. This is not only a form of autonomy related to the actions they decide to carry out for experimental activities, but it is also the autonomy to construct new knowledge, which in turn implies that they develop a responsibility vis-à-vis knowledge.

To develop this autonomy, we take a theoretical approach for which the goal of teaching is to develop understanding of content, procedural and epistemic knowledge and that focuses on the teacher and students joint actions to achieve this goal. This choice of actions implies a holistic perspective in the sense that the relationships between knowledge, teaching and learning are conceptualized. This allows us to consider IBST as a basic choice to teach science, like it is presented in chapter. "Introduction: What Is Inquiry-Based Science Teaching and Learning?", since it is related on one hand to opportunities to learners for achieving a better understanding of science concepts, principles and phenomena and on the other hand to learner's metacognition like process skills, critical thinking, decision making, etc.

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The conceptual network used in this chapter called "theory of joint actions in didactics" guides us first to analyse the practices of a 10th grade physics classroom during a teaching sequence on mechanics. This analysis is focused on how the progression of knowledge and scientific practices are developed in the classroom in relation to the evolution of the respective students' and teacher's ownership of knowledge, which is a way to acquire intellectual autonomy. Let us note that here IBST is used for teaching across a typical science domain and not when teaching some specific science content or socio-scientific issues. This is particularly important to the extent that science domains such as classical mechanics are often taught in a "traditional way".

In the second part of the chapter, this framework also guides us to discuss the teachers' choices and actions to propose bases to design resources for teacher development.

2 Classroom Analysis

2.1 Theoretical Framework

In our theoretical framework, the classroom is approached from a didactic perspective in order to account for its practices. This framework is based on the theory of joint action in didactics. In this theory, the main object of study is the classroom, viewed as a community of practice where two joint actions are involved: teaching and learning (Sensevy, 2007). These two joint actions are based on communication between the teacher and students and between students. Due to the instructional goals given by society to school, knowledge is at stake in classroom communication. In most countries, this goal is made explicit through official texts including standards or an official curriculum. An important component of classroom communication is the reciprocal expectations that the teacher and the students may have; Brousseau (1997) called this the "didactic contract". This contract forms a system of norms or habits, some of which are generic and will be lasting and others, which are specific to current elements of knowledge, need to be redefined when new elements are introduced. For example, after the teacher has introduced the concept of force in a physics class, his/her expectations of the students' interpretations of material situations will be different from before, particularly concerning the justification of the interpretations. Another important component is "the milieu" that is the social and material components with which the students construct knowledge meaning. Thus, understanding classroom practices necessitates understanding the temporal evolution of the didactic contract and of the milieu, not only on the teaching or learning side but also on the side of joint teaching-learning actions.

In the frame of the didactic contract, two types of moment related to the status of certainty of knowledge are important. There are moments where the class group accepts that the ideas under discussion are only propositions and where the students recognize that they do not know this scientific knowledge; such moments are necessary to construct new knowledge. We call them "moments of epistemic uncertainty" (Tiberghien, Cross & Sensevy, 2014). The other type of moment, called "institutionalization", occurs when the teacher decides to tell the students that their activity has enabled them to construct knowledge that is legitimate in institutions outside the classroom (like scientific communities) and to make them take account of such knowledge in future actions (Sensevy, 2007). Even if the status of some elements of knowledge evolves during these two particular moments, a continuity of knowledge is necessary; thus relationships between these elements of knowledge are established.

The institutionalization does not imply that students have necessarily learnt this knowledge. We differentiate the student learning pathway called "the learning time" from the rhythm of introduction of new knowledge in the classroom called "the teaching time".

Note that we do not specifically focus here on the verbal temporal links that are made explicit in the teacher's discourse but rather on the temporalities of the teacher's action in constructing a didactic contract and a milieu (activity, classroom organization, etc.) in the classroom (Badreddine & Buty, 2011; Mercer, 2008).

2.2 Research Questions

Consequently, the following research questions deal with the teachers' actions associated with the introduction and progression of knowledge during a teaching sequence associated with the development of students' intellectual autonomy, a central component of IBST. These actions change some aspects of the didactic contract, but they are also dependent upon the contract already established in the previous sessions.

1. What kind of didactic contract favours the continuity of knowledge in the classroom between students' propositions and the knowledge that the teacher should introduce according to the official curriculum?
2. What are the actions that the teacher should carry out in a classroom in order to foster a didactic contract and a milieu which may enable students to acquire knowledge, and to develop intellectual autonomy, and more generally a scientific approach?

2.3 Main Components of the Evolution of an Element of Knowledge in the Classroom

The data used in this chapter were collected in the context of a research-based design project for teaching sequences (Tiberghien, Vince, & Gaidioz, 2009). The teacher followed a teaching sequence in mechanics at grade 10 elaborated in the context of this project. We succinctly present our analysis of the classroom practices.

For the previous study, two classrooms with different teachers were observed during the teaching of the topic “dynamics” (six sessions for a teacher and seven for the other one). All the sessions were videotaped with two cameras, one covered the teacher and part of the class, whilst the other one covered two students (the same students during the whole teaching sequence) and a part of the class (Malkoun, 2007; Tiberghien & Malkoun, 2010). The two students of each class were chosen by the teacher (at the request of the researchers) to select students with a middle or low level and who discuss with each other.

The conceptual structure of the sequence is based on epistemological choices regarding modelling, differentiation between concepts and objects/events in the material world. This choice leads the designers to use the word “force” only with its meaning as a physics concept and not with its everyday meaning. Therefore, the word “action” designates the event: an object acts upon another object. Thus, the notion of action is introduced first and then the concept of force, and finally the inertia principle is introduced. Let us note that the idea of object is already the results of a categorization which is not the same in physics and in everyday life. In physics, following the Newton law of universal attraction, any object (e.g. a book, a small stone, a hair, or the planet Earth) can be modelled as a point mass and thus belongs to the same category of material objects, whereas in everyday life, most of the time, an object is subject to manipulation (which is not the case of the Earth).

In order to discuss the teacher’s action in the observed classroom, we present the evolution of the classroom during six sessions dealing with the introduction of dynamics in grade 10. This presentation is focused on a specific element of knowledge: the differentiation between the action of the ground and of the Earth. The difference between the actions of the Earth (the planet) and the ground (e.g. the solid surface of the Earth) is based on experimental considerations: they have opposite directions, and the effects of their action on objects are the reverse, the Earth attracts downwards, and the objects fall down, whereas the ground (or any support) prevents an object from falling down. Let us note that from the scientific argumentation perspective, not all elements of knowledge are associated with experimental evidence. This is the case for the first law of Newton (inertia principle), which is constructed, like the other physics principles, by scientists and is true until a series of experimental facts contradict it and are recognized as such by the scientific community (Valentin, 1983). Due to their different epistemological status, the learning pathways to acquire these elements of knowledge are also very likely to be different. In the case of the inertia principle, it is the first time that students have learnt a physics principle, and they have to acquire the way of thinking based on a principle, whereas they have already acquired elements of knowledge based on experimental facts, even if they are related to concepts. This chapter is focused on the first element of knowledge, the differentiation between the actions of the Earth and of the ground on an object (like a book).

Let us note that choosing a particular element of knowledge does not mean that it is “isolated” from other elements; on the contrary, we emphasize the importance

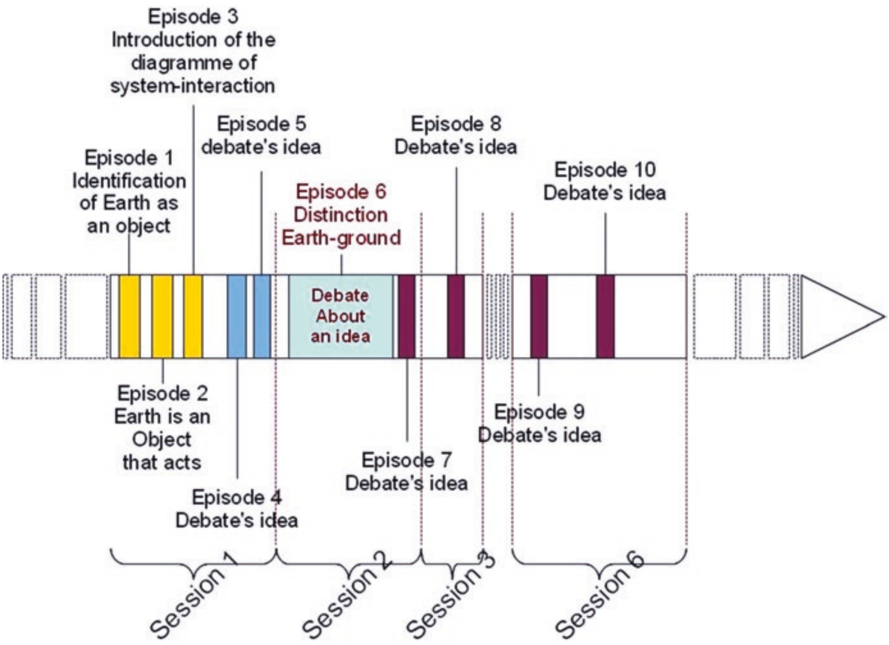

Fig. 1 Episodes where the element of knowledge, "the difference between the action of the ground and of the Earth", is involved in the timeline of the teaching sequence on mechanics (10th grade) (during sessions 4 and 5, this element is not involved)

of explicitly relating elements of knowledge to improve science understanding and learning (Roth et al., 2011).

We present the series of episodes in a timeline corresponding to the teaching sequence in the classroom (Fig. 1). The selection of episodes is based on a systematic analysis of the classroom discourse; when the students work in small groups, we take the discourse of the videotaped small group (two students) and the discussions of other small groups when the teacher intervenes.

- In episode 1 (session 1), the idea that the Earth is a material object emerges in small groups.
- In episode 2 (session 1), the teacher in whole class confirms that the Earth is a material object and that this element of knowledge is, therefore, certain from the physics perspective. Thus it becomes a public element of the physics classroom knowledge we can say that it is institutionalized.
- In episode 3 (session 1), the teacher introduces a formal representation of interactions called the diagram system-interactions where an ellipse represents an object, a full double arrow a contact action and a dotted double arrow a distant action (see, e.g. Appendix, Fig. 2). This associated knowledge is presented as not being open to question and is accepted as such by the students who use it rather easily in the following activities.

- Episode 4 (session 1) shows the emergence of the idea that the actions of the ground and of the Earth are not the same, proposed by a student working in a pair with another student during the activity where the students have to draw the diagram system-interactions showing all the objects that act on a table where there is an object (like a book).
- Episode 5 (session 1) also corresponds to work in a small group where the teacher helps students to clarify their ideas.
- Episode 6 (session 2) corresponds to a debate that takes place at the whole class level during the correction of the activity on which students work in episodes 4 and 5. During this debate, students present their ideas as being possible but not necessarily correct; now at the whole class level, these ideas are questioned. This questioning has evolved from private (small group) to public status (whole class). The debate ends with an intervention by the teacher who gives rational arguments. At this point, there is an institutionalization of this element of knowledge supported by these rational arguments (e.g. the ground or the soil prevents the table from sinking downward).
- In the next episode (episode 7, session 2), the teacher makes it explicit that this knowledge is now public and is recognized as a part of the physics knowledge of the class; in other words, she institutionalizes this knowledge.
- The following episodes (8 (session 3), 9 and 10 (session 6)) show that some students have not learnt these elements of knowledge after their institutionalization. In three sessions after session 6, several students, in small groups and in the whole class, are still having difficulties in using this difference between the ground and the Earth in different material situations.

3 Main Teaching Conditions to Establish Students' Intellectual Autonomy

On the basis of our theoretical framework and classroom analysis, we propose some main conditions, to establish a didactic contract and a milieu to enable students to learn science by developing intellectual autonomy. Four main conditions can be selected from our framework: sharing some common knowledge and meaningful vocabulary, managing moments of "epistemic uncertainty", institutionalizing the main elements of knowledge involved in the previous class activity and differentiating teaching and learning time.

3.1 Premise of Developing New Issues: Sharing Some Common Knowledge and Meaningful Vocabulary

Figure 1 shows that the first three episodes in session 1 are dealing with activities about the idea of action between objects and about learning or relearning that the Earth is an object. In everyday life, the notion of objects is limited to objects that can be handled.

In Newtonian mechanics, the law of attraction is relevant for the Earth or a book modelled in the same way; they are in the same category of objects. As introduced above, the categorization of objects in everyday life and in physics is not the same.

These episodes illustrate that students should learn some basic notions that are often considered as obvious, and are not made explicit in the official curriculum; they are, however, premises of classical notions or concepts presented in the official curriculum.

In terms of actions, this implies that the teacher, when preparing a teaching sequence, should be aware of this, should try to identify these basic notions and should design classroom activities allowing the students to construct or reconstruct these premises. This allows students to share the same elements of knowledge and therefore the same vocabulary with a shared meaning in the classroom. This necessity of sharing common knowledge to construct arguments and new ideas is also particularly important when problems in IBST come from everyday life or social situations, because the meaning of the words and expressions used to introduce the problem is not identical to those used to construct hypotheses and questions from a scientific point of view. The teacher should be aware of this and should be careful, when supporting discussions, that students understand each other. S/he can be enabled to design activities that allow the students to share basic common knowledge and an associated vocabulary. This sharing must be supported by a didactic contract, where the students are responsible for knowledge, in order to discuss and develop their argumentation in constructing new ideas.

3.2 Development of New Ideas with Students: Managing Moments of "Epistemic Uncertainty"

Episode 4 illustrates a moment where the students are aware that they do not know how to solve the problem but "play the game" to work on it and construct propositions. In this episode (Fig. 1), the students M and C are working together on the following question: draw the diagram system-interactions of a table on which an object (like a book) is set (see the right solution Fig. 2 part 2, Appendix). Before the point where the excerpt begins, the two students have agreed on their answer, i.e. that the object and the Earth are acting on the table (Fig. 2 part 1, Appendix); they have just had a short interaction with the teacher, and then they start to write their answer. However, one of the students stops writing and asks her peer whether or not the Earth and the ground are the same (see the extracts given in the Appendix, turns 1 and 5). This question emerges from the students' discussion in the group work situation, where they have to identify what is acting on the table and distinguish between distant and contact action. Here, as we explained before, the students are familiar with the notion of action, the type of questions and the diagram: they do not ask questions about how to draw it. The exercises and in particular the series of situations to analyse (before and after the situation with the table) and the use of the symbolic representations of the diagram system-interactions help students to raise questions about the difference between the ground and the Earth. Thus, this questioning emerges from knowledge as presented above.

This example illustrates that, through the didactic contract established in the classroom, the students are ready to construct an answer with justification but this answer does not have to be the correct one. It also shows that the teacher only helps the students to understand the situation. This is a moment of "epistemic uncertainty". The teacher expects the students to construct new propositions, and the students expect the teacher's help in understanding rather than in finding the correct answer. Usually, these reciprocal expectations slowly develop into habits in the class, when the teacher constructs them from the beginning of the academic year, but it can take several weeks or even months to develop the habit. This moment is possible because the activity and more globally "the milieu" are adapted; it involves a semiotic representation (the diagram Appendix, Fig. 2) and the notions of distant and contact actions that are shared in the class and which then allow students to discuss and understand each other and to relate the material situations studied to these notions. This type of "milieu" fosters students' construction of ideas focused on the core of the activity, and not its peripheral aspects, as can be observed in some classrooms.

This type of moment in a class is crucial for IBST; it is the core of scientific inquiry. This questioning component supposes that the questions are not only about events (when studying energy, questions such as "will this propeller move?" can be raised) but also about theoretical hypotheses involving a model and concepts ("how much energy is needed to move the propeller?"). If the model elaborated is not relevant, the teacher can then design activities to support students in constructing questions about new science knowledge, relating objects/events and notions/concepts. This epistemic uncertainty can give the opportunity to think at an epistemological level: What are we doing? What types of knowledge are involved – evidence, hypotheses, concepts and laws? It can also provide opportunities to think about the value and degree of certainty that science brings to societal problems. All this thinking can be done because students know enough science to construct new ideas in the framework of an adequate didactic contract and milieu.

These moments are selected from what was going on in the observed classroom. Their analysis aims to propose hypotheses on the conditions of developing scientific inquiry in physics education. Therefore, it is necessary to situate these moments in the type of teaching situations like teacher's introduction of a task, students' working in small groups to carry out a task, or a pooling of the work in small groups, managed by the teacher, etc. The observed moments of "epistemic uncertainty" are situated in two types of teaching situations: when the students are working in small groups and also when the teacher manages a pooling of the work in small groups.

In terms of teacher's actions, this example and the associated comments show that they occur at different points in time: planning the teaching sequence, redesigning activities in accordance with students' actions and understandings, managing the teaching session and reacting on the spot to students' questions or actions to help them think about situations and to be responsible for constructing new ideas involving science knowledge. All these actions necessitate a deep analysis of the knowledge involved in these activities, not only the scientific knowledge but also the knowledge held by students, and a clear overall view of the intended learning outcomes.

3.3 Progression of Knowledge in the Classroom: Institutionalizing the Main Elements Involved in the Previous Class Activity

In Fig. 1, episode 6 that takes place at the whole class level just after the small group work, the teacher initiates a classroom debate. The first stage of this debate is a discussion initiated by the teacher, who describes the diagram proposed by a student on the blackboard and asks the students to give their point of view (this diagram is similar to the diagram presented in Appendix, Fig. 2, part 1, but there is a dotted arrow between the table and the Earth). In the second stage, where two points of view emerged on the actions of the ground and the Earth on an object, such as a book on a table, the teacher intervenes to introduce a scientific point of view; at this moment, she/he takes responsibility for this knowledge.

The teacher institutionalizes the difference between the actions of the ground and the Earth by giving the direction of each action, using verbs like "attracting" and "falling down" in the case of the Earth and "preventing the table from sinking down" for the ground. This institutionalization is a bridge between the knowledge that has been already institutionalized, the ideas developed by the students during the work in small groups and the new elements of knowledge which are currently institutionalized. It should help students to relate these new elements to other elements already acquired. To do that, the teacher uses rational arguments, based on experimental facts that are easily understandable by the students.

In discussions about IBST, institutionalization is rarely mentioned. This is not surprising because IBST is often perceived to be about the nature of science and methods of learning science wherein particular students should be engaged in hands-on activity, but not about classroom management during an academic year. Moreover, institutionalization may be perceived as transmission teaching. In our perspective, these moments of institutionalization, however, regulate the progression of knowledge in the classroom and also introduce knowledge legitimate by the scientific community. From both teacher and student perspectives, the institutionalized elements of knowledge are established, and rather than being considered as questionable, they are themselves used to bring new elements of knowledge into question. Of course, in some cases, these institutionalized elements can also be further questioned, but not in the same way as before, since new questions are fed by the previous elements of knowledge. In a classroom, this progression of knowledge is necessary for effective learning.

When institutionalizing knowledge, the teacher is in the position of a representative of the scientific community; statements are not made from his/her own authority but from the authority of the scientific community. For example, the teacher can say "scientists say that…", or she/he can refer to scientific documents, etc. In such a position, the teacher can argue for these new elements of knowledge, whatever their actual scientific status. In the example given above (episode 6), the argument comes from experimental facts, but in other cases, it might be from a principle based on consensus within the scientific community or from a hypothesis that is still questioned by scientists. Institutionalization is a teaching moment that, depending on the way the teacher proceeds, can give students insight into the ways of the scientific community. Alternatively, it can be reduced to a personal act of authority, if the knowledge is presented as coming from the teacher as a person and not as a representative of the scientific community.

3.4 Students Learning: Differentiating Teaching and Learning Time

The last three episodes, and in particular the last two in session 6, show that some students do not correctly use the knowledge that the teacher institutionalized in session 2. These students are able to use appropriate rational arguments when the teacher invites them to do so, but cannot systematically do this by themselves. Consequently, the teacher, after the moment of institutionalization, manages the students' difficulties, firstly, at the classroom level immediately after the moment (episode 8) and, then individually, when students are working in small groups. The teacher takes the time to help students use the arguments already introduced (episode 9) and also explains them further at the whole class level, but in terms of forces introduced after the institutionalization (episode 10).

More generally, the teacher should be aware of the possible gap between what is taught and what is learnt. In other terms, the institutionalization of an element of knowledge does not imply that students have learnt it. In the classroom, it will be regarded as an established element of scientific knowledge, but it is understood that some students need more time to learn it. In the didactic contract perspective, it also means that new knowledge can be constructed from this previously institutionalized knowledge. Thus, the teacher's management and balancing of teaching time and learning time are not easy. Recognizing this difference allows teachers to use the collective class memory and to adapt their teaching to the students according to their understanding.

In IBST, this difference between teaching time and learning time is rarely discussed. However it is necessary to take it into account if the teacher asks the whole class to propose and discuss new ideas, hypotheses or results, in order that students can understand each other.

Globally, these four conditions facilitate student responsibility for the progression of knowledge in the classroom and the development of students' intellectual autonomy, as we stressed in the discussion of the episodes.

The implementation of these conditions in classroom necessitates some teacher's actions to plan and to teach in the classroom. In the following we specify some of these actions.

4 Teacher's Actions Associated to the Main Teaching Conditions for Students' Intellectual Autonomy

In Table 1 we propose teacher's actions associated to the four teaching conditions presented above. These actions are based on research studies focused on the design of teaching sequences (Tiberghien et al., 2009) and on analyses of classroom practices (Tiberghien & Venturini, 2015; Tiberghien & Venturini, under press). The planning actions aim mainly to design the milieu whereas the classroom actions set up a specific contract with the management of the milieu.

The list of actions is not exhaustive; we present those particularly relevant. They aim at developing students' ownership of knowledge, and thus they develop a continuity of knowledge and a coherent didactic contract. For the first three conditions, the proposed classroom actions correspond to the management of a specific classroom moment situated mainly during small group work, pooling and institutionalization situations; they are at the scale of the duration of this moment that is about some minutes or dozen of minutes. These three conditions (first three lines of Table 1) are sequential even if the teacher's actions associated to a moment may happen incidentally during another one. On the other hand, the last condition leads the teacher to actions which can be done at almost any classroom moment like teacher-student interaction in small group or even a recall during a whole class moment like the two first ones in Table 1. This condition of differentiating teaching and learning time does not correspond to a specific classroom moment. This is why we separate this last condition from the others by a thicker line.

These classroom actions associated to planning actions and the conditions can be studied in teacher's professional development with relevant associated videos (Alonzo, Kobarg, & Seidel, 2012; Cross, 2010; Tiberghien, 2015).

Although our examples concern mechanics, a "traditional scientific theme", these same conditions are also relevant for other types of knowledge such as socio-scientific issues. They are not specific to content, even if they necessitate a deep analysis of it, and favour classroom practices beyond the teaching time of a specific theme.

Table 1 Teacher's action during planning teaching and classroom teaching associated to the main teaching conditions for intellectual autonomy. The thicker line means that the last condition does not correspond to a specific teaching moment

	Teacher's action	
Teaching conditions	*Teaching planning*	*Classroom teaching*
Sharing some common knowledge and meaningful vocabulary	Choosing the necessary elements of knowledge including the associated representations (e.g. to act, action, diagram system-interaction)	When students work in small group, helping them to raise awareness of the essential elements of knowledge (e.g. to act, action, objects) and helping students to express their ideas
	Designing classroom activities that involve these elements	In whole class, ensuring that students having different propositions intervene and favouring a discussion (the next step is the institutionalization)
Managing moments where an epistemic uncertainty can emerge	Designing classroom activities where main elements of knowledge (according to the content analysis) can be put in question	When students work in small group, helping them to clarify their propositions and to debate them
		In whole class making public the work of some students with different propositions and putting it in debate to bring out rational arguments that could be accepted or rejected (the next step is the institutionalization)
Managing moments of institutionalization	Planning a text and drawings that present the new elements of knowledge	In whole class, proposing the text and drawings of the new knowledge elements to the students whilst relating them to elements already used in the classroom including the developed arguments
Differentiating teaching time and learning time	Planning classroom activities where the elements of knowledge already introduced should be reused	When students work in small group or in whole class:
		Recognizing that students still have not understood elements of knowledge already taught
		Using similar arguments to those already used in the classroom
		Helping students to relate these elements to other elements already acquired

5 Conclusion

In this chapter we presented some main conditions so that the teacher can help students to develop the intellectual autonomy that is a central component of IBST as presented in the introductory section. We analyse and propose some components of teaching practices to mainly develop some cognition and metacognition aspects, which address some constraints relative to teacher professional development.

It showed teacher's actions outside the classroom like planning the academic year, the lesson sequence and the lessons themselves and inside the classroom like managing the course of the session, debates, answering students on the spot and institutionalizing knowledge. These actions should be coherent, in order to develop a didactic contract where students know that teacher expects them to develop new ideas with arguments based on their prior (or previously taught) knowledge and that these ideas should be respected and discussed in the whole classroom. This type of contract needs particular moments in the classroom, and we discussed two of them: moment of "epistemic uncertainty" and institutionalization. Whereas the former allows the presentation and discussion of new ideas that can help to solve problems, the latter allows the teacher to make statements about elements of knowledge on the authority of the scientific community.

The DVD that we have designed provides opportunities to construct and discuss these actions, based on the series of annotated episodes reflecting the dynamics of a class.

Appendix: Extract of the Transcription of a Small Group Working on an Activity in Episode 4

Question of the Activity to Which the Students Answer in Episode 4

Draw the diagram system-interactions of a table on which an object (like a book) is set.

Transcription Extract

(M and C are working together in small group)
… (0:41:15.8)
… (*M and C writes their answer*)

1.M (*stopping writing*) ah but between the Earth and the ground, may be it is not the same because it is on the…it is the Earth it acts the Earth it acts, but it is the ground…that acts do you understand what I mean?
2.C yes
3.M but here
4.C but the ground it is normal, we have the Earth…
5.M …not necessarily…look, imagine that you are on something hard there…it does not act directly on the Earth, if the Earth…
6.C I agree with you but do not go too far; it is like the story of the support…
7.M yeah you're right…
8.C you put the Earth…it is largely enough for [*question above*] b (0:43:33)

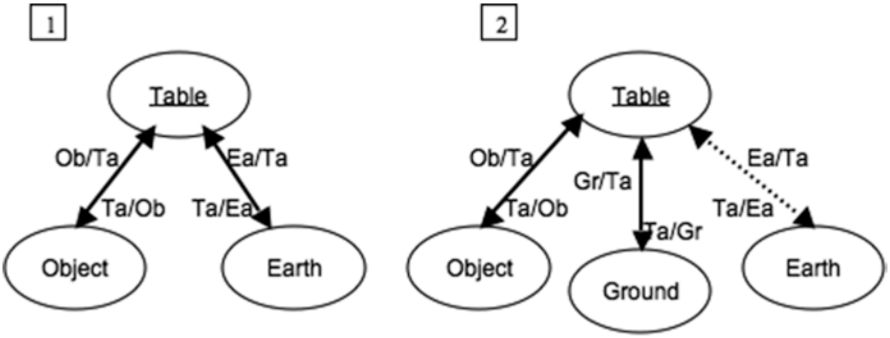

Fig. 2 Part 1, student's solution; part 2, correct solution. In this diagram system-interactions, an ellipse represents an object, a full double arrow a contact action and a dotted double arrow a distant action; the object under study (on which the actions are represented) is underlined (*Ob* means object, *ta* table, *Gr* ground, *Ea* Earth)

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